C-MIGITS™ III User's Guide

Integrated INS/GPS Navigation System

MEMS Inertial Sensors

Systron Donner Inertial
355 Lennon Lane
Walnut Creek, California 94598-2418

June 07, 2007

RELEASED DOCUMENT
DATE: 06-22-07

WARNING

IMPROPER WIRING OF THE USER CABLE CONNECTING TO THE **C-MIGITS III** CAN CAUSE IRREVERSIBLE DAMAGE THAT IS **NOT** COVERED UNDER PRODUCT WARRANTY,

COMMON MISTAKES INCLUDE:

(1) INCORRECTLY IDENTIFYING PIN ASSIGNMENTS (E.G., MIRROR IMAGE WIRING ASSIGNMENTS), RESULTING IN POWER BEING APPLIED TO THE WRONG PINS.

(2) APPLYING POWER WITH POLARITY REVERSED.

BEFORE APPLYING POWER, VERIFY THAT IT IS BEING SUPPLIED TO THE CORRECT PINS.

FOR CUSTOMERS WHO PURCHASED THE OPTIONAL MATING CONNECTOR (WITH COLOR CODED WIRES) POWER CONNECTION PINS ARE IDENTIFIED IN THE TABLE BELOW;
(PIN 1 IS CONNECTED TO THE BLACK WIRE).

SIGNAL	PIN	COLOR
+28 V POWER IN	6	**RED SHRINK SLEEVE**
+28 V POWER IN	27	**RED SHRINK SLEEVE**
POWER RETURN (GROUND)	17	**BLACK SHRINK SLEEVE**
POWER RETURN (GROUND)	18	**BLACK SHRINK SLEEVE**

PLEASE CALL 925-979-4500 IF THERE ARE ANY QUESTIONS.

Information to the user - *The user of this device is cautioned that changes or modifications not expressly approved by SDI could void the user's warranty.*

Proprietary Notice - *Information provided by Systron Donner Inertial is believed to be accurate and reliable. However, no responsibility is assumed by Systron Donner Inertial for its use, nor any infringements of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent rights of Systron Donner Inertial. Systron Donner Inertial reserves the right to change circuitry or software at any time without notice. This document is subject to change without notice.*

GPS End of Week (EOW) Rollover - *GPS weeks are numbered from 0 to 1023, starting at midnight on 5-6 January 1980. At 00:00 hours UTC (midnight) 21-22 August 1999, the GPS week number rolls over to 0. C-MIGITS III has been successfully tested by means of a simulated (via a satellite signal generator, which is itself EOW compliant) transition through the EOW rollover. System operation was transparent to the EOW rollover, and no anomalies were encountered. The system is considered GPS EOW rollover ready.*

No part of this document may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, mechanical, electronic, photocopying, recording, or otherwise, without prior written permission of Systron Donner Inertial.

ITAR Statement

Information included herein is controlled under the International Traffic in Arms Regulations ("ITAR") by the U.S. Department of State. Export or transfer of this information to a foreign person or foreign entity requires an export license issued by the U.S. State Department or an ITAR exemption prior to the export or transfer.

Printed in the United States of America. ©1998 The Systron Donner Inertial. All rights reserved.

Contents

Chapter 1- Introduction

C-MIGITS III Integrated INS/GPS

Overview

Systron Donner Inertial (SDI) has developed a family of Guidance, Navigation, and Control (GN&C) products that use the latest solid state inertial sensor technology integrated with advanced Standard Positioning Service (SPS) and Precise Positioning Service (PPS) Global Positioning System (GPS) engines.

The modular family of Miniature Integrated GPS/INS Tactical System (MIGITS™) come in both tightly-coupled and loosely- coupled configurations, each with a selected Inertial Measure-ment Unit (IMU) and a GPS engine.

C-MIGITS III represents the tightly-coupled SPS version of the MIGITS family. It contains a twelve channel, Coarse/Acqui-sition (C/A) code, L1 frequency GPS engine, and a Digital Quartz IMU (DQI). The two subsystems are integrated together through a Kalman filter mechanization to produce a small, lightweight, synergistic GN&C system. It requires only a 28 Vdc power supply and any device capable of accepting RS232 asynchronous serial data. The electronics are housed in an extruded aluminum chassis that is hermetically sealed, forming a compact, robust package.

These proven off-the-shelf products integrated into one package translate into affordability and low risk. C-MIGITS III provides all essential GN&C data, including three-dimensional position and velocity, precise time, attitude, heading, angular rate, and acceleration.

MIGITS configurations can be tailored to meet operational performance requirements, while meeting budgetary constraints to provide affordable, operationally effective system solutions. These integrated solutions offer an affordable suite of compact and lightweight systems that are ideally suited for GN&C applications, such as tactical missiles, guided munitions, unmanned aerial vehicles (targets, decoys, etc.), land vehicles, geolocation, and a host of other uses.

Additional technical data, physical characteristics, operation, and system integration information for the C-MIGITS III product are presented in subsequent chapters of this guide.

Why INS/GPS?

Many guidance and control problems in the past have been addressed with stand-alone Inertial Navigation System (INS) or GPS solutions; however, the inherent characteristics of each system do not provide an ideal GN&C solution. By properly integrating the INS and GPS systems, the strengths of one can offset the deficiencies of the other.

An INS is generally characterized as a self-contained, autonomous navigator, whose position and velocity outputs will degrade over time. Alternatively, the GPS is generally described as a navigator relying on external satellite signals, whose high accuracy solution is time independent.

When the two systems are combined, the INS/GPS system will bound the INS error growth, and provide a continuous navi-gation solution when GPS signals are not available. In add-ition, high-speed attitude, velocity, angular rate, and acceleration are available at accuracies not achievable by GPS, even when special equipment is installed.

About This Book

This guide provides basic navigation concepts, INS/GPS concepts, configuration, operation, and characteristics of the system, and defines the mechanical, electrical, and data interfaces of C-MIGITS III to the Host Vehicle (HV). The DQI and the Jupiter® LP GPS engine will be typically referred to in this guide as the *Inertial Measurement Unit* (IMU) and the *GPS receiver*, respectively.

This guide will discuss and illustrate some possible system applications for commercial and military markets, and will help the end-user determine how to use the C-MIGITS III features.

The glossary contains abbreviations of terms commonly used by SDI and in the navigational and inertial fields of technology, as well as some terms common to commercial electronics and software fields.

Note pages have been included to allow the designer to jot down notes for quick easy reference that might otherwise be misplaced.

This page left intentionally blank.

Chapter 2- INS/GPS Concepts

What is Navigation?

Navigation is the art and science of directing a vehicle from one place to another. When navigating for long periods of time, a slight error in direction will create a sizable distance off course. This shows that the efficiency of a vehicle depends ultimately on the navigation accuracy.

The science of navigation can be reduced to five basic questions, and the navigator must be capable of obtaining quick and accurate answers to them.

- What is the present *position* (latitude, longitude, and altitude)?
- What is the vehicle's *heading*?
- What is the vehicle's *attitude* (roll and pitch)?
- What is the vehicle's *velocity* (north/south, east/west, total, and vertical)?
- What is the vehicle's *acceleration*?

Answer these questions and you have the solution to navigation. With proper navigation equipment, these questions can be answered with reasonable accuracy.

The primary task of navigation is the determination of present position. *Inertial navigation* is the method of accurately and continuously extrapolating a vehicle's position, velocity, and attitude, by processing changes in its motion as sensed by inertial instruments.

An *Inertial Navigation System* (INS) measures changes in velocity through the use of accelerometers and gyroscopes. This information is fed to a computer that is used to keep track of velocity and to continuously maintain an indication of position. Today these same instruments typically provide rate and state data to other avionics subsystems such as weapon computers, flight controls, or radar sensors.

An INS makes its measurements with respect to *inertial space*. Inertial space is a reference frame, consisting of a set of axes that do not rotate, and has no acceleration from its origin relative to the average position of the fixed stars. Any set of rigid axes moving with constant velocity, and without rotation relative to inertial space, also constitutes an inertial reference frame.

The INS needs to be properly initialized and periodically reinitialized.

As with any dead reckoning system, it is important that an INS be properly initialized and periodically reinitialized. Other methods of navigation, such as Navigation Satellite Timing and Ranging (NAVSTAR) GPS, can be used in conjunction with the INS. Both of these methods are discussed later in this chapter.

Inertial Navigation Advantages

Some of the advantages of inertial navigation are as follows:

- All types of navigation data are determined simultaneously, i.e., position, velocity, heading, and attitude. Most other methods of navigation provide only position data.
- Navigation data is continuously available.
- Even though some errors can be additive, inertial navigators can be made to be very accurate.
- Navigation data is provided at a high rate so vehicle, weapon, or sensor stabilization is possible.

Since the earth is itself moving in inertial space, the relationships between a vehicle, the earth, and inertial space are fundamental to the solution of the inertial navigation problem.

These relationships are defined by the laws of mechanics, which describe the motions and interactions of material bodies in inertial space. The inertial navigation systems that we typically deal with compute and output velocity and attitude parameters, as well as latitude, longitude, and altitude position.

Position

Position is defined as the *location of a body in space*, and can be described completely by referencing the body to an appropriate coordinate system. Usually, rectangular coordinates are used.

Heading

Heading is commonly known as *compass direction*, or, the direction that the vehicle points. True heading is defined as the angle in the local horizontal plane measured clockwise (about a downward vertical) between North and a vertical plane, containing the ship's, aircraft's, or other vehicle's longitudinal axis (with an aircraft, this axis is known as the *thrust* axis).

Attitude

Attitude is defined as the angular position of a ship, aircraft, or other vehicle, determined by the relationship between its axes and a reference datum, such as the horizon or a particular star. Attitude parameters are defined in terms of three "Euless" angles: true heading, pitch, and roll. See the previous paragraph for true heading. *Pitch* is the angle measured in the vertical plane between a vehicle's longitudinal axis and the horizontal axis (nose up in an aircraft would be positive).

Roll is the angle measured about the vehicle's longitudinal axis that will rotate the vehicle from a horizontal orientation (such as an aircraft's wings being normally horizontal, to the actual flight orientation).

An example of roll is a climbing right hand turn from a level northerly flight path direction, generating a positive heading, pitch, and roll angle. A *drift angle* can be generated by crosswinds, causing the aircraft to point in the direction of the wind, rather than along the ground-referenced velocity direction.

Velocity

Displacement indicates *extent of motion*, that is, the magnitude and direction of change in position. Velocity is a measure of *how fast displacement takes place*, or, how much displacement occurs in a given unit of time.

Velocity parameters are typically expressed in terms of the vertical and horizontal components of translational movement relative to the earth. In an example of an aircraft, the vertical component of velocity is called the *altitude rate.* The horizontal component of velocity can be expressed in terms of North and East components, or in terms of the net horizontal velocity component magnitude (commonly called *ground speed*), and horizontal velocity vector direction relative to North (known as the *track angle*).

Acceleration

Since the velocity of a body has both magnitude and direction, a change in velocity occurs whenever:

- The body's *rate* of motion changes while its direction remains the same.
- The body's *direction* of motion changes while its rate of motion remains the same.
- The body's *rate* and *direction* of motion change simultaneously.

Whenever the velocity of a body changes in any manner, the body is said to be *accelerated*.

Gravity

In addition to the forces caused by the motions of the INS and the Earth, the system is subject to the mass attraction, or *gravitational force* of the Earth, which is the most significant force acting on inertial instruments.

Gravity's interaction with the Earth's rotational forces is responsible for the very shape of the Earth itself. The shape of the Earth is fundamental to terrestrial navigation, since the designation of a system's position is only as precise as the relationship between the describing coordinates and the Earth's shape. Gravitational attraction is a property of matter (inertial mass) that is possessed by all material bodies.

NAVSTAR GPS General Theory

NAVSTAR GPS is a space-based satellite radio navigation system developed by the United States Department of Defense (DoD).

GPS receivers provide land, marine, and airborne users with continuous three-dimensional position, velocity, and time data. This information is available free of charge to an unlimited number of users. The system operates under all weather conditions, 24 hours a day, anywhere on Earth.

GPS System Design

The GPS system consists of three major segments: Space, Control, and User, as shown in Figure 2-1.

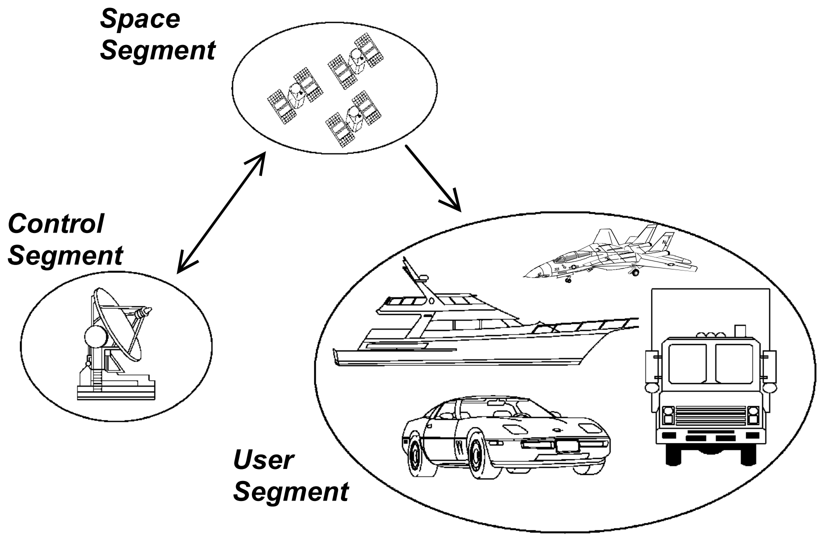


Figure 2-1. Major Segments of the NAVSTAR GPS System

Space Segment

This segment consists of a nominal constellation of 24 operational satellites (including 3 spares) which have been placed in 6 orbital planes about 10,900 miles (20,200 km) above the Earth's surface (see Figure 2-2) .

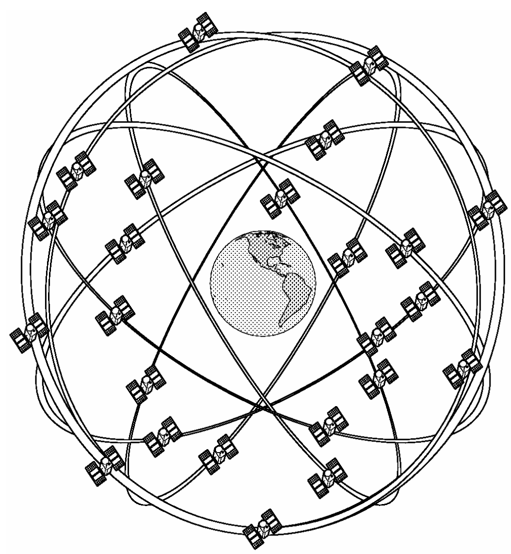


Figure 2-2. NAVSTAR GPS Operational Satellite Constellation

The satellites are in circular orbits with a 12-hour orbital period and inclination angle of 55 degrees. This orientation normally provides a GPS user with a minimum of five satellites in view from any point on Earth at any one time.

Each satellite continuously broadcasts Radio Frequency (RF) signals at two L-band frequencies. The L1 frequency is 1575.42 MHz and is modulated by a 10.23 MHz clock rate Precise ranging signal (P), or *Precision Code* (P-code), and by a 1.023 MHz clock rate C/A code ranging signal, or *Coarse/ Acquisition Code* (C/A-code). The L2 frequency is 1227.6 MHz and carries P-code only. Non-military navigation sets, such as the C-MIGITS III, typically have access to the L1 C/A-code only.

Before the P-code and C/A-code are modulated for transmission, they are combined with navigation data, 50 bits per second (bps), by Modulo-2 addition. The navigation data, which is computed and controlled by the GPS Control Segment, includes each satellite's time, clock correction, ephemeris parameters, almanac data, and health status for all GPS satellites. From this information, the user computes the satellite's precise position and clock offset.

Currently, the DoD encrypts P-code ranging signals and thus denies access to the Precise Positioning Service (PPS) by unauthorized users. The Standard Positioning Service (SPS) uses the C/A-code ranging signal, which is intended for general public use.

Control Segment

This segment consists of a Master Control Station, located in Colorado Springs, Colorado, and a number of monitor stations at various locations around the world.

Each monitor station tracks all GPS satellites in view and passes signal measurement data back to the Master Control Station. There, computations are performed to determine precise satellite ephemeris and satellite clock errors.

The Master Control Station generates the upload of user navigation data for each satellite. This data is subsequently re-broadcast by the satellite as part of its navigation data message.

User Segment

This segment is the collection of all GPS receivers and their application support equipment, such as antennas and processors. This equipment allows users to receive, decode, and process information necessary to obtain accurate position, velocity, and timing measurements. This data is used by the GPS receiver's support equipment for specific application requirements.

GPS supports a wide variety of applications including navigation, surveying, and time transfer. Receivers may be used in a stand-alone mode, or integrated with other systems to enhance overall system performance.

How The GPS Receiver Determines Position

The GPS receiver determines its geographic position by measuring the ranges of several satellites and computing the geometric intersection of these ranges.

Range is the distance between a satellite with known coordinates in space and the receiver's antenna.

To determine a range, the receiver measures the time required for a GPS signal to travel from a satellite to a receiver antenna. A timing code generated by each satellite is compared to an identical code generated by the receiver.

The receiver's code is shifted until it matches the satellite's code. The resulting time shift is multiplied by the speed of light to arrive at the apparent range measurement.

Since the resulting range measurement contains propagation delays due to atmospheric effects, and satellite and receiver clock errors, it is referred to as a *pseudorange*. Changes in each of these pseudoranges over a short period of time are also measured and processed by the receiver. These measurements, referred to as *delta-pseudoranges*, are used to compute velocity.

A minimum of four pseudorange measurements are required by the GPS receiver to mathematically determine time and the three components of *position* (latitude, longitude, and altitude). The equations used for these calculations are shown in Figure 2-3.

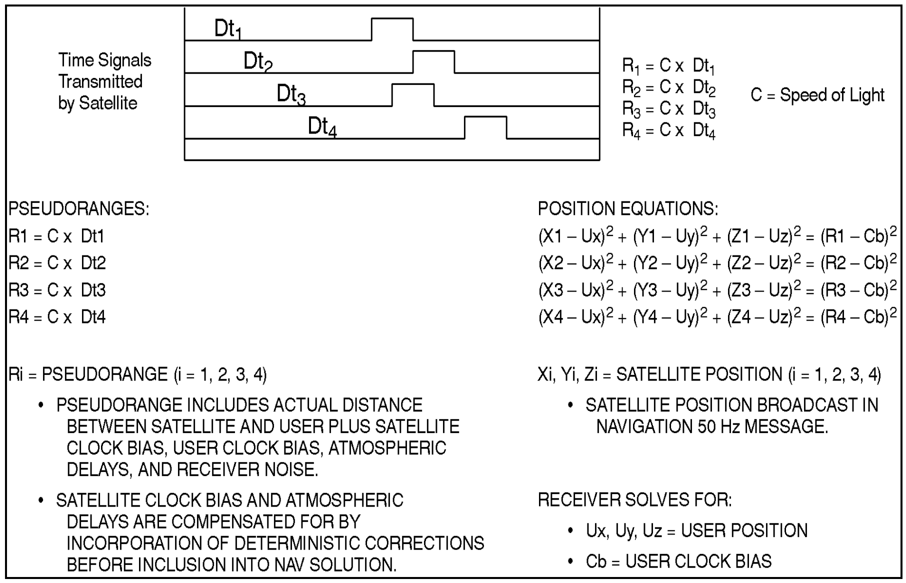


Figure 2-3. Range Processing Equations

The solution of these equations may be visualized as the *geometric intersection* of four ranges from four known satellite locations.

Figure 2-4 illustrates *triangulation*, which is a way to envision the navigation process. For ease of understanding, time information, which would be derived from a fourth satellite, is not shown.

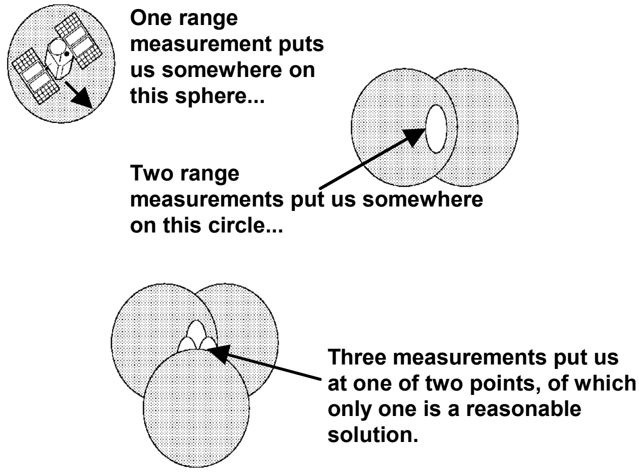


Figure 2-4. Satellite Ranging Intersections

After the four range equations are solved, the GPS receiver has estimates of its position and time. Similar equations are then used to calculate velocity using relative velocities instead of pseudoranges. The position, velocity, and time data are generally computed once per second.

If one of these parameters, such as altitude, is known, only three satellite pseudorange measurements are needed for the GPS receiver to determine its position, velocity, and time. In this case, only three satellites need to be tracked.

GPS Accuracy

GPS accuracy has a statistical distribution that is dependent on two important factors. The expected accuracy will vary with the *error* in the range measurements, as well as the *geometry* or *relative positions* of the satellites and the user.

Dilution of Precision (DOP)

The Geometric Dilution of Precision (GDOP) indicates how much the geometric relationship of the tracked satellites affects uncertainty of the GPS receiver's position, velocity, and time estimates.

There are four DOP components that are commonly used to indicate how the geometry specifically affects errors in horizontal position (HDOP), vertical position (VDOP), three-dimensional position (PDOP), and time (TDOP).

DOPs are computed based on spatial relationships of the lines of sight between the satellites and the user. The motion of the satellites relative to each other and the user causes the DOPs to vary constantly. For the same range measurement errors, lower DOPs relate to more accurate estimates.

The errors in range measurements (the measurements that are used for solving position) can be magnified by poor geometry. The least amount of error results when the lines of sight have the greatest *angular separation* between them (see Figure 2-5).

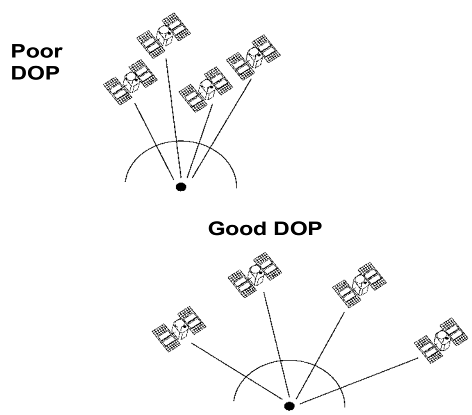


Figure 2-5. Geometric Dilution of Precision

For example, if two lines of sight are necessary to establish a user position, the least amount of error is present when the lines cross at right angles.

Range Measurement Error

The error in the range measurement is dependent upon one of two levels of GPS accuracy. PPS is the most accurate, but is reserved for use by the DoD and certain authorized users. SPS is less accurate and intended for general public use. This is the level of accuracy used by the C-MIGITS III GPS receiver.

The SPS signal can be intentionally degraded to a certain extent by a process known as *Selective Availability* (SA). SA has been used to limit access to the full accuracy of SPS in the interest of United States national security. SA was discontinued by the U.S. Government on May 2, 2000.

Digital Quartz IMU (DQI) General Theory

The DQI (Figure 2-6) is designed around an *Inertial Sensor Assembly* (ISA). The ISA consists of six single-axis sensors, three *Quartz Rate Sensors* (QRS), three *Vibrating Quartz Accelerometers* (VQA), the drive electronics, preamplifier circuitry for the sensor outputs, and digital conversion electronics.

The output of the VQA is digital, and will be explained later in this section. The QRS output is an analog sinusoid, which is converted to a digital signal in the ISA. The ISA also supplies monitors for health checks and sensor compensation.

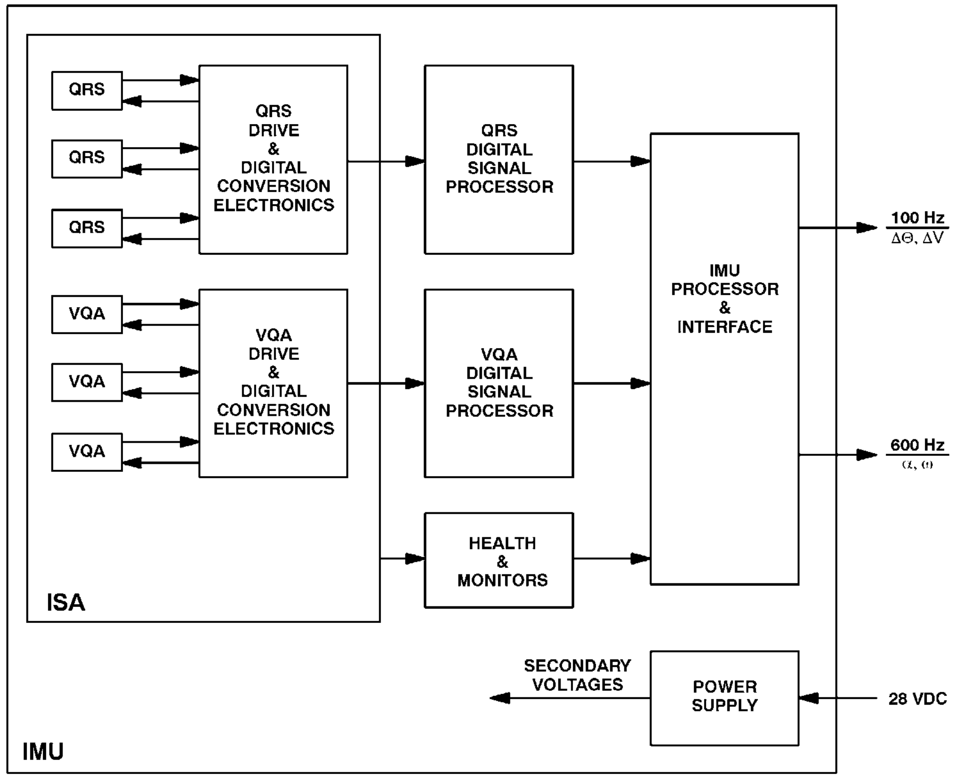


Figure 2-6. DQI Functional Block Diagram

The IMU contains the electronics that process the raw sensor signals for compensation. It provides the $\Delta\theta$ and Δv for navigation at 100 Hz, and acceleration and angular velocity for flight control or sensor stabilization at 600 Hz.

VQA Principles

The basic principle of the VQA is to use a long narrow vibration beam as a *force sensor*. When a force is applied to the beam, its fundamental natural frequency of vibration changes.

An *acceleration sensor* can be designed using a proof mass, so that the force transmitted from the case of the accelerometer through the vibration beam to the proof mass is proportional to acceleration, per Newton's law.

Several *piezoelectric accelerometers* of this type have been developed, and have at least one vibrating beam as a *free sensor* attached to a pendulous or translational mass. Figure 2-7 shows a typical configuration.

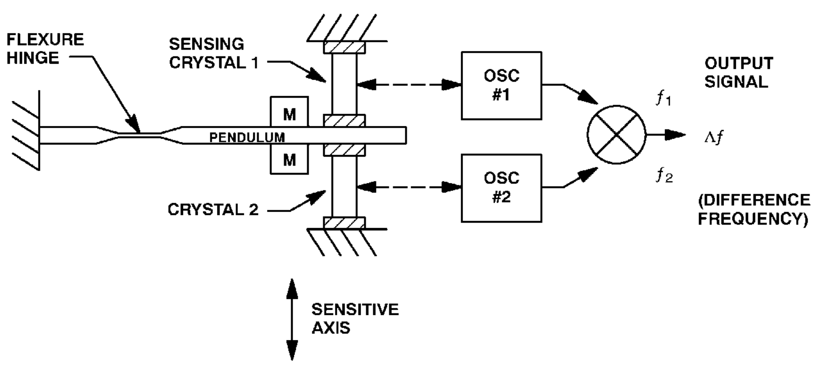


Figure 2-7. VQA Configuration

The vibration of the tines are in the plane of the figure and horizontal. In drive mode of oscillation, the tine of each fork vibrates 180 degrees out of phase with respect to each other.

Double-Ended Tuning Fork Technology

Most *vibrating beam accelerometers* have been designed with two vibrating beam sensors, each consisting of a Double-Ended Tuning Fork (DETF). The DETF design has been chosen because of the inherently higher quality (Q) factor over the single-beam resonator.

The DETF is constructed of crystalline quartz, and made to oscillate electrically by its piezoelectric nature. An input acceleration will cause the beam to be placed into tension or compression, depending on the direction of motion of the proof mass.

The DETF resonance frequency will change, as a piano string resonance frequency changes, with applied tension. Common mode errors for the two DETFs associated with mounting strain and thermal mismatch will cancel with the configuration.

One frequency will increase and the other decrease with motion of the proof mass. Many error sources cause the frequencies to move in the same direction. In signal processing, the difference frequency is used to determine acceleration.

This differencing increases the sensitivity by a factor of two, and the nonlinear frequency versus acceleration characteristic contains only odd terms in the acceleration power series expansion approximation. In practice, the linear term dominates and modeling accounts for the third order term.

VQA Framed Crystal Advantages

The crystal is mounted using the framed crystal approach shown in Figure 2-8. This has eliminated several problems plaguing recent DETF designs. Using linkage to frame the crystal avoids rotation of the end mounts, which causes tines to decouple and oscillate at different frequencies.

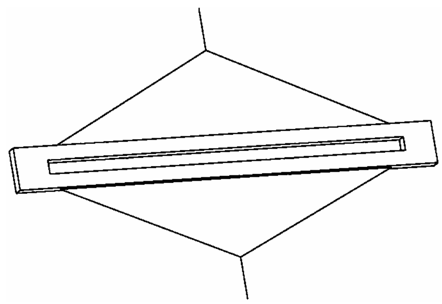


Figure 2-8. Framed Crystal

The typical DETF can withstand very little (~0.002 in.) deformation before fracturing. The framed crystal approach decreases the sensitivity to deflection by a factor of five, and realistic shock caging is easily obtained.

Another advantage to the framed crystal approach is that the tines are better isolated acoustically from surrounding structures. This is important for the sensor assembly, which contains six vibrating sensors operating in a non-vibration free environment. There is also a decrease in sensor length, which aids in manufacturing a smaller IMU.

The VQA's seismic mass is suspended using a Quartz Flexure Suspension (QFS), and is also made of crystalline quartz for stability and elasticity. Resonant frequencies of each sensor assembly exceeds 2000 Hz, and are spaced apart from the crystal drive resonant frequencies to avoid any interaction.

QRS Principles

The DQI uses a *dual tuning fork design* shown in Figure 2-9. The drive fork is set into oscillation at its natural frequency. When the device is rotated about the vertical axis, the Coriolis force causes the tines to oscillate at the drive frequency, which is orthogonal to the plane of the fork.

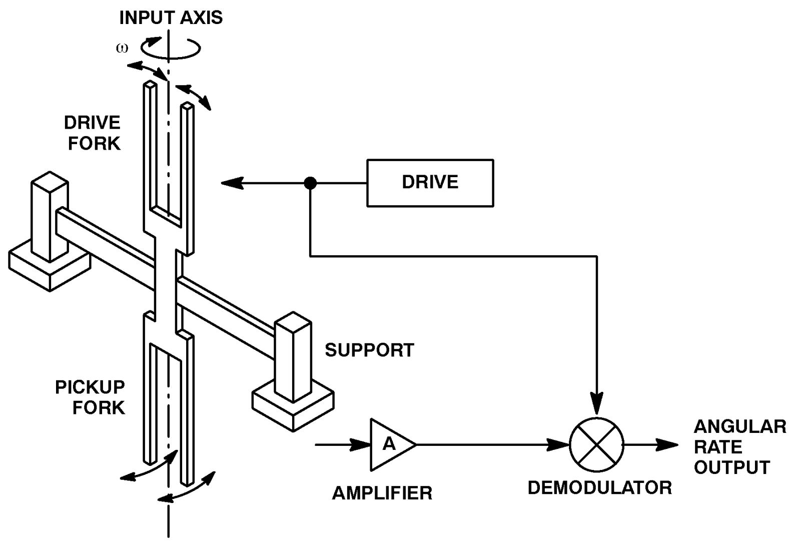


Figure 2-9. Simplified Block Diagram Quartz Rate Sensor

The Coriolis motion is transmitted to the pickoff tines, causing them to oscillate orthogonal to the plane of the fork. The amplitude of the pickoff motion is proportional to the velocity of the drive tines and the angular rate.

The pickoff motion is detected by electrodes attached to the pickoff tines. This pickoff signal is demodulated with respect to the reference drive signal, to give a DC output proportional to the input rate.

To maintain scale factor stability, an automatic gain control loop around the drive tines ensures a constant oscillation amplitude over temperature.

QRS Technological Advances

Micromachining has opened up the potential of using crystalline structures as the complete sensor element.

Recently, the technological approach of *micromachining* has opened up the potential for using crystalline structures as the complete sensor element. This approach is used in manufacturing the IMU by using quartz for the fork material, and by using deposited electrodes on both the drive and pickoff sides.

The mount that supports the quartz element provides isolation to maximize Coriolis coupling torque into the pickoff tines. Drive and pickup voltages are also routed via the mount.

The drive and signal processing electronics are typically contained within an *Application Specific Integrating Circuit* (ASIC) chip, providing a direct current (DC) input/output capability for ease of interfacing.

INS/GPS General Theory

Accuracy vs. Time

Inertial navigation systems sense acceleration and angular rate information, which can be integrated to determine position, velocity, and attitude solutions. However, due to inertial instrument imperfections, inertial navigation solution accuracies will deteriorate, or *drift* over time.

INS position error will drift with time; GPS high accuracy solution is time independent.

A GPS high accuracy solution is based on 1-hertz measurements from GPS satellites. As long as GPS satellite signals are available, the accuracy of the GPS solution is time independent. This characteristic allows the GPS solution to be used to bound the error growth in the inertial navigation solution in an integrated INS/GPS system.

Data Frequency

INS output is high frequency and relatively quiet; GPS output is low frequency.

The INS measurement data is high frequency (greater than or equal to 100 Hz), which allows for computation of *position, velocity*, and *attitude* solutions based on integration of high-rate data.

GPS measurement data is low frequency (typically computed at 1 Hz), which allows for computation of *position, velocity*, and *time* solutions.

Guidance and control algorithms require accurate, high frequency data. Although GPS solution extrapolation can be done to estimate navigation data at a higher frequency, this method is not accurate in dynamic environments when velocities are not uniform over extrapolation intervals.

Therefore, when GPS bounds long-term, IMU-based solution error drift, the IMU provides measurements for computation of accurate, high-frequency solution data for dynamic environments.

GPS Satellite Signal Dependency

GPS solutions depend on availability of GPS satellite signals. When GPS satellite measurements become unavailable, GPS stand-alone system navigation accuracies quickly degrade due to dead reckoning-based solutions.

INS is a totally self-contained autonomous operation; GPS is dependent on availability of satellite signals.

Although GPS satellite signals are always transmitted, a GPS receiver may not be able to track the GPS signals due to the operational environment. Typical conditions that may preclude the ability to track GPS satellites include *jamming* and *antenna masking*.

Jamming can be the result of intentional GPS signal interference or random signal interference. Antenna masking is an obstruction between the antenna and the GPS satellite, such as the wing of an aircraft or a tall building.

Regardless of the cause of GPS signal denial, the IMU system is autonomous, which allows an INS/GPS system to continue navigating during periods of GPS signal loss.

The IMU can also be used to aid the GPS in reacquisition after periods of shading or jamming. *Shading* can occur when the line-of-sight GPS signal is obscured by blockage or maneuvers.

Attitude Data Capabilities

As previously mentioned, inertial navigation systems sense acceleration and angular rate. Angular rate data can be integrated to determine *attitude*. GPS systems inherently do not provide attitude information; however, GPS can be used with multiple antenna inputs to estimate attitude, but is limited by jamming, antenna masking, and shading.

INS provides accurate, high rate attitude data; GPS attitude capability is limited.

GPS attitude determination systems are not robust in dynamic environments, and encounter the same deterioration as GPS position solutions when GPS signal obscuration occurs. In an INS/GPS system, inertial angular rate data can be integrated to determine attitude.

In addition, the GPS velocity vector can be used to estimate INS attitude errors. This results in an attitude solution with greatly reduced inertial-based errors. It also enables integrated INS/GPS solutions with low-cost, less accurate IMUs to achieve the attitude accuracy of high-accuracy IMU systems. Error growth over time (an INS-only problem) is also eliminated.

Initialization Capabilities

Stand-alone IMU systems make assumptions about gravity and earth rate to self-initialize. This self-alignment process usually takes time, and often requires a stationary platform.

INS requires dynamic-limited initial conditions; GPS can self-initialize on the fly, and "align" the IMU.

When a GPS system is initialized with crude position, velocity, and time data, it can acquire and track satellites in less than a minute. Even without initialization data, a GPS receiver can acquire satellites in a dynamic environment.

This is achieved by using data stored in GPS memory from a prior successful period of navigation, or by executing *cold start* algorithms that search the sky for any GPS satellite signals.

Once the GPS receiver acquires satellites for navigation, the GPS information can be used to align the IMU. This IMU alignment does not require a stationary platform. In fact, this type of alignment requires vehicle dynamics, which provides increased visibility into IMU navigation solution error sources.

To summarize, an integrated INS/GPS system can power up and self-align in a dynamic environment without cumbersome stationary alignment requirements.

This page left intentionally blank.

Chapter 3- System Overview

System Configuration

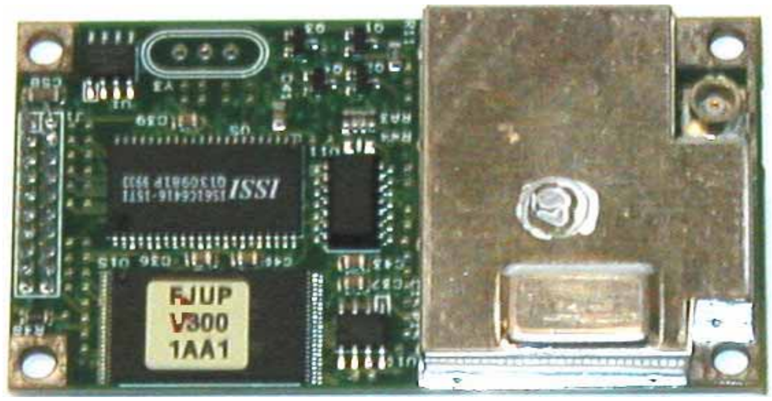
The C-MIGITS III is designed to provide a low-cost solution for applications that require an Integrated INS/GPS system. As introduced earlier in this guide, C-MIGITS III is composed of two basic elements: the Digital Quartz IMU (DQI) and the Jupiter LP GPS receiver.

The DQI is a strapdown inertial measurement unit designed to provide internally compensated, body referenced, orthogonal, simultaneous measurements of angular rate and linear acceleration at a 600-Hz rate.

Digital Quartz IMU (DQI)

The DQI provides angular rate and linear acceleration information at a 600-Hz rate, and delta-velocity and delta-theta information about three axes at a 100-Hz rate. The DQI data is output on an Advanced Medium Range Air-to-Air Missile (AMRAAM) formatted serial interface. The DQI uses micro-machined quartz rate sensors and vibrating quartz accelerometers to achieve low cost, weight, and volume.

The Jupiter LP GPS Receiver is a single board, twelve-parallel channel L1 only Coarse/Acquisition (C/A) code GPS engine. This GPS receiver tracks up to twelve satellites, providing accurate satellite-based positioning data while using minimal power.



Jupiter™ LP GPS Receiver

The GPS receiver is a highly integrated digital receiver incorporating four custom devices, including a fully integrated Gallium Arsenide (GaAs) radio frequency (RF) front end. This minimizes the receiver's size to about 36 square centimeters and satisfies harsh environmental requirements.

System Technical Description

The SDI C-MIGITS III system, shown in Figure 3-1, uses DQI high-rate, inertial delta-velocity and delta-theta outputs, and Jupiter LP 1-Hz GPS range and range rate measurements to compute a complete navigation solution.

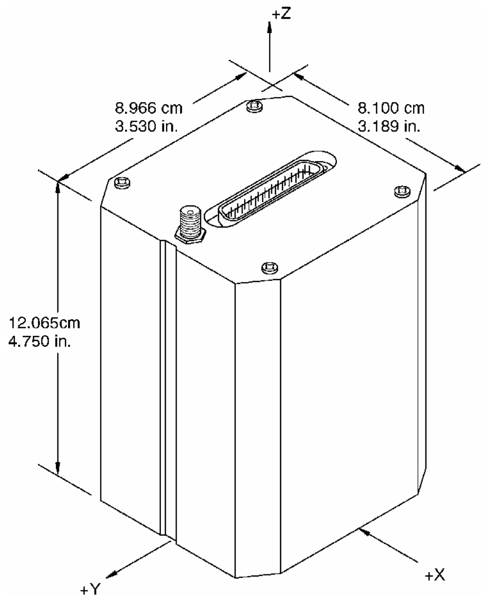


Figure 3-1. C-MIGITS III Form Factor (Nominal dimension)

In normal operation, a three-dimensional navigation solution (including attitude and heading) is computed based on integrated inertial data. This inertial solution is corrected using a Kalman filter, which processes GPS range and range rate measurements at a 1-Hz rate.

This results in a robust navigation solution that reduces inertial sensor errors. This solution remains accurate during periods of GPS signal loss due to satellite obscuration or high dynamics.

The C-MIGITS III must complete both inertial system alignment and GPS signal acquisition to achieve an integrated navigation solution. In this system, inertial alignment can occur in both stationary and dynamic environments.

Stationary alignment assumes a motionless platform, and requires heading initialization data. This alignment process requires that the platform remain motionless for a period of two minutes. *Dynamic alignment* assumes a moving platform. This alignment process requires GPS measurement information to compute IMU alignment.

C-MIGITS III satellite acquisition time is dependent on the initialization data quality and age of GPS almanac. An external battery may be utilized to maintain acquisition critical information such as ephemeris and time. The C-MIGITS III also has a built-in feature that will maintain GPS acquisition critical data for up to 4 hours.

The length of time required to receive four satellite measurements such that a fully determined three-dimensional solution can be computed is referred to as the Time-To-First-Fix (TTFF). Table 3-1 provides the TTFF information for C-MIGITS III. The values shown are based on unobscured satellite signals.

Table 3-1. GPS Signal Acquisition TTFF

Initial Error Uncertainties (3 sigma)			**Maximum Almanac Age**	**Maximum Ephemeris Age**	**Time-To-First-Fix ***	
Position (km)	Velocity (m/sec)	Time (min)	(weeks)	(hours)	Typical (minutes)	90% Probable (minutes
100	75	5	1	4	0.3	0.4
100	75	5	1	U/A	0.8	1.0
100	75	U/A	1	U/A	2	2.5
U/A	U/A	U/A	52	U/A	8	15

* = Assumes no GPS signal blockage

U/A = Unavailable in real-time to the receiver

System Operation

Operation of the C-MIGITS III system requires conditioned power, L1 GPS RF Standard Positioning Service (SPS) signals (1575.42 MHz) from a passive or active antenna, and an RS-232 bi-directional serial port to interface with C-MIGITS III data.

The bi-directional serial port is used to output position, velocity, time, and attitude (PVTA) , and status information. Input initialization data and commands are received on this port.

An additional *AMRAAM synchronous serial output* (three RS-422 pairs) provides 600-Hz autopilot acceleration and angular rate, as well as 100-Hz inertial delta-velocity and delta-angle data. Use of this interface is optional; it is typically used for flight control applications that require data rates of 100 Hz or greater.

In a stationary environment, the C-MIGITS III powers up in *Initialization* mode. When it receives serial port initialization data including position, heading, and time, C-MIGITS III will begin IMU alignment. GPS acquisition will start immediately upon power application, and will utilize serial port initialization data only if it has not already acquired GPS satellite signals.

After an alignment period of 2 minutes, the system will transition to *Navigation* mode, using GPS signals when available.

In a dynamic environment, C-MIGITS III powers up in *Initialization* mode. Once again, GPS satellite acquisition will start immediately upon power application, and will utilize serial port initialization data only if it has not already acquired GPS satellite signals. After satellite acquisition is complete, the GPS position and velocity vector is used to initiate INS dynamic alignment.

IMU alignment quality then becomes a function of system dynamics. A heading change is required for the system to complete alignment and proceed to *Navigation* mode.

Product Performance

Integrated INS/GPS PVTA Accuracy

The accuracies achievable in SPS mode are limited by the GPS Satellite Control Segment Selective Availability (SA). However, SA was discontinued by the U.S. Government on May 2, 2000.

.

Table 3-2. Position, Velocity, Time, and Attitude Accuracies								
	Position (meters)			Velocity (meters/sec)		Time	Roll/Pitch	Heading
State	3D Position SEP	Horizontal Position CEP	Vertical Position VEP	Horizontal 1 sigma	Vertical 1 sigma	μsec 1 sigma	mrad 1 sigma	mrad 1 sigma
SPS	3.9	2.5	3	0.1	0.1	1	1.0	1.5 + d

Notes:

1. Time performance is for GPS time as referenced to Time Mark 1 PPS output pulse.
2. Attitude accuracies are referenced to the IMU case mounting interface.
3. Heading accuracy includes a growth rate (d) which is based on the time since horizontal accelerations, which allow for IMU instrument calibration last occurred. The error growth rate will typically be in the range of 2 to 3 degrees/hr, 1 sigma.

SPS performance shall apply when conditions in Table 3-3 are satisfied.

Table 3-3. INS/GPS System Accuracy Assumptions, SPS Operation (Corrected Data Only)	
User range error due to Control/Space Segment errors.	$\leq$ 6 m, 1σ
User range error due to SA effects.	$\leq$ 34 m, 1σ
PDOP (RMS)	$\leq$ 2.6
HDOP (RMS)	$\leq$ 1.45
VDOP (RMS)	$\leq$2.21
TDOP (RMS)	$\leq$ 1.21
Ionospheric model error, per satellite.	$\leq$ 5 m, 1σ
Tropospheric model error, per satellite.	$\leq$ 2 m, 1σ
Multipath signal error, per satellite.	$\leq$ 1.2 m, 1σ
State 5 J/S (20 MHz BW AWGN)	$\leq$ 41 dB
State 3 J/S (20 MHz BW AWGN)	$\leq$ 57 dB

INS Only Performance

Accuracy during *INS-Only operation* (e.g. during periods of heavy jamming or satellite obscuration) is determined by the level of calibration obtained during *INS/GPS operation* and the level and type of dynamics sustained after GPS is lost.

C-MIGITS III INS-only outputs meet the accuracies described below, which describe C-MIGITS III performance under typical conditions. These accuracies assume that C-MIGITS III is under nominally constant cruise conditions after a period of State 5 INS/GPS operation, and includes a minimum of two, 30 degree turns. Failure to provide sufficient dynamics for IMU calibration will result in degraded performance.

- The navigation attitude accuracy shall degrade at no more than 5 degrees per hour (1σ).
- Position Accuracy - Position error growth during INS-Only operation will obey the following equation:

$$\varepsilon P = \sqrt{k_0^2 + (k_1 \Delta t)^2 + (k_2 \Delta t^2)^2 + (k_3 \Delta t^3)^2}$$

given in meters - Circular Error Probable (CEP)

The time variable, Δt, represents the interval of time since loss of GPS. The constants k_0 and k_1 reflect the position (meters - CEP) and velocity (m/s - 1σ) accuracy obtained during INS/GPS operation.

The constant k_2 shall be no more than 0.00737 (m/s^2 - 1σ) and k_3 shall be no more than 0.0000153 (m/s^3 - 1σ). Figure 3-2 shows the expected position error after loss of GPS.

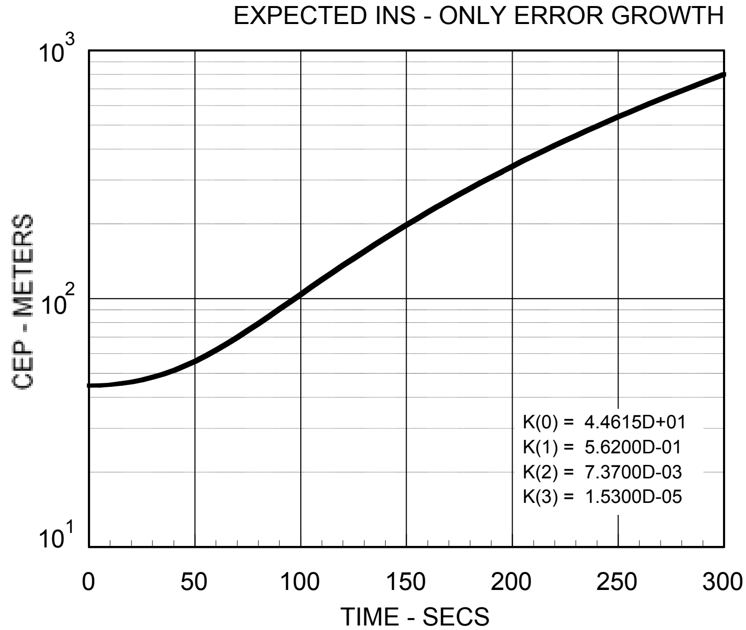


Figure 3-2. Expected INS Only Error Growth

System Power Requirements

The following is a brief overview of C-MIGITS III power requirements, including input voltage, current, overvoltage protection, and battery voltage.

Input Voltage

The prime power input voltage to C-MIGITS III is within +20.0 to +34.0 Vdc as measured at the input. The typical input voltage is 28 Vdc.

Current

The typical start-up current drawn by the unit is +1.5 amps at +28 Vdc. The typical steady-state current drawn by C-MIGITS III is +0.65 amps at +28 Vdc.

Overvoltage Protection

C-MIGITS III contains a transient absorption zener diode that clamps the input voltage at 41 Vdc.

Battery Voltage

C-MIGITS III provides for an *optional battery input*. This optional input power is used when prime power is off, to maintain a low-power time source and an accurate set of satellite parameters in SRAM.

Battery voltage must be within the range of +3 to +5 Vdc. Typical current requirements are 16 milliamps at +3 Vdc, or 30 microamps at +5 Vdc. Users who require fast TTFF may choose to utilize this optional power interface.

C-MIGITS III has a built-in capability to maintain critical data in the absence of prime power for up to 4 hours without the use of an external battery. This is achieved through an internal capacitor. Although the period of effectiveness is dependent on temperature, critical data will be maintained for a minimum of 2 hours for the system-specified temperature range.

Signal Interface Environment

C-MIGITS III provides one full-duplex, asynchronous RS232 serial data port for communicating with the Host Vehicle. It provides an output only, synchronous RS422 AMRAAM data port for IMU data.

C-MIGITS III also provides a single mode input to command the Built-in-Test (BIT), and a Time Mark output. The final input is the RF connector for the antenna that supplies GPS satellite signals.

Radio Frequency Signal Environment

The GPS RF input is 1575.42 MHz (L1 band) at a level between -130 dBW and -163 dBW. Burnout protection is provided for a -10 dBW signal within a bandwidth of 10 MHz centered about the L1 carrier frequency.

Physical Dimensions

This section describes the C-MIGITS III envelope dimensions, installation requirements, mass properties, coordinate systems, and polarities.

Envelope Dimensions

The C-MIGITS III envelope dimensions (max) are given below and shown in Figure 3-3.

For standard C-MIGIT III:

Dimensions:	8.10 cm x 8.99 cm x 12.14 cm
	(3.19 in x 3.54 in x 4.78 in)
Volume:	53.97 cu. in.

For C-MIGIT III with EMI filter:

Dimensions:	8.10 cm x 8.99 cm x 13.84 cm
	(3.19 in x 3.54 in x 5.45 in)
Volume:	61.54 cu. in.

Installation Requirements

The C-MIGITS III shall be mounted to the host vehicle using four NAS 1351-C3 socket cap screws, tightened to a torque between 20-28 in-lb.

Mass Properties

The weight of the Standard C-MIGITS III is 1.1 kilograms (2.4 pounds) and weight of the C-MIGIT III with EMI filter is 1.22 kilograms (2.7 pounds) The C-MIGITS III cg location for the standard model and the model with EMI filter are shown in Figure 3-3.

Boresight / Axis Alignment

Mechanical system axes are a right-hand orthogonal set labeled x,y, and z, as shown in Figure 3-3. In addition to the mounting screw holes, two holes are provided to accept locating pins. Care must be taken, because it is still possible to install 180 degrees in error, even when using the locating pins. Use of the locating pins when mounting to a flat surface should ensure that the mechanical mounting uncertainty is less than or equal to 5 milliradians.

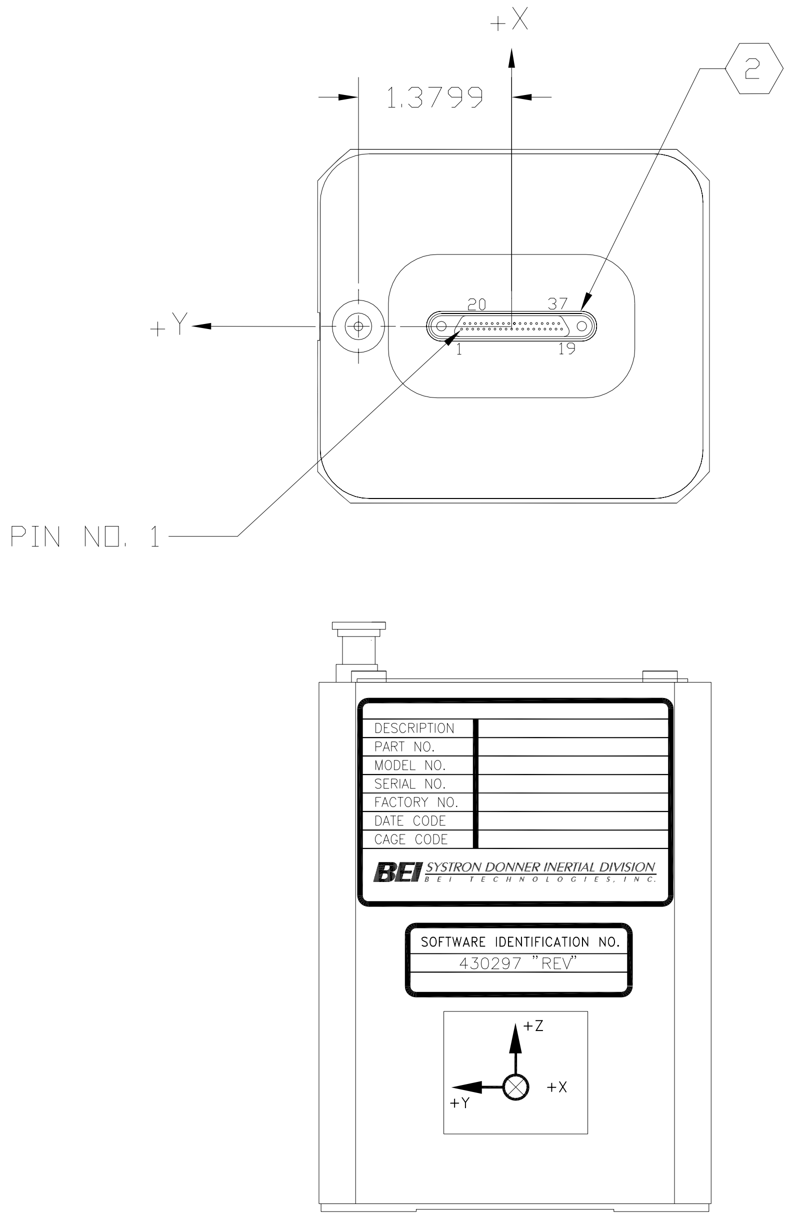


Figure 3-3 (Sheet 1 of 6). C-MIGITS III Mechanical Configuration (standard model)

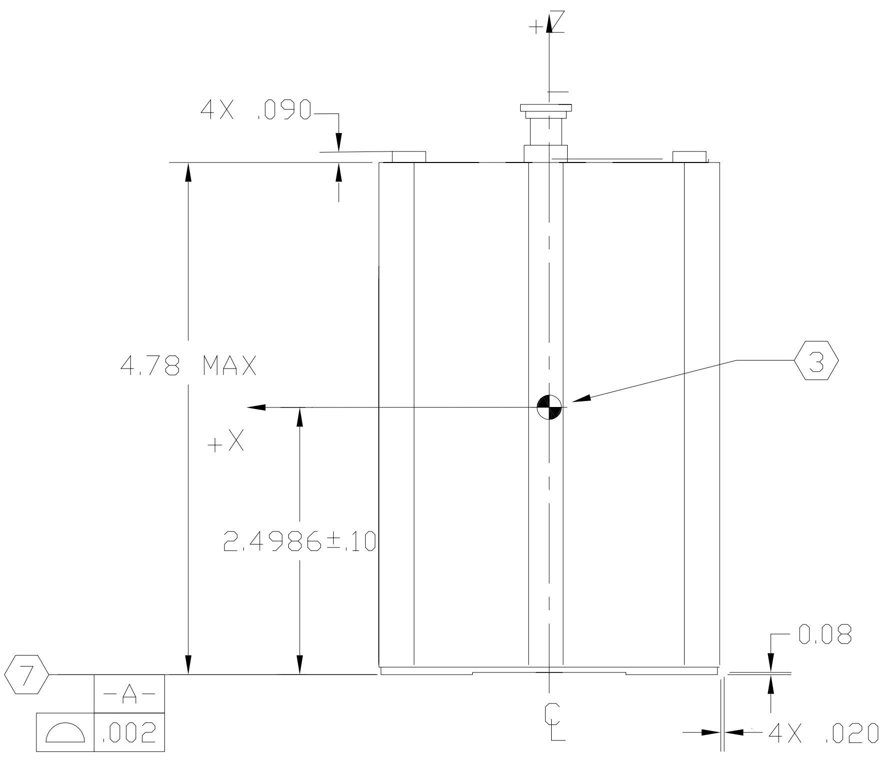
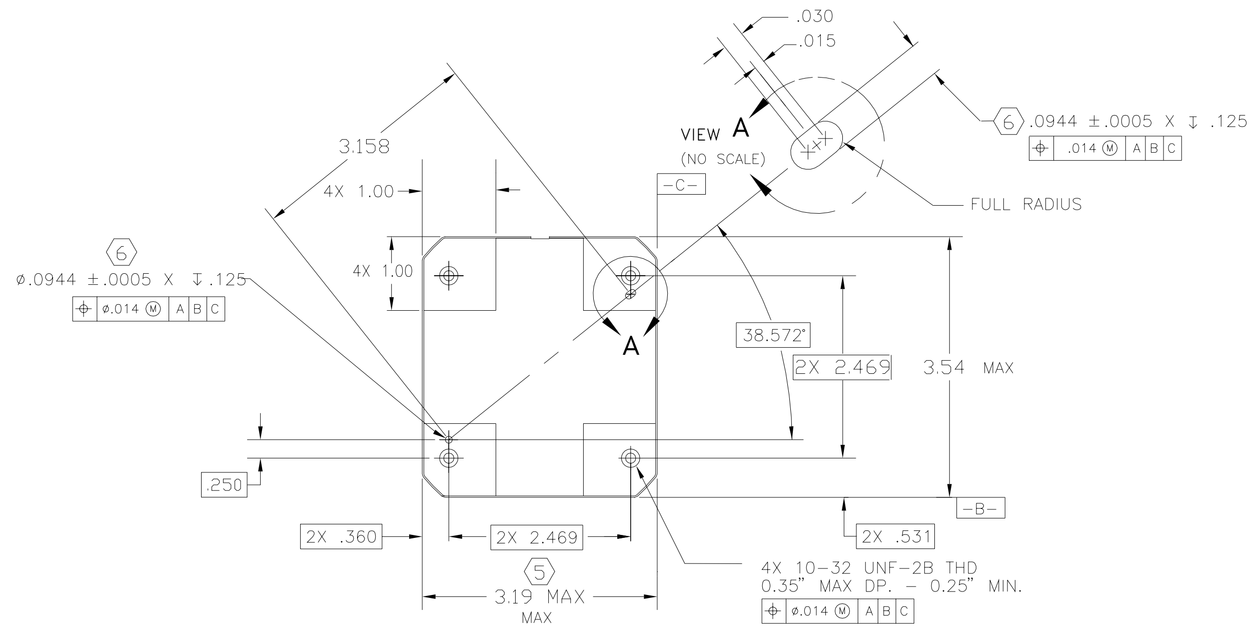


Figure 3-3 (Sheet 2 of 6). C-MIGITS III Mechanical Configuration (standard model)



NOTES: 1. WEIGHT 2.4 POUNDS MAX.

2. CONNECTOR (J1) MATES WITH CONNECTOR SDID P/N 414-4072-001

3. CENTER OF MASS OF THE IMU PACKAGE IS CENTERED IN X & Y AXIS.

4. MOUNTING SCREWS .350 DEEP MAX. TORQUE TO 57 IN. LB. MAX.

5. LABEL THICKNESS NOT INCLUDED IN PACKAGE DIMENSIONS.

6. AXIS ALIGNMENT DEFINED BY DATUM -A- AND ALIGNMENT HOLES - SEE VIEW A.

7. MOUNTING/ALIGNMENT SURFACE TAKE CARE NOT TO DAMAGE.

8. FOR HEAT DISSIPATION, UNIT MUST BE MOUNTED TO THERMALLY CONDUCTIVE SURFACE.

9. ORIENT AXES TO GROOVE, ON SIDE OF OUTER CASE.

10. OPTIONAL EMI FILTER FITTED TO CERTAIN MODELS IS NOT SHOWN.

Figure 3-3 (Sheet 3 of 6). C-MIGITS III Mechanical Configuration (standard model)

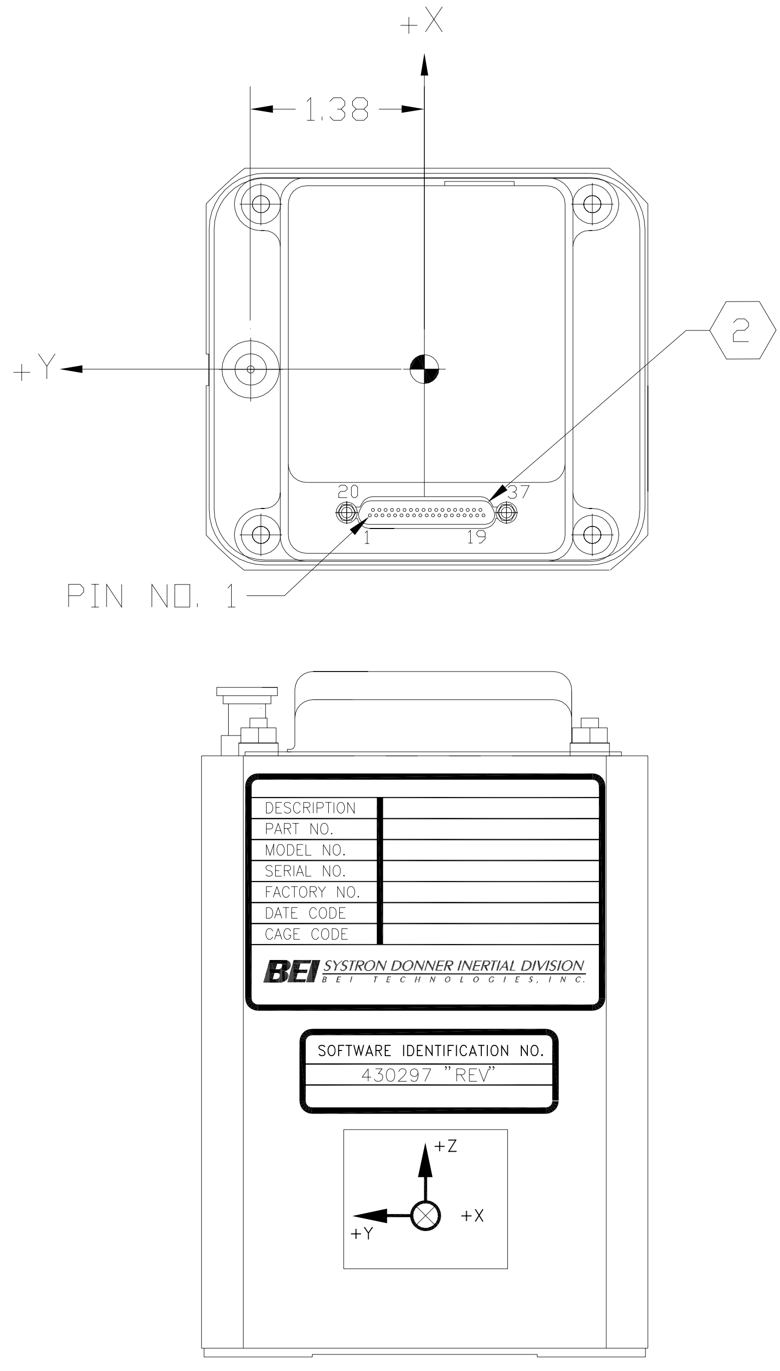


Figure 3-3 (Sheet 4 of 6). C-MIGITS III Mechanical Configuration (with EMI filter)

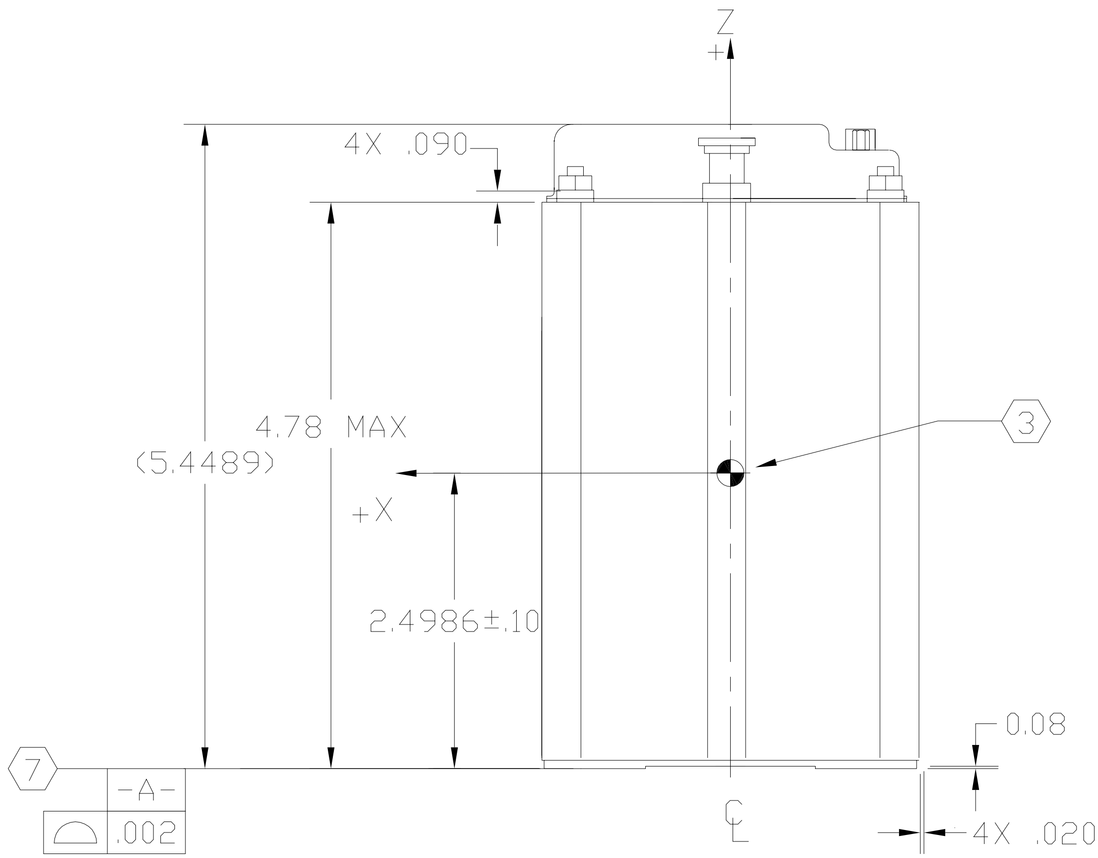
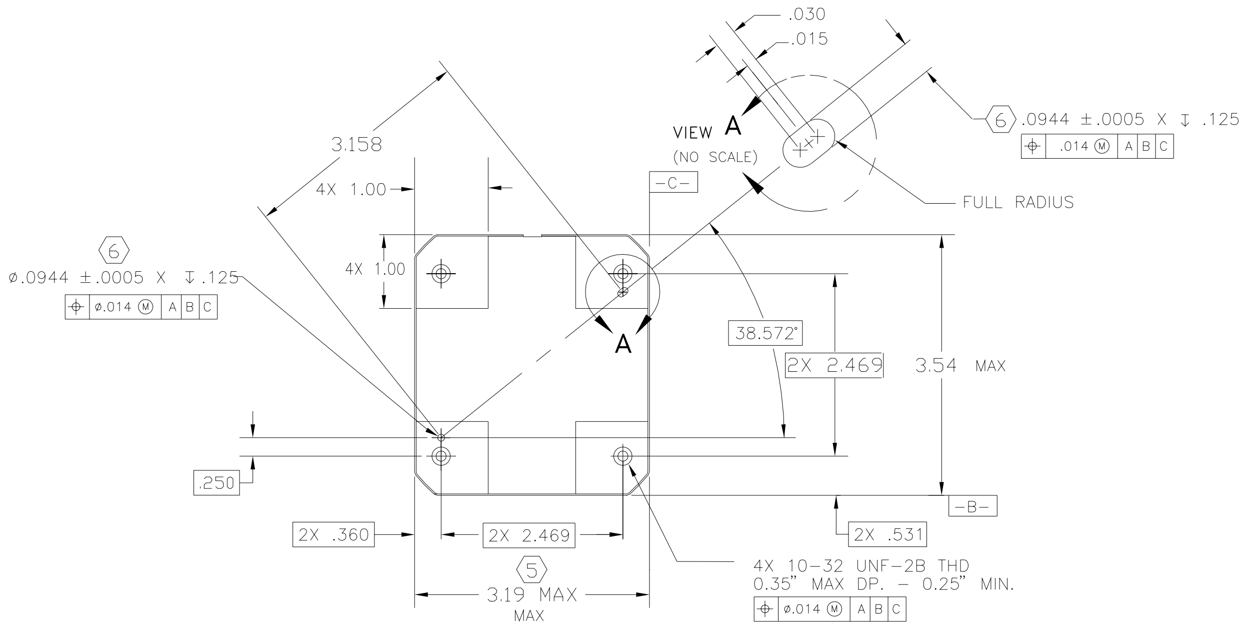


Figure 3-3 (Sheet 5 of 6). C-MIGITS III Mechanical Configuration (with EMI filter)



NOTES: 1. WEIGHT 2.7 POUNDS MAX.

2. CONNECTOR (J1) MATES WITH CONNECTOR SDID P/N 414-4072-001

3. CENTER OF MASS OF THE IMU PACKAGE IS CENTERED IN X & Y AXIS.

4. MOUNTING SCREWS .350 DEEP MAX. TORQUE TO 57 IN. LB. MAX.

5. LABEL THICKNESS NOT INCLUDED IN PACKAGE DIMENSIONS.

6. AXIS ALIGNMENT DEFINED BY DATUM -A- AND ALIGNMENT HOLES - SEE VIEW A.

7. MOUNTING/ALIGNMENT SURFACE TAKE CARE NOT TO DAMAGE.

8. FOR HEAT DISSIPATION, UNIT MUST BE MOUNTED TO THERMALLY CONDUCTIVE SURFACE.

9. ORIENT AXES TO GROOVE, ON SIDE OF OUTER CASE.

10. OPTIONAL EMI FILTER FITTED TO CERTAIN MODELS IS NOT SHOWN.

Figure 3-3 (Sheet 6 of 6). C-MIGITS III Mechanical Configuration (with EMI filter)

Environmental Specifications

The C-MIGITS III environmental specifications are provided in Table 3-5. These conditions are without safety and/or intensification factors. Under these conditions, the C-MIGITS III system can withstand damage or material degradation, and can perform within the specifications listed when tested and verified.

Table 3-5. C-MIGITS III Environmental Specifications				
Test Condition	**Test Method**	**Specification**	**A**	**T**
Altitude	MIL-STD-810 E, Section 500.0			
Operating		Up to 21336 meters (70000 ft), 10 minutes	X	
Storage		Up to 21336 meters (70000 ft), 1 hour	X	
Decompression		70,000 ft to 40,000 ft, 15 seconds	X	
Temperature Range				
Operational	MIL-STD-810 E, Section 501.3	-40 °C to +71 °C		X
Storage (non-operational)	MIL-STD-810 E, Section 502.3	-54 °C to +85 °C	X	
Temperature Shock	MIL-STD-810 E, Section 503.3	-54 °C to +71 °C, 0.42°C/sec	X	
Combined Temp & Altitude	MIL-E-5400T, Section 3.2.24.3	Class 2, Curve A, 70,000 ft, -54 °C to +71 °C	X	
Solar Radiation	MIL-STD-810 E, Section 505.3	Procedure I, 1120 Watts/m^2	X	
Rain	MIL-STD-810 E, Section 506.3	Procedures I, II, III	X	
Humidity	MIL-STD-810 E, Section 507.3	100%, with condensation	X	
Fungus	MIL-STD-810 E, Section 508.4	28 days	X	
Salt Fog	MIL-STD-810 E, Section 509.3	48 hours	X	
Explosive Atmosphere	MIL-STD-810 E, Section 511.3	Procedure I, +71°C	X	
Leakage (Immersion)	MIL-STD-810 E, Section 512.3	1 meter, 2 hrs	X	
Acceleration, Operating	MIL-STD-810 E, Section 513.4	15 g per direction, 1 minute	X	
Vibration, Performance	MIL-STD-810 E, Section 514.4	6 grms, 10 minutes/axis		X
Vibration, Endurance	MIL-STD-810 E, Section 514.4	12 grms, operating, 10 minutes/axis, reduced GPS performance		X
Vibration, Transportation	MIL-STD-810 E, Section 514.4	0.2, 0.74, 1.04 grms, 3 hrs/axis, Category I	X	
Shock, Operating	MIL-STD-810 E, Section 516.4	20G, 11 msec, Half-Sine Pulse		X
EMI/EMC (with EMI Filter)	MIL-STD-461C/462			
CE03		Power Lines, 15 kHz to 50 MHz		X
CE06		Antenna Terminals, 10 kHz to 15.8 GHz		X
CE07		Switching Spikes (42 Vdc to -14 Vdc)		X
CS01		Power Lines, 30 Hz to 50 kHz, 2.8 vrms		X
CS02		Power Lines, 50 kHz to 400 MHz, 1 vrms		X
CS03		Intermodulation, 15 kHz to 10 GHz		X
CS04		Rejection, 34.8 MHz to 10 GHz		X
CS06		Spikes, 0.15 µsec @ 150Vp-p, 10.0 µsec @ 200Vp-p		X
RE02		E-Field (Emissions), 14 kHz to 10 GHz		X
RS03		E-Field (Suscept.) 14 kHz-100 MHz @ 40 v/m		X
		100 MHz-200 MHz @ 20 v/m		X
		200 MHz-10 GHz @ 50 v/m		X
Dynamics				
Velocity		12,000 m/sec		X
Acceleration, Perf.		8 G (INS/GPS), > 8 G (INS only)		X
Acceleration, Oper.		15 G		X
Jerk		9 G/sec		X
Angular Rate Range		± 1000 deg/sec	X	
Angular Rate, Calibrated		± 300 deg/sec		X

A = Verified through analysis   T = Verified through test

Temperature

The C-MIGITS III will meet its performance requirements during and after exposure to temperatures from -40 degrees C to + 71 degrees C. Heat is dissipated by conduction through the respective mounting plate.

Vibration, Performance

The C-MIGITS III will meet its performance requirements during and after exposure to the random vibration levels shown in Figure 3-4 (6.0 grms), for a period of 10 minutes in each of the three orthogonal axes.

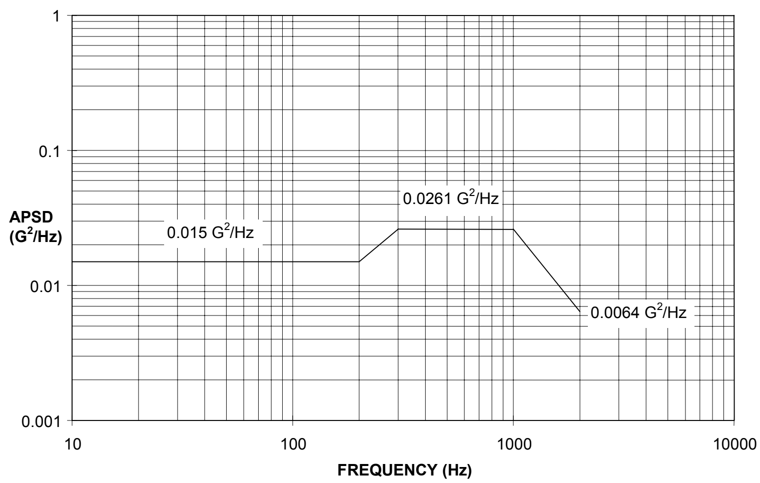


Figure 3-4. Vibration Spectrum, Performance

Vibration, Endurance

The C-MIGITS III will meet its performance requirements after exposure to the random vibration levels shown in Figure 3-5 (12.0 grms), for a period of 10 minutes in each of the three orthogonal axes.

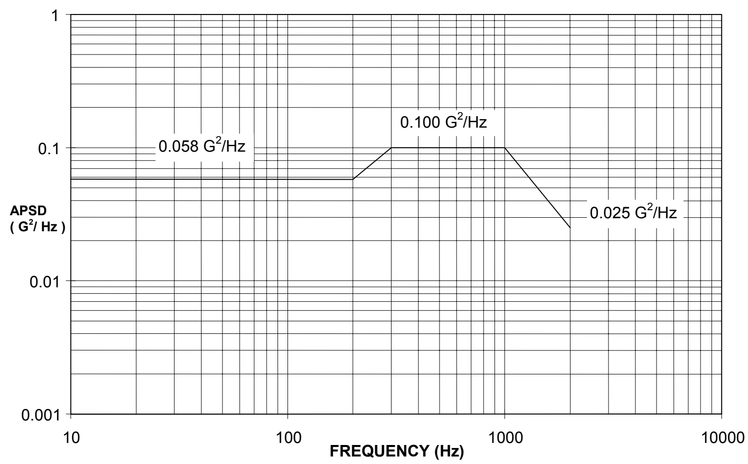


Figure 3-5. Vibration Spectrum, Endurance

Shock

The C-MIGITS III will meet its performance requirements after exposure to a 20 g, 11 millisecond, half-sine shock applied in each direction of the three orthogonal axes while operating.

Electro-Magnetic Interference and Compatibility (EMI/EMC)

C-MIGITS III will meet its performance requirements during and after exposure to EMI if equipped with the optional EMI filter. The C-MIGITS III , with the optional EMI filter, is designed to meet MIL-STD-461C/462 requirements using the preferred cable configuration. Contact your local SDI applications engineer for details. The EMI filter (see Figure 3-6) provides protection to the DC power lines from outside sources, and attenuates any conducted emissions generated by the DQI electronics.

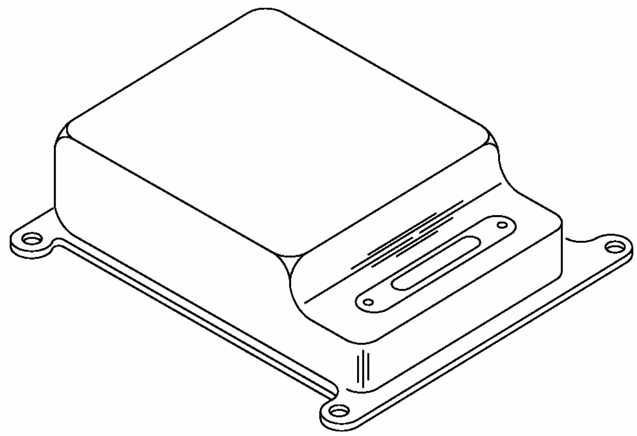


Figure 3-6. EMI Filter (Optional)

The EMI filter is a bolt-on unit that mates to the top of C-MIGITS III, and adds approximately 1.78 cm (0.7 in.) to the height of the unit.

C-MIGITS III will meet its performance requirements during exposure to the test levels of CS04 and RS03, except for a ±50 MHz bandwidth around the center frequency of 1575.42 MHz (L1 band).

C-MIGITS III Reliability

The Mean Time Between Failures (MTBF) of C-MIGITS III is no less than the values shown in Table 3-6. These values were established using MIL-HDBK-217F analysis methods and supplemented by commercial parts data.

Table 3-6. Mean Time Between Failures

MIL-HDBK-217 Environment	MTBF, hours
Ground, Benign @ 35 C	52900
Airborne, Uninhabited Fighter @ 35 C	9400
Ground, Benign Storage	44,754,700

Chapter 4 - Operation

Operating Modes

The processing state of the C-MIGITS III at any particular time is defined by a mode. C-MIGITS III utilizes the following operating modes:

- *Test*
- *Initialization*
- *Fine Alignment, Air Alignment, or Transfer Alignment*
- *Air Navigation or Land Navigation*
- *GPS-Only Navigation*

Mode sequencing after a normal startup of the C-MIGITS III is shown in Figure 4-1. After startup, the C-MIGITS III sequences automatically through *Test* mode to *Initialization* mode.

After navigation initialization data is entered by the user and accepted, sequencing continues to one of three alignment modes: *Fine Alignment, Air Alignment*, or *Transfer Alignment*. The choice of sequencing is made by user input. During these modes a Kalman filter is used to estimate IMU parameter errors and vehicle attitude.

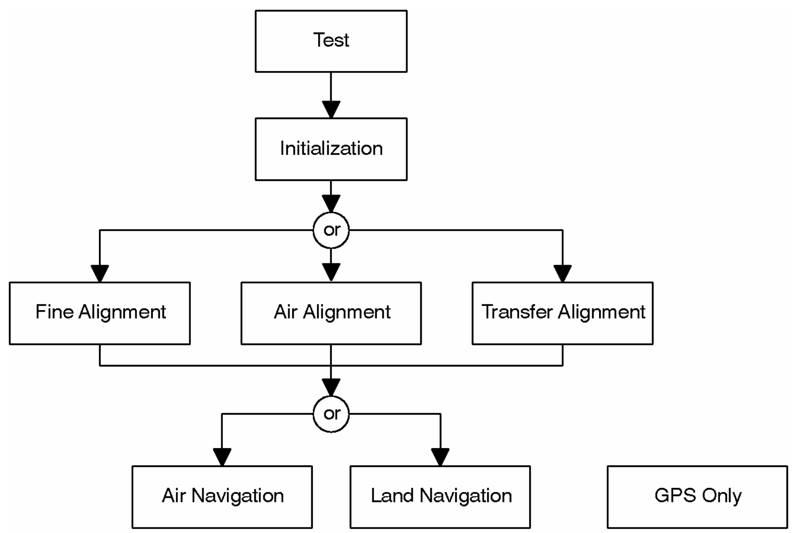
After completion of an *Alignment* mode, sequencing continues to one of two navigation modes: *Air Navigation* or *Land Navigation*. Choice of sequencing, again, is by user input.

IMPORTANT!

The C-MIGITS III must be securely mounted to a good thermally conducting (metal) surface during operation to prevent thermal damage.

In these modes, navigation is performed based on INS data, with updates from GPS data. If GPS data temporarily becomes unavailable, navigation will continue with only INS data.

GPS Only mode may be entered from any post-initialization mode if INS data becomes unavailable.



Note: Presently the Transfer Alignment, Land Navigation, and GPS Only modes are not implemented.

Figure 4-1. C-MIGITS III Operational Mode Sequence

The processing performed by C-MIGITS III during the various modes is described below.

Test Mode

Test mode is in effect while *Built-In Test (BIT)* is being performed, either as a part of normal startup sequencing or by user command.

The *BIT* function is entered immediately after power-on or after a software reset. *BIT* tests the functional areas of

C-MIGITS III, providing at least 80 percent failure coverage as weighted by failure rate. The test detects and isolates failures to the *Shop Replaceable Unit (*SRU*)* level. The false alarm rate is less than 5 percent.

The duration of *Test* mode is 10 seconds maximum. Data interfaces are not functional during this mode. Transition to *Initialization* mode occurs when *Test* mode is complete.

Initialization Mode

Initialization mode is in effect after completion of BIT, but before navigation initialization data is provided. During this mode, the GPS processor attempts to acquire satellite signals and enter navigation mode. It can succeed in doing this even before navigation initialization data is provided.

Navigation initialization data may either be provided by the user, or obtained from the GPS processor after it enters navigation mode. Choice of these options is made by user input.

Once navigation initialization data is obtained, then position, velocity, and heading are initialized. Accelerometer data is used to obtain initial coarse estimates of pitch and roll. After this is performed, Initialization mode is exited automatically, and continues to one of the three *Alignment* modes.

Fine Alignment Mode

Fine Alignment mode performs alignment when C-MIGITS III is stationary. Fine Alignment consists of estimation via a Kalman filter of the vehicle orientation, as well as estimation of IMU parameter errors (accelerometer scale factor and bias, and gyro scale factor and bias). Fine Alignment mode is exited automatically after 120 seconds to one of the navigation modes.

Air Alignment Mode

This mode performs alignment using GPS data as a velocity reference. GPS data must be available for the processing of this mode to be complete. The alignment process estimates the vehicle orientation and IMU parameter errors, and also the GPS clock error and antenna lever arm. Air Alignment mode is exited to one of the navigation modes when Kalman Filter covariances of the heading and the lever arms fall below specified thresholds.

If Air Alignment is entered while the vehicle is traveling at speeds greater than 50 m/sec, a submode called *Coarse Air Alignment* will be initiated. This submode is indicated by bit 8 (mask 0x0100) of the System Status Validity word (word 11) of the System Status message, 3500 (see page 137). During this submode, the vehicle should maintain a straight and level course until the submode bit indication is reset. Afterwards, the C-MIGITS III will continue in normal Air Alignment mode and it will no longer be necessary to maintain a straight and level course. In fact, some maneuvers are advisable to speed up the convergence of the error covariance values that control the exit from Air Alignment mode. For further information, see the *Frequently Asked Questions* section on Air Alignment on page 189.

Transfer Alignment Mode

This mode performs alignment using INS data from an external source as a velocity reference. The alignment process estimates the vehicle orientation and IMU parameter errors, and also the GPS antenna lever arm.

Transfer Alignment mode is not currently implemented.

Transfer Alignment mode is exited to one of the navigation modes when Kalman Filter covariances of the heading and the lever arms fall below specified thresholds.

Air Navigation Mode

This mode is one of the two normal navigational modes of C-MIGITS III. Navigation is performed using IMU data, and the Kalman filter is used to estimate errors in position, velocity, attitude, IMU parameters, and GPS time. The observables for the Kalman filter are the GPS pseudorange and delta pseudorange measurements. If available, measurements can also be processed from a heading reference such as a compass, or an altitude reference such as a barometric altimeter. The errors of these reference instruments may be estimated.

Land Navigation

Land Navigation mode is not currently implemented.

This mode is one of the two normal navigational modes of C-MIGITS III. Navigation and error estimation are performed as in Air Navigation mode except that, instead of estimating gyro scale factor errors, the Kalman filter processes measurements from an odometer and estimates error in the scale factor of the odometer.

GPS Only

GPS only mode is not currently implemented.

This mode is entered if IMU data becomes unavailable, which should not normally happen. During this mode, the Kalman filter uses GPS measurements to estimate vehicle acceleration as well as the usual navigation and GPS clock errors. This allows the 1-Hz GPS navigation solution to be interpolated to the 100-Hz rate of the normal INS navigation solution.

If available, measurements can also be processed from an altitude reference such as a barometric altimeter and the error of this reference instrument may be estimated. Figure 4-1 shows the normal mode sequencing of the C-MIGITS III after startup. Other mode transitions are also possible by user command. Allowed mode transitions and the conditions for them are summarized in Table 4-1.

Table 4-1. Mode Transition Table

From/To	Tes t	Init	Fine Align	Air Align	Transfer Align	Air Nav	Land Nav	GPS Only
Test	-	A	-	-	-	-	-	-
Initialization	C	-	A	A	A	-	-	-
Fine Alignment	C	C	-	-	-	A	A	A
Air Alignment	C	C	-	-	-	A	A	A
Transfer Alignment	C	C	-	-	-	A	A	A
Air Navigation	C	C	-	-	-	-	-	A
Land Navigation	C	C	-	-	-	-	-	A

GPS Only	C	C	-	-	-	-	-	A

A = automatic, C = commanded

GPS Receiver Operation

This section summarizes the operation of the GPS receiver during acquisition of GPS data.

Satellite Acquisition

The GPS receiver enters acquisition when system power is applied, or whenever there are not enough satellite measurements available for navigation. Activities performed by the receiver while in acquisition involve searching for satellite signals with which to navigate, acquiring and tracking those satellite signals, and collecting data from the tracked signals, if necessary, before navigating.

RF Signal Requirements

The signal strength at the RF input into the receiver should support a Carrier-to-Noise density ratio (C/No) of at least 34 dB-Hz. This is required in order for a given satellite to have a 99 percent chance of being successfully acquired in one attempt. The success rates are reduced to less than five percent as the signal-to-noise ratio is reduced to 29 dB-Hz.

Data Requirements

To begin acquisition activities, the GPS receiver must determine the approximate position and movement of satellites in relation to the position and movement of the receiver's antenna. The receiver will attempt to acquire and track those satellites visible to the receiver antenna at the current time. To do this, the GPS receiver, at a minimum, needs the following:

- Current antenna position
- Current antenna velocity
- Current UTC time
- Satellite almanac

In addition to satellite orbit information, almanac data includes the health status of the satellites. No attempt is made by the GPS receiver to acquire satellites indicated as “unhealthy” in the almanac data. An elevation mask angle value is used to screen out lower elevation satellites, whose signals are likely to be obscured. The default angle for the receiver is 10 degrees

If necessary, the almanac may be initialized by allowing the receiver to track at least one satellite for 15 minutes. A new almanac should be initialized if the age of the almanac resident in the receiver's EEPROM is greater than six months.

In all *Navigation* modes, the receiver will be updating the almanac with ephemeris data received from the satellites, which will normally be more current than data loaded via the serial port.

Data Initialization

There are two fundamental means by which the data outlined above is initialized. The first, *Initialization*, occurs automatically each time the receiver enters the Operational Mode from either the Off or "Keep-Alive" state. The second, *Commanded Initialization*, is an initialization commanded by the Host Vehicle.

Self-Initialization

The receiver first examines internal RAM and the Real-Time Clock (RTC) to determine if the data required to begin acquisition exists. This is the case if the GPS receiver received battery back-up power (after successfully navigating in Air, Land, or GPS Only modes), and none of the data has become invalid (either the ephemeris is older than 4 hours or it has been corrupted).

If the data is not there, EEPROM data is used as a source of satellite almanac, antenna position, and current week. Also, the antenna velocity components are set to zero, the current time-of-week is set to a default setting of Saturday midnight, and Cold Start is enabled.

Except for Cold Start, a valid current time must be supplied by the Host Vehicle when battery back-up power is not maintained.

Commanded Initialization

A critical step in reducing the acquisition time, or TTFF, is to ensure that the receiver is supplied the correct values for the self-initialization data. If any of the data from self - initialization is incorrect or unavailable, TTFF is increased.

The Host Vehicle can supply data and command the receiver to perform initialization through the use of serial input messages. After powering up the receiver, and receiving the first Time Mark Solution message (message 3623) via serial data output, a serial input Position, Velocity, and Time (PVT) initialization message (message 3510) can be safely transmitted to the receiver for data initialization.

Current user antenna position, velocity, and current time may be initialized to the correct values through the use of the initialization message. Until such a message is input, the self-initialization values of these three data items are shown in the Time Mark Solution message that is output by the receiver.

If an initialization message is input, then the values in the Time Mark Solution message during acquisition will be replaced by these new values.

When initial position and velocity values are within the uncertainty limits described in Table 3-1, the average TTFF will continue to be reduced as the uncertainties in the supplied values become smaller. The initial Universal Time Coordinate (UTC) time should be within five minutes of actual UTC time.

Cold Start

Lacking position, time, current ephemeris, and almanac data, the receiver can still arrive at a navigation solution. This situation is known by the term *"Cold Start"*. Cold Start is an enhanced algorithm by which the GPS receiver searches the sky to locate visible satellites.

The TTFF for this process is longer than commanded or self-initialization (see Table 3-1).

Acquiring Satellites (Except For Cold Start)

When acquiring GPS data, the GPS receiver determines the approximate positions of all visible satellites. From this group, a set of four satellites with the best GDOP is chosen. This group is called a *Primary* set.

The GPS receiver then begins acquisition of the first satellite by choosing the highest of the primary satellites (by elevation angle) and commanding all twelve receiver channels to search for that satellite, each in a different Doppler frequency range. These frequency ranges are obtained by applying Doppler shifts, computed from the satellite's position and movement, to the Ll satellite signal frequency.

In each channel, the GPS receiver correlates the incoming signal with a locally generated replica of the C/A code sequence for the particular satellite being acquired.

Once the code is detected (i.e., correlated), a pair of tracking loops is activated to track both the code sequence and the signal carrier. As the code and carrier are tracked, the GPS receiver determines the location of the navigational data bit sequence within the signal. This provides additional time-of-day and time-of-arrival data to be used along with the current value of GPS time to compute more precisely the Doppler frequency ranges in which the remaining satellites may be found.

On occasion, the GPS receiver may "miss" the first satellite, or, unable to acquire the satellite within a certain amount of time. This could be due to an obscuration, incorrect, or old initialization data. If the receiver is unable to find the first satellite, the next highest primary satellite (by elevation angle) is assigned to all twelve channels and the acquisition process restarts. The receiver will continue cycling through the visible satellite list, according to its current almanac, until a satellite is acquired and tracked.

After successful acquisition and tracking of the first satellite has been accomplished, one of the receiver channels continues to track it while each of the remaining channels is released to search for a different visible satellite.

Cold Start Acquisition

In Cold Start operation, the GPS receiver computes a visibility list based on whatever initialization data is available. If no acquisitions occur on the highest four satellites on this list and Cold Start is enabled, Cold Start function will be entered, at which time the remaining satellites will be added to the search queue. The order of search may be modified as time and position data is obtained from tracked satellites.

Ephemeris

Satellite ephemeris data is considered to be valid if its age is within its curve-fit validity window (usually 4 hours). When available in RAM, valid satellite ephemeris is used instead of the almanac to determine visible satellites, their positions, and movements relative to the GPS receiver.

The GPS receiver must have valid ephemeris for at least four satellites being tracked (three if three-satellite navigation is enabled) to begin navigating.

Therefore, for each acquired satellite that is to be used for navigation, but has non-existent or invalid ephemeris in RAM, ephemeris data must be collected for the satellite before the receiver begins navigating.

If the ephemeris data is valid, but has been updated by the GPS Control Segment (i.e., the data in RAM is greater than 1 hour old), then new ephemeris data is collected to update the data onboard the GPS receiver. Usually 18 to 36 seconds of uninterrupted tracking of a given satellite is required to obtain ephemeris for that satellite.

Collected ephemeris data may indicate that the satellite is "unhealthy", in which case the satellite cannot be used for navigation and is replaced with another satellite if one is available. This increases TTFF.

Acquisition from First Power-Up

When powering up the GPS receiver for first time, initial acquisition data will reflect default factory settings. For a rapid TTFF, it is necessary to send an initialization message containing position and time, or rely on a Cold Start. It also is necessary to input velocity if the 75 m/sec uncertainty limit is exceeded from a default velocity of zero.

Reducing Time-to-First-Fix

The GPS receiver contains a section of volatile static RAM (SRAM) where navigation data can be maintained for a limited time on battery power while the receiver is off. During this time, the GPS receiver is said to be in the "*Keep-Alive*" state. After the navigation data is lost, the GPS receiver is said to be in the "*Off*" state.

Minimized Acquisition Time From Off State

When power is applied to the system from the *Off* state, the receiver loses the data retained in SRAM. Through self-initialization, the receiver retrieves position, almanac, and current week data stored in EEPROM. An initialization message containing, at a minimum, UTC time is required to overwrite the default time.

Note: The last stored position in EEPROM is not necessarily the last user position just prior to the previous power-down.

A new position is stored during a navigation state when both of the following occur:

- The distance to the previously stored position is greater than 100 km.
- The age of the previously stored position is greater than 6 hours.

If the position uncertainty is greater than 100 km (e.g., due to transport of the receiver while in the *Off* state), then the initialization message should also contain current position. As before, it will be necessary to include current velocity in this message if the uncertainty is greater than 75m/sec.

If the receiver has been off for a period of time greater than six months, the almanac will be updated when satellite tracking is resumed.

Minimized Acquisition Time From "Keep-Alive" State

When powering up using backup battery power (or the *"Keep-Alive"* state), and, assuming there has been prior operation the normal navigational modes and the receiver has not been removed from its battery power), the receiver has access to the data maintained in volatile memory (SRAM). Therefore, it has the last navigation solution and set of satellite ephemeris that were present at the time of power-down.

The TTFF depends on the age of this data (i.e., the length of time that the receiver was using keep-alive power). The low-power timer will maintain time when utilizing keep-alive power, but position and velocity may require initialization if uncertainties are outside the 100 km and 75 m/sec limits, respectively.

If the receiver was using keep-alive power for a length of time that caused the resident ephemeris to be older than the age allowed by its curve-fit validity window (typically 4 hours), then TTFF will be impacted due to collection of new ephemeris, which takes 18 to 36 seconds (24 seconds average).

Almanac

Almanac data is used by the receiver to determine where best to search for the satellites' signals. This data is uploaded to the satellites by the GPS Control Segment of NAVSTAR. Although frequently updated, the same set of almanac parameters can be effectively used for several months, except in rare cases when satellites are repositioned or new satellites are launched.

Once a satellite is being tracked by the GPS receiver, ephemeris parameters are used to continue tracking the satellite or re-acquire a satellite if its signal is lost. Ephemeris data is more accurate than almanac data, but is typically valid for a 4-hour portion of the satellite's orbit. If the GPS receiver remains without power for several months, acquisition time increases.

Note: Almanac data for all GPS satellites is broadcast by each satellite, but each satellite broadcasts ephemeris data only for itself.

Solution Time of Validity

GPS receivers provide almost instantaneous position and velocity solutions. In general, GPS receivers take a snapshot of the satellite measured ranges, at a precise moment in time, to calculate the user position. Then, a time exposed snapshot of the change in ranges is taken to reach the velocity solution.

The single snapshot is actually called a *pseudorange measurement*, while the time-exposed snapshot is called a pseudorange rate or *delta-range measurement*. A GPS receiver requires processing time between measurements to calculate the user position and velocity.

During the computations, the receiver compensates for position errors by propagating the user position forward one second, based on the velocity of the user. The user velocity is derived from a delta-range measurement. The delta-range measurement is calculated by monitoring and integrating the Doppler shift between the receiver and a satellite over a finite, predetermined period of time.

At the completion of a delta-range measurement, a pseudorange measurement (see Figure 4-2) is performed. This provides the receiver velocity and instantaneous range for each of the receiver channels. The receiver processes this data and calculates a user position and velocity. Since the receiver may be moving during processing time, the data is extrapolated by using the user velocity projected in time by one second (the time required to provide the data at the serial data port).

The GPS receiver provides the user with position and velocity data every second. The system integrator's equipment is provided a *Time Mark* pulse at the instant the data at the serial port is valid. Figure 4-2 illustrates a timing diagram for these events.

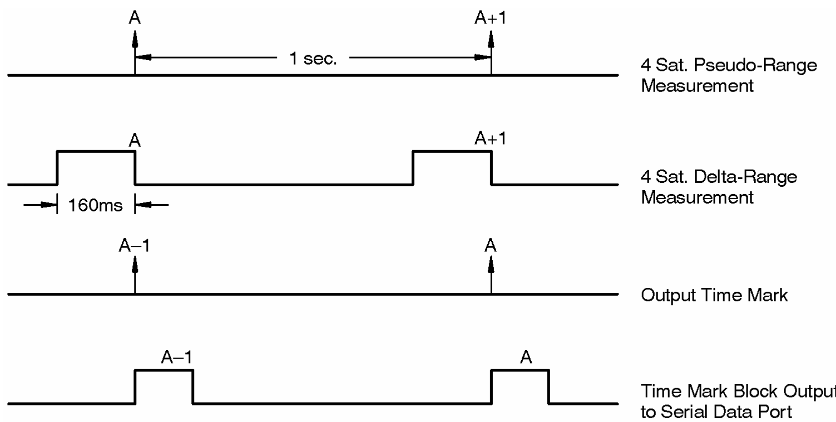


Figure 4-2. Typical Navigation Solution "Time Mark" Output

"A" represents a particular navigation solution, whereas "A-l" and "A+1" represent the prior and future navigation solutions, respectively.

Once the four satellite pseudorange and delta-range measurements are made, the data is processed and projected forward 1 second to prepare for an *Output Time Mark* pulse. At the leading edge of this pulse, the valid navigation data is provided to the *serial data port*.

In some instances, the navigation data will be delayed by a short period of time due to "bus" contention by the Host Vehicle, or by messages previously queued or in progress as a valid transmission by the receiver to the Host Vehicle. In any case, the navigation solution presented is valid at the instant the Time Mark pulse occurred.

Geometric Dilution of Precision

During navigation modes, C-MIGITS III maintains a constellation of four satellites (if four are available) that provide the best geometry for an accurate navigation solution. These satellites are referred to as *primary* satellites. The remaining satellites are considered to be *secondary*.

The measure of the quality of a satellite constellation's geometry is called *Geometric Dilution of Precision* (GDOP). GDOP reflects the influence of satellite geometry on the accuracy of user position estimates and user time. The best geometry is that which produces the lowest GDOP value. GDOP is a multiplier of position error due to other sources.

Components of GDOP

GDOP is a composite measure. It includes *Position Dilution of Precision* (PDOP), which reflects the effects of geometry on three-dimensional position estimates, and *Time Dilution of Precision* (TDOP), which reflects geometric effects on time estimates. The relationship can be expressed as:

$$GDOP = \sqrt{(PDOP)^2 + (TDOP)^2}$$

In turn, PDOP can be expressed in terms of *Horizontal Dilution of Precision* (HDOP) and *Vertical Dilution of Precision* (VDOP), which are geometric effects on two-dimensional horizontal position estimates and on vertical position (altitude) estimates, respectively. This relationship can be expressed as:

$$PDOP = \sqrt{(HDOP)^2 + (VDOP)^2}$$

IMU Operation

The IMU is designed to provide internally compensated, body referenced, orthogonal, simultaneous measurements of angular rate and linear acceleration at a 600-Hz rate. In addition, the IMU provides delta velocity information in three axes and delta attitude information about three axes at a 100-Hz rate. The data is output on an AMRAAM formatted serial bus with the 600-Hz data defined as *autopilot data* and 100-Hz data defined as *inertial data*.

The IMU consists of an *Inertial Sensor Assembly* (ISA) and *Inertial Sensor Electronics* (ISE). The ISA contains a cluster assembly and an electronics module. The cluster assembly consists of three block mounted, mutually orthogonalized *Quartz Rate Sensors* (QRS), and three mutually orthogonalized *Vibrating Quartz Accelerometers* (VQA), in a shock-mount configuration.

The electronics module contains the direct interface electronics to the inertial instruments, that provide a digital interface to the ISE. The ISE provides the signal processing and computational capability required to convert the inertial instrument outputs to formatted autopilot and inertial data. A summary of error sources used to characterize C-MIGITS III are shown in Table 4-3.

Table 4-3. C-MIGITS III Error Budget			
Coefficient (1)	**Units**	**Meas.**	**C-MIGITS III**
Gyro Channel			
Bias	deg/h	1σ	20
Bias - In run stability from turn-on	deg/h	1σ	3 (3)
SF stability (all causes)	ppm	1σ	350
Angle Random Walk	deg/root-h	max. nom.	0.09 0.035
Rate Noise	deg/hr rms	max.	360
$\Delta\theta$ Noise	μrad rms	max.	4
Bias G Sensitivity	deg/h/g	1σ	1.0
Gyro drifts due to vibration rectification	deg/h/g-rms	1σ	1.0
Angular rate quantization (LSB) (2)	micro-rad/s	nom.	500
Angular change quantization (LSB) (2)	micro-rad	nom.	5
Non-orthogonality	milli-rad	1σ	0.5
IA alignment to case	milli-rad	max.	10
IA alignment to case stability	milli-rad	1σ	1
Data Latency	milli-sec	nom.	5.98
Bandwidth, Gain (3 dB)	Hz	nom.	101
Bandwidth, Phase (-90°)	Hz	nom.	37.5
Accelerometer Channel			
Bias	milli-g	1σ	4.0
Bias - In run stability from turn-on	micro-g	1σ	200(3)
SF stability (all causes)	ppm	1σ	350
Velocity random walk	micro-g/root-Hz	max. nom.	180 60
Acceleration Noise	milli-g rms	max. nom.	400 100
Velocity Noise	ft/sec rms	max.	0.006
Accelerometer vibration rectification	$\mu g/grms^2$	max.	100
Acceleration quantization (LSB) (2)	milli-g	nom.	3
Velocity change quantization (LSB) (2)	mm/s	nom.	0.2
Non-orthogonality	milli-rad	1σ	0.2
IA alignment to case	milli-rad	max.	10
IA alignment to case stability	milli-rad	1σ	1
Data Latency	milli-sec	nom.	5.37
Bandwidth, Gain (3 dB)	Hz	nom.	60
Bandwidth, Phase (-90°)	Hz	nom.	48
Operating Range			
Angular Rate - Dynamic Range	deg/s	nom.	1000
Angular Rate - Calibrated Range	deg/s	nom.	300
Acceleration - Dynamic Range	g	nom.	70
Acceleration - Calibrated Range	g	nom.	50

(1) Applicable to all three axes.
(2) With default data scaling/dynamic range as measured in serial output.
(3) Markov with 60 sec correlation time.
note: for purposes of this user's guide, a standard g is defined as 9.80665 m/sec^2 .

INS/GPS Interaction

The C-MIGITS III system contains IMU software and Integrated INS/GPS software algorithms that reside in the same Central Processing Unit (CPU). The CPU is a Texas Instruments TMS320C31 processor. An overview of the software architecture is shown in Figure 4-3.

INS/GPS interaction is accomplished using a 28-error state Kalman filter. This filter uses GPS range and range rate data inputs to compute corrections for an IMU driven strapdown/navigation solution. The corrections are updated by the Kalman filter at a 1-Hz rate, then provided as controls for the strapdown and navigation algorithms.

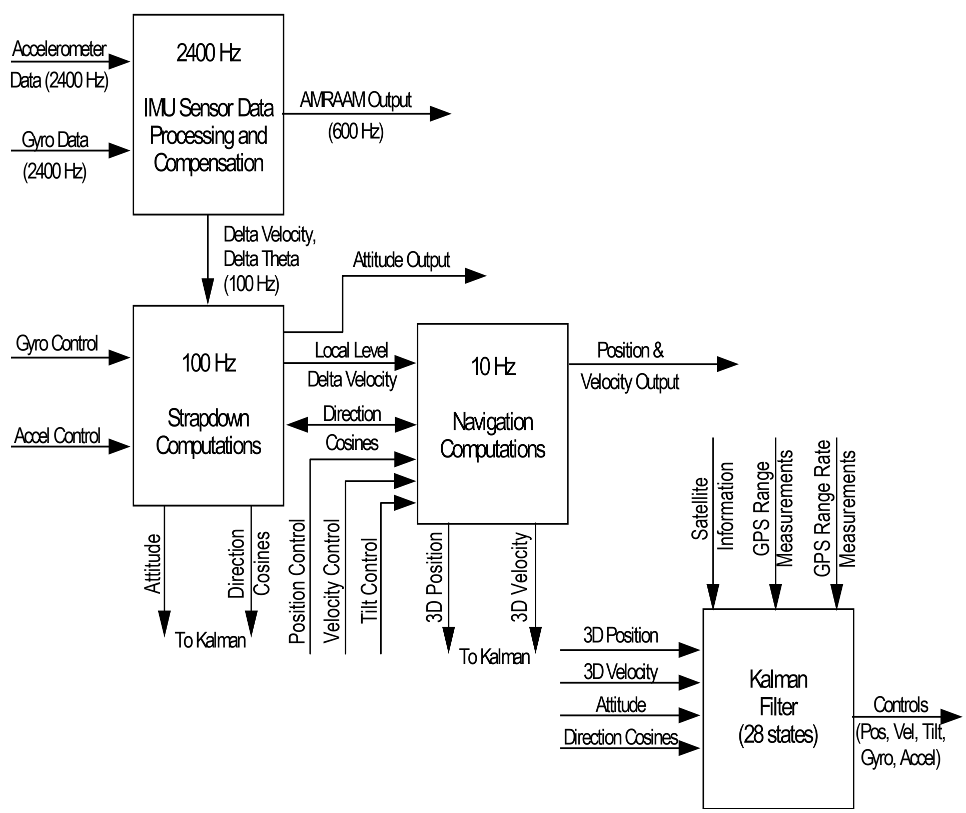


Figure 4-3. C-MIGITS III INS/GPS Software Algorithm

Chapter 5- Hardware Integration

Overview

The C-MIGITS III system is designed to be integrated within a navigation or flight control system by a systems integrator. The system can be implemented in many end-product solutions, including missiles, aircraft, guided munitions, and other military and commercial applications; however, it is not limited to these markets.

This chapter describes the various hardware-related features of C-MIGITS III that should be considered for an efficient and effective system integration.

Electrical Interface

Signal Types

The characteristics defined in this section are for C-MIGITS III connector inputs Jl and J2. The four types of digital signals are defined in Table 5-1. The Jl connector contains these four types of digital signals, power inputs, and internal power supply voltage monitors (see figure 5-1). A detailed description of these signals for J1 is given in Table 5-2.

The J2 connector provides the GPS RF antenna input. A description of the GPS RF input is given in Table 5-3.

Table 5-1. Signal Type Definitions
HCMOS:
High-level input voltage (logic 1): $3.15 \leq V_{IH} \leq 5.0$ volts
Low-level input voltage (logic 0): $0 \leq V_{IL} \leq 0.9$ volt
Maximum input current: ±1000 nAmp
Maximum rise and fall times: 50 nsec
TTL:
High-level input voltage (logic 1): $2.0 \leq V_{IH} \leq 5.0$ volts
Low-level input voltage (logic 0): $-0.3 \leq V_{IL} \leq 0.8$ volt
Maximum input current: ±10 µAmp
Maximum rise and fall times: 50 nsec
RS232:
High-level input voltage: $2.4 \leq V_{IH} \leq 30.0$ volts
Low-level input voltage: $-30.0 \leq V_{OL} \leq 0.8$ volts
Input resistance: 3 kOhms $\leq R_{IN} \leq$ 7 kOhms
High-level output voltage (R_L=3 kOhm): $5.0 \leq V_{OH} \leq 15.0$ volts
Low-level output voltage (R_L=3 kOhm): $-15.0 \leq V_{OL} \leq -5.0$ volts
Transition slew rate: $6.0 \leq T_{SR} \leq 30$ V/µsec
Maximum data rate: 115.2 kbits/sec
RS422:
Minimum differential input voltage: ±0.2 volt
Maximum differential input voltage: ± 7.0 volts
Maximum common mode input voltage: ±7.0 volts
Differential input resistance: >100 Ohms
High-level output voltage (I_{OH}=-2OmA): $2.5 \leq V_{OH} \leq 5.0$ volts
Low-level output voltage (I_{OL}=2OmA): $0 \leq V_{OL} \leq 0.5$ volts
Maximum data rate: 6.20 Mbits/sec

C-MIGITS III Prime Interface (J1)

C-MIGITS III J1	**EXTERNAL MATING CONNECTOR**
MIL-C-83513/2 OR COMMERCIAL MDM-37S	MIL-C-83513/1 OR MIL-C-83513/1 OR COMMERCIAL MDM-37P

C-MIGITS III J1	
TEST MODE ENABLE #2	1
RESERVED	2
TEST MODE ENABLE #1	3
FRAME SYNC IN P	4
FRAME SYNC IN N	5
+28 VDC (POWER IN)	6
DATA SYNC PULSE N	7
DATA SYNC PULSE P	8
-5 VDC ANALOG VOLTAGE	9
CLOCK IN P	10
CLOCK IN N	11
SERIAL DATA OUT N	12
SERIAL DATA OUT P	13
BIT COMMAND	14
SPARE	15
+5 VDC ANALOG VOLTAGE	16
POWER RETURN (GROUND)	17
POWER RETURN (GROUND)	18
CHASSIS GROUND	19
SERIAL DATA IN N	20
SERIAL DATA IN P	21
100 HZ DISCRETE N	22
100 HZ DISCRETE P	23
DATA SHIFT CLOCK N	24
DATA SHIFT CLOCK P	25
+12 VDC ANALOG VOLTAGE	26
+28 VDC (POWER IN)	27
DATA FROM HV	28
ANALOG GROUND	29
DIGITAL GROUND	30
BATTERY	31
DATA TO HV	32
GPS OUT	33
TIMEMARK	34
BOOT LOADER MODE	35
INTERRUPT 3	36
+5 VDC DIGITAL VOLTAGE	37

Figure 5-1. C-MIGITS III Electrical Interface

Table 5-2. C-MIGITS III J1 Electrical Interface Description					
Pin No.	**Mnemonic**	**Signal Flow**	**Signal Type**	**Description**	**Wire Type**
1	TMODE2	In	HCMOS	Test Mode Enable #2 *	-
2	RESERVED				
3	TMODE1	In	HCMOS	Test Mode Enable #1 *	-
4	FSR0P	In	RS422	C31 Sync_In Positive *	-
5	FSR0N	In	RS422	C31 Sync_In Negative *	-
6	+28V	In	POWER	+ 28 Vdc Primary Pwr In	Tw Pr
7	DATSYNCN	Out	RS422	Data Sync Pulse Negative**	26 AWG TSP
8	DATSYNCP	Out	RS422	Data Sync Pulse Positive**	26 AWG TSP
9	A-5V	Out	POWER	Analog - 5 Vdc Monitor *	-
10	CLKR0P	In	RS422	C31 Serial Clk_In Positive *	-
11	CLKR0N	In	RS422	C31 Serial Clk_In Negative *	-
12	SERDATN	Out	RS422	Serial Data Out Negative**	26 AWG TSP
13	SERDATP	Out	RS422	Serial Data Out Positive **	26 AWG TSP
14	BIT_REQ	In	HCMOS	BIT Command	26 AWG
15	SPARE	In	HCMOS	Spare discrete input line	-
16	A+5V	Out	POWER	Analog + 5 Vdc Monitor *	-
17	PWR GND	In	POWER	Primary Pwr Ret (Ground)	26 AWG Tw Pr
18	PWR GND	In	POWER	Primary Pwr Ret (Ground)	26 AWG Tw Pr
19	GND_CHASSIS	In	REF	Chassis Ground	26 AWG
20	DR0N	In	RS422	Serial Data_In Negative *	-

(Continued next page)

Table 5-2. C-MIGITS III J1 Electrical Interface Description (Cont)

21	DR0P	In	RS422	Serial Data_In Positive *	-
22	SYNC100N	Out	RS422	100 Hz Discrete Negative	26 AWG TSP
23	SYNC100P	Out	RS422	100 Hz Discrete Positive	26 AWG TSP
24	DATSFTCKN	Out	RS422	Data Shift Clock Negative **	26 AWG TSP
25	DATSFTCKP	Out	RS422	Data Shift Clock Positive **	26 AWG TSP
26	+12V	Out	POWER	+ 12 Vdc Monitor *	-
27	+28V	In	POWER	+ 28 Vdc Primary Pwr In	26 awg Tw Pr
28	RS232IN	In	RS232	Serial Data from Host Vehicle	26 AWG
29	GNDANALOG	In	POWER	Analog Ground*	-
30	GND_DIG	In	POWER	Digital Ground	26 AWG
31	BATTERY	In	POWER	GPS “Keep Alive” Battery Input	26AWG
32	RS232OUT	Out	RS232	Serial Data to Host Vehicle	26 AWG
33	GPSTXDB	Out	RS232	GPS to IMU Serial Data	-
34	TIMEMARK	Out	RS232	1 Hz Time Mark Pulse from GPS	26 AWG
35	BLMODE	In	TTL	C31 Boot Loader Mode Enbl*	-
36	INT3C	In	TTL	C31 Interrupt #3 *	-
37	D+5V	Out	POWER	Digital + 5 Vdc Monitor *	-

General notes **:**

1. The shaded pin numbers are reserved.
2. Pins that have an asterisk (*) are for testing purposes only; no connections should be made to these pins, particularly not to an unterminated wire in a cable bundle.
3. Pins that have two asterisks (**) contain AMRAAM data.
4. AWG = American Wire Gage, Tw Pr = Twisted Pair, TSP = Twisted Shielded Pair
5. Pairings are: signal, signal complement, e.g., DATSFTCKP with DATSFTCKN.
6. Shields of Twisted shielded pair wire should be connected to the mating connector EMI backshell.
7. Cable overbraid should be connected to the mating connector EMI backshell.

RF Interface (J2)

The C-MIGITS III RF interface is described below, with the characteristics defined in Table 5-3.

Table 5-3. GPS RF Input Interface Definition		
Signal Name	**I/O**	**Electrical Characteristics**
RF_IN	INPUT	50 OHM @ L1 with VSWR OF 2:1 or better

- **RF_IN**. This interface signal provides the path for GPS RF signals from an antenna to C-MIGITS III. C-MIGITS III is capable of operating with GPS signals generated by a mixture of all GPS satellite types specified in SS-GPS-300.

Impedance

The input impedance at the RF connector is 50 Ohms, with a VSWR of 2:1 or better.

Center Frequency Input

The input center frequency is 1575.42 MHz.

Signal Level Input

The operational input range is -163 to -130 dBW (with operational satellite signals).

Noise Figure Input

The composite noise figure of a preamplifier, cable, and GPS receiver must be less than 5.0 dB for operation with minimum guaranteed GPS satellite signal levels.

To determine this composite noise figure, a typical noise figure of 4.0 dB is used for the GPS receiver, measured at the RF input port at L1 with a 10-MHz bandwidth.

Input Burnout Protection

The maximum input power level is -10 dBW at the RF port (at L1 with a 10-MHz bandwidth).

Delay

The delay (for example, due to line length) between the antenna and J1 RF connector is not important. The GPS receiver will compute a navigation solution at the phase-center of the antenna.

Antenna

The antenna is required to be right-hand circular polarized, exhibiting a gain of not less than -3 dBiC above a 10-degree elevation.

Power Interface

Input Voltage

The input voltage to C-MIGITS III should be within +20 to +34 Vdc, as measured at the input. The typical input voltage is +28 Vdc, as referenced to power return/ground.

Current

The typical steady-state current drawn by C-MIGITS III is +0.65 amps at +28 Vdc. The typical startup current drawn is +1.5 amp at +28 Vdc for 0.3 msec.

Overvoltage

C-MIGITS III contains a transient absorption zener that clamps the input voltage at +41 Vdc.

Power Supply Considerations

The primary function of any regulated power supply is to hold the voltage in its output circuit while maintaining the current delivery over temperature. It is quite evident that power, current, and ripple under full load are important.

The system integrator needs to account for noise contributors when placing a power supply in a system. Even though the power supply required for a C-MIGITS III system is dependent on the application, care should be taken to specify the electrical and mechanical characteristics of the power supply.

In a system design using a switching power supply, EMI is a natural by-product of the on-off switching. The interference can be conducted to the load, resulting in higher output ripple and noise. It also can be conducted back into the AC line in the case of AC-to-DC switchers, and can be radiated into the atmosphere and surrounding equipment. Shielding and filter networks may be needed to reduce the ripple and noise.

Keep Alive Battery

The **BATTERY** input to C-MIGITS III provides "keep-alive" power to the SRAM and real-time clock in the GPS receiver. This is intended to provide the GPS receiver with a "hot start" capability by maintaining position, time, and ephemeris data in SRAM when primary power is removed from C-MIGITS III.

The voltage applied to this input should be in the range of +3.0 to +5.0 Vdc referenced to **GND_DIG**. If no voltage is applied to the **BATTERY** input, an internal super capacitor will maintain the "keep-alive" voltage for a minimum of 2 hours after primary power has been removed.

Ground

The three signals, **GND_CHASSIS, GNDANALOG,** and **GND_DIG**, are all tied together at a single ground point inside C-MIGITS III. The single ground point is the "output common" pin of the DC-DC converter. Note that these signals are electrically isolated from the power return/ground signals.

Voltage Monitors

The voltage monitor outputs from the IMU are derived directly from the IMU's internal DC-DC Converter. The DC-DC converter provides output current limiting in the event of a short circuit. No other buffering or short circuit protection is provided for these outputs.

Digital Interface

Host Vehicle (HV) Serial Interface

The HV interface is a full-duplex asynchronous RS232 serial data communication port. This port is the interface for command and control of the C-MIGITS III by the HV. Message formats, communications, and control protocol are defined in *Chapter 6- Software Integration*.

The interface consists of the following signals with the signal types and interface descriptions defined earlier in Tables 5-1 and 5-2. Both of these signals are referenced to **GND_DIG**.

RS232OUT: Data transmitted by C-MIGITS III to the external equipment. The interface circuit for this signal is shown in Figure 5-2.

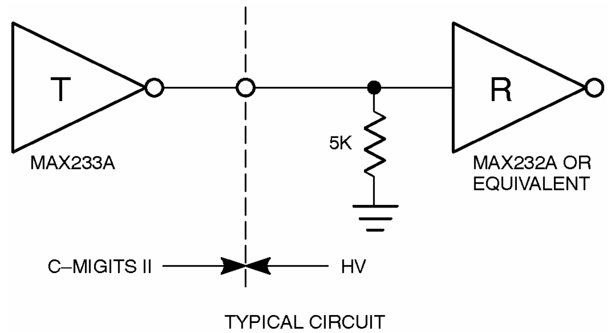


Figure 5-2. Host Vehicle RS232 Output Circuit

- **RS232IN**: Data received by C-MIGITS III from external equipment. The interface circuit for this signal is shown in Figure 5-3.

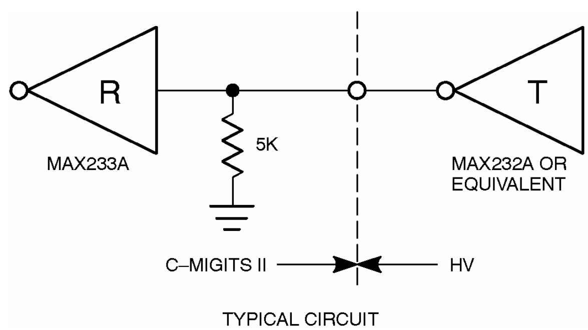


Figure 5-3. Host Vehicle RS232 Input Circuit

Data is transmitted and received within a UART-compatible frame. The default frame format is:

- One start bit.
- 8 data bits (least significant bit first).
- One parity bit (odd parity).
- One stop bit.
- Data rate of 38400 baud.

The interface supports reconfiguration of data rates and frame formats as follows:

- Data rates for transmit and receive are independently selectable from 9600, 19200, 38400, 57600 and 115200 baud.
- The parity bit is selectable as present or not present; if present, is selectable as even or odd parity.
- Start and stop periods are fixed at one bit.
- Data is fixed at 8 bits.
- Port idle is nominally a logical low (-5 Vdc).

Timemark Signal

C-MIGITS III provides a Timemark signal described below. The Timemark signal's type and interface description are previously defined by Tables 5-1 and 5-2.

- **TIMEMARK**: C-MIGITS III provides a one pulse-per second (pps) output signal to the external equipment. This pulse represents the instant in time when the navigation solution is valid. The precision of the Timemark output is ±1 μsec, exclusive of the effects of SA.

This pulse is provided for synchronization with the Timemark output message (binary message 103; refer to Chapter 6). This output message contains the local estimate of GPS time and position. The Timemark pulse width is 20 μsec, and the polarity is negative-going.

The navigation solution that is provided subsequent to the pulse contains solution data that is valid at the leading edge of the Timemark pulse. The interface circuit for this signal is shown in Figure 5-4.

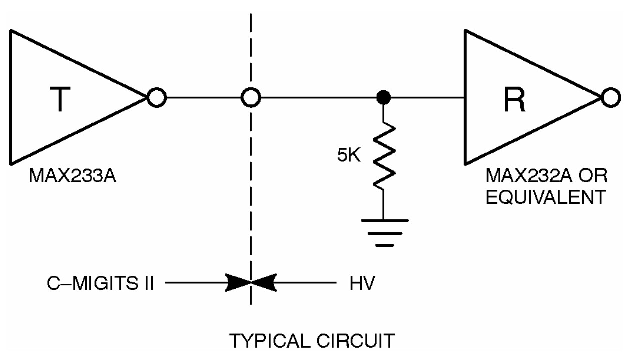
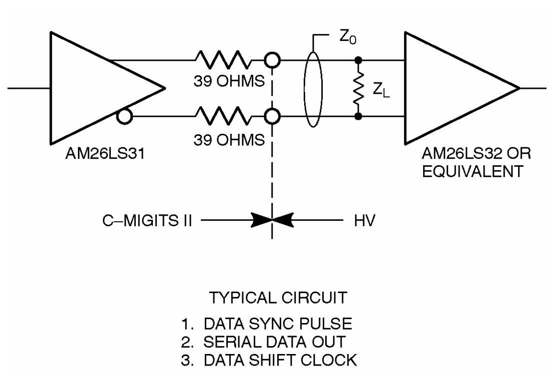


Figure 5-4. Timemark Output Circuit

IMU Synchronous Serial Interface

C-MIGITS III provides IMU output data in serial AMRAAM format. This interface consists of three RS422 differential signal output pairs. The signals are the three traditional AMRAAM signals of Serial Data Out, Data Shift Clock and Data Sync Pulse.

The interface circuit for these signals is shown in Figure 5-6. Timing diagrams for these signals are shown in Figures 5-7 and 5-8.



Z_L typically 78 to 250 Ω

Figure 5-6. Output Data Driver Circuit

AMRAAM Serial Data Word

High frequency IMU data output of C-MIGITS III is transmitted over the AMRAAM serial data interface. This data includes signal identification, six channels of autopilot data, six channels of inertial data, and Built-In-Test status.

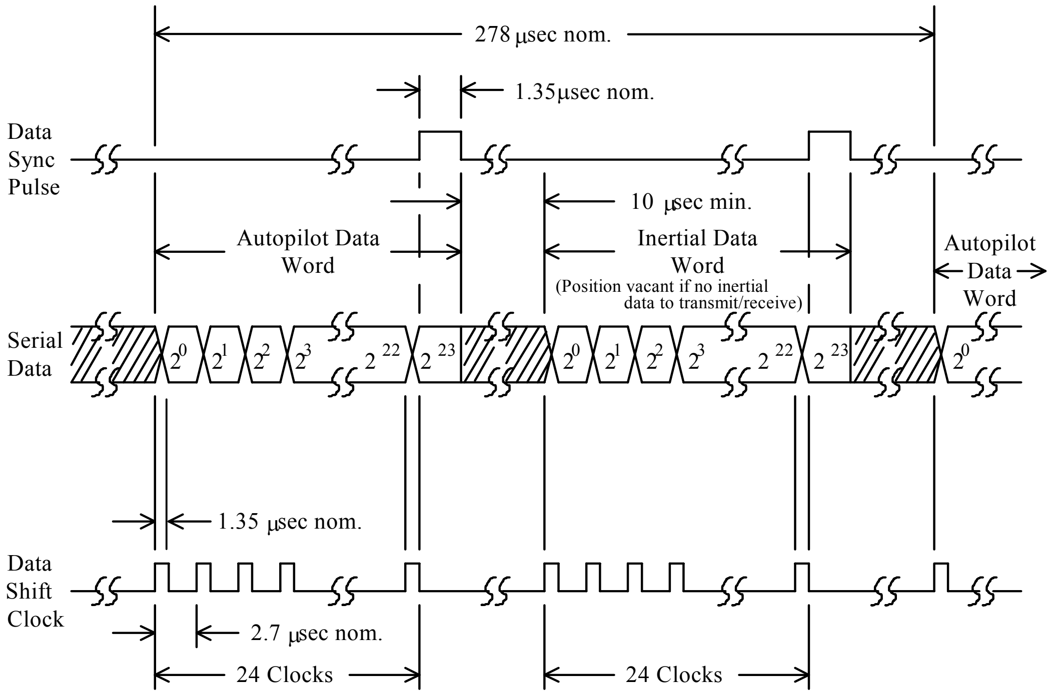


Figure 5-7. IMU Output Data Timing Diagram

The diagram is applicable to the non-inverting side of a differential pair, but the requirements are applicable to the inverting side also. Data is stable prior to the negative clock transmission.

Using the Data Sync Pulse as a reference, each autopilot channel has a repetition rate of 600 Hz $\pm$ 0.02 % (updated each transmission).

Each inertial channel has an average frequency of 100 Hz ± 0.02 percent. The time jitter between data sync pulses for any channel is ± 15 microseconds from the nominal time period. The nominal time period is the reciprocal of the nominal average frequency.

The inertial data is transmitted after a minimum 10 microsecond interval following completion of the autopilot data word from which it was derived. Data transmission is completed before the next autopilot data word transmission starts. Figure 5-8 shows the serial data transmission sequence.

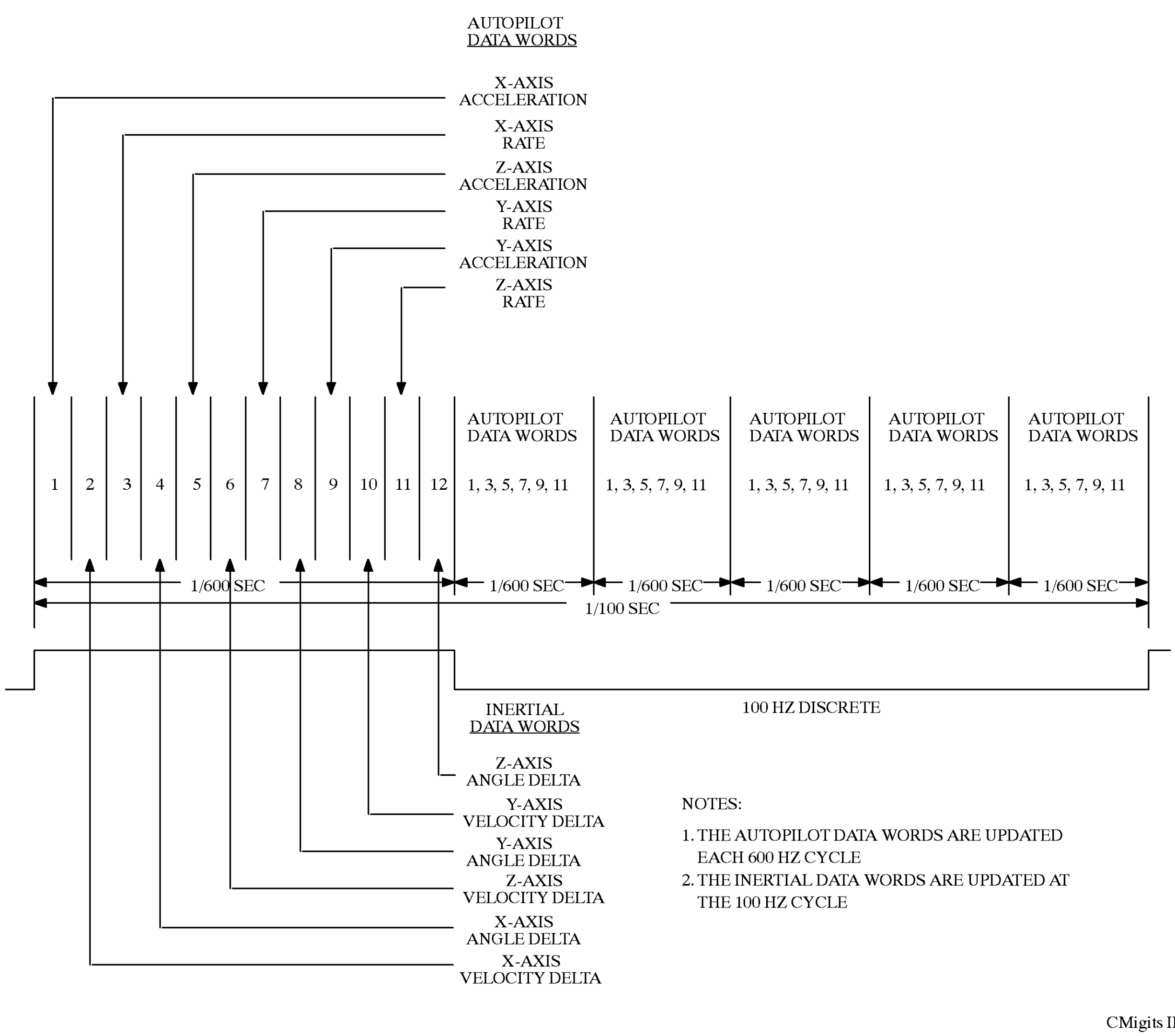


Figure 5-8. IMU Output Data Transmission Sequence

AMRAAM Serial Data Word Format

The data transferred over the AMRAAM serial interface is in 24-bit words. Each word consists of an 8-bit tag and 16 bits of data. The tag is comprised of three bits of data ID, one bit for data type identification, two IMU identification bits and two BIT status bits. The data portion of the word contains a 16-bit two's complement number. Table 5-4 defines the *Order of Transmission, Type, Tag Field,* and *Data Field.*

Table 5-4. Serial Data Tag Definitions and Transmission Order

Order of Transmission Word#	Type	Tag Field LSB MSB 0 1 2 3 4 5 6 7	Data Field LSB 8 MSB 23
1	Autopilot	1 0 0 1 1 0 A B	X-Axis Acceleration
3	Autopilot	0 1 0 1 1 0 A B	X-Axis Rate
5	Autopilot	1 1 0 1 1 0 A B	Z-Axis Acceleration
7	Autopilot	0 0 1 1 1 0 A B	Y-Axis Rate
9	Autopilot	1 0 1 1 1 0 A B	Y-Axis Acceleration
11	Autopilot	0 1 1 1 1 0 A B	Z-Axis Rate
2	Inertial	1 0 0 0 1 0 A B	X-Axis Velocity Delta
4	Inertial	0 1 0 0 1 0 A B	X-Axis Angle Delta
6	Inertial	1 1 0 0 1 0 A B	Z-Axis Velocity Delta
8	Inertial	0 0 1 0 1 0 A B	Y-Axis Angle Delta
10	Inertial	1 0 1 0 1 0 A B	Y-Axis Velocity Delta
12	Inertial	0 1 1 0 1 0 A B	Z-Axis Angle Delta

Notes to Table 5-4:

1. LSB of tag field transmitted first followed by the LSB of the data field.

2. TAG Bits 4 and 5 = IMU Identification

3. A, B = BIT status (see *BIT Output Indication* paragraph)

AMRAAM Serial Data Word Content

Autopilot data words represent the average linear acceleration and angular rate for the period since the last transmission. Inertial data words represent the accumulated linear velocity change and angular attitude change since the prior transmission.

For the inertial data, the last data accumulated prior to inertial data transmission shall originate from the autopilot data transmitted in the same cycle.

AMRAAM Serial Data Word Scale Factors

The autopilot and inertial data are output as 16-bit two's complement integers. The autopilot data is scaled so that the value of the LSB for the average linear acceleration is 3.0 milli-g, and the value of the LSB for the average angular rate is 500 microradians/second.

The inertial data is scaled so that the value of the LSB for the velocity change is 0.2 millimeters/second and the value of the LSB for the angular change is 5 microradians.

AMRAAM Data Shift Clock

The DQI generates the data shift clock as shown earlier in Figure 5-7. Twenty-four clocks are generated for each data word transfer, with the first bit (LSB) being present on the serial data line after the occurrence of the rising edge of the first clock.

The frequency of the clock is 368.64 KHz $\pm$ 2 %. Data is stable at the falling edge of the clock. The data shift clock is transmitted as a differential signal defined by RS-422A.

AMRAAM Data Sync Pulse

The data sync pulse occurs at the end of each word transmission in accordance with Figure 5-7. The data sync pulse is transmitted as a differential signal defined by RS-422A (Figure 5-6).

Built In Test (BIT)

The IMU contains internal circuitry which upon external command of a logic zero or ground (capable of driving one standard TTL load) will perform BIT. The duration of the external command is 0.2 seconds minimum and the IMU remains in the BIT mode for the duration of the signal application.

The IMU resumes nominal performance within 0.1 second after application of a logic one or open. The BIT command can be applied at any time, including simultaneously with the application of power to the IMU. The input circuit for the BIT request is shown in Figure 5-9.

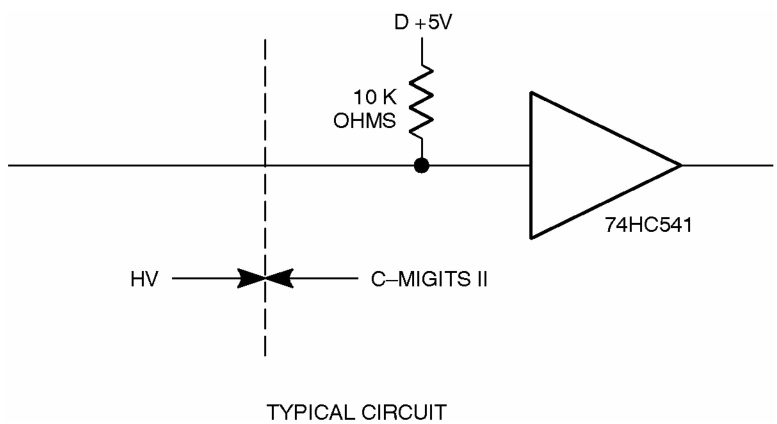


Figure 5-9. BIT Input Circuit Diagram

BIT Output Indication

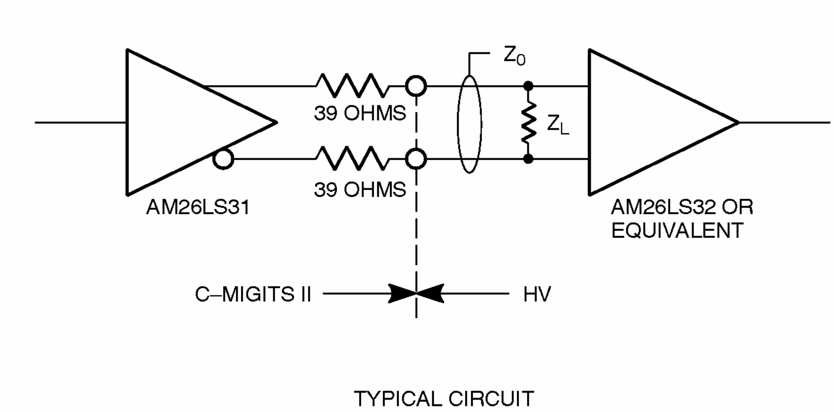
The Tag bits described in the *AMRAAM Serial Data Word Format* paragraph contain BIT status bits A and B. Table 5-5 defines these bits.

Table 5-5. IMU BIT Status Indication via Tag Bits		
State	**Bit Status Bit A**	**Bit Status Bit B**
Non-Test Mode	0	0
Test in Progress	1	0
Test Completed - Failed	0	1
Test Completed - Passed	1	1

The pass/fail BIT status is indicated 0.2 seconds after the application of the BIT command. The data in the data field will contain an alternating one/zero bit pattern, with LSB=0 for autopilot data (AAAA) and LSB=1 for inertial data (5555) during the BIT command. Data returns to normal within 0.1 seconds after removing the BIT command.

100-Hz Discrete

The IMU outputs a 100-Hz discrete that coincides with the output of inertial data contained in the AMRAAM Serial Data Word. The 100-Hz discrete is transmitted as a differential signal. The 100-Hz discrete's signal type and interface description was defined earlier in Tables 5-1 and 5-2. The IMU differential driver circuit is shown in Figure 5-10.



Z_L typically 78 to 250 Ω

Figure 5-10. 100-HZ Discrete Output Circuit

Connector Types

Connectors that are used to interface C-MIGITS III to the Host Vehicle are defined in Table 5-6. Examples of mating connectors, cables, and backshells are included in the table.

Table 5-6. C-MIGITS III Connector Types

Connector Designation	Type	Example Mating Type
J1 - I/O Interface	MIL-C-83513 Series 37 Socket Micro-D	M83513/03 - F14C (See Note) Backshell : Glenair 500T010A37H09
J2 - RF_IN	SMA Jack (socket) Receptacle	Any SMA plug (pin) MIL-C-39012 series, Typically RG-400, 50-ohm, coaxial cable used.
Note: (1) These part numbers include a 72-inch 26 AWG per MIL-W-22759/11-26 color coded per MIL-STD-681, system 1, prewired cable.		

Input/Output (I/O) Interface (J1) Connector

The I/O interface is through a 37-pin receptacle of the MIL-C-83513 series, often called the Micro-D connector series. The following is a list of mating connector manufacturers to contact for procurement.

Airborn, Inc.
4321 Airborn Drive
Addison, TX 75001-0519
Telephone - (214) 931-3200

Cinch Connector Division
1501 Morse Avenue
Elk Grove Village, IL 60007
Telephone - (708) 981-6000

If backshells are needed for the systems integration and application, below is a list of possible backshell manufacturers for procurement.

Airborn, Inc.
4321 Airborn Drive
Addison, TX 75001-0519
Telephone - (214) 931-3200

Glenair, Inc.
1211 Air Way
Glendale, CA. 91201-2497
Telephone - (818) 247-6000

RF Input (J2) Connector

The straight RF input connector is standard SMA jack (female) receptacle of the MIL-C-39012 series. Below is a list of possible mating connector manufacturers for procurement. Final choice of connector is affected by cable selection, which is discussed in *Cable Considerations*.

AMP, Inc.
P.O. Box 1608
Harrisburg, PA. 17105
Telephone - (800) 522-6752

AMPHENOL
RF/Microwave Operations
One Kennedy Avenue
Danbury, CT. 06810
Telephone - (203) 743-9272

Kings Electronics West
15152 Golden West Circle
Westminster, CA. 92683
Telephone - (213) 596-4485

MACOM
Interconnect Division
140 Fourth Avenue
Waltham, MA. 02254-9101
Telephone - (800) 366-2266

Antenna Considerations

Antenna Types

Although there is some flexibility in the choice of GPS antennas, there are three essential requirements:

- Right-hand circular polarization.
- A gain minimum of -3 dBiC above 10 degree elevation.
- 50-ohm impedance with < 2:1 VSWR

Two types of commonly available GPS antennas are *Patch* antennas and *Helix* antennas. Each has distinct electrical and physical properties, lending itself to different applications. The system integrator must evaluate the performance requirements together with the mechanical size, form, and mounting capability, along with the physical aesthetics of the overall product, to determine the type of antenna to use.

Patch Antennas

Patch antenna technology is relatively new to the market. The antenna is simple in design and predictable in performance by using microstrip technology for its receiving elements. Microstrip Patch antennas are typically mass-produced and are inexpensive to manufacture.

The most appealing aspect of the Patch antenna, and a major reason for its acceptance, is its low profile. Microstrip designs require only a patch of thin metallic film bonded to a dielectric substrate with a ground plane, allowing the Patch antenna to be shaped to meet specific mechanical requirements. The most common shapes produced are rectangles and circles.

Patch antenna patterns typically contain one main lobe in the direction normal to their surface. Therefore, the gain of the signal is reduced as a satellite moves from the perpendicular axis of the antenna.

This reduction in gain at the horizon can help reduce multipath interference. Most Patch antennas are integrated with a radome. The radome provides essential protection from the environment.

Helix Antennas

The design of a Helix antenna uses a conductor wound in the shape of a screw thread (Helix) together with a flat metal plate called a ground plane. This type of antenna is not extremely complicated in design and offers a predictable performance.

The Helix antenna demonstrates slightly higher gain and smoother phase than the Patch antenna. The patterns of a Helix antenna are a main lobe normal to the ground plane and minor lobes at oblique angles to the main lobe. As a result of these patterns, when a satellite moves from the antenna's perpendicular axis, the gain is reduced. However, the minor lobes provide more gain than the Patch antenna when the satellite is off axis due to the symmetry of the Helix design. Lobing can degrade tracking under certain kinds of motion.

The height and broad bandwidth are disadvantages to the Helix antenna. Since the Helix antenna is made of a helical coil, the shape is not flat as with Patch antennas. In general, the higher the required gain, the longer the coil. Helix antennas typically have broader bandwidths than Patch antennas, permitting the reception of more interfering signals.

Helix antennas require mounting in a filled radome to mechanically stabilize the coil from shock and vibration. These radomes usually are molded in cylindrical or aerodynamic shapes.

If the system's design requires an active antenna and alternative cable types or lengths, SDI application engineers are available to help the system integrator with link budget calculations. Please contact your local sales office for assistance. Also, see the discussion of preamplifiers later in this chapter. The following is a list of antenna manufacturers to contact for procurement.

Ball Telecommunication Products Division
10 Longs Peak Drive
Broomfield, CO 80021
Telephone (303) 460-5840

Macom
Haverhill Road
Amesbury, MA 01913
Telephone (508) 388-5210

Micro Pulse Inc.
409 Calle San Pablo
Camarillo, CA 93012
Telephone (805) 389-3446

Sensor Systems Inc.
8929 Fullbright Avenue
Chatsworth, CA 91311
Telephone (818) 341-5366

Tecom Industries, Inc.
9324 Topanga Canyon Boulevard
Chatsworth, CA 91311-5795
Telephone (818) 341-4010

Cable Considerations

As with antennas, the choice of cable is application-dependent. There are many cables manufactured that will meet the performance requirements for specific applications that mate with a variety of connectors.

The primary consideration in choosing a cable is the net *attenuation* at the desired frequency. The secondary consideration is the *shielding* of the cable. Other considerations such as flexibility, jacketing, size, and cost need to be factored into the selection process.

Cable Attenuation

The attenuation a cable exhibits at the desired frequency is important to the system design. The materials of a cable directly relate to the attenuation characteristics it exhibits. The center conductor of a good quality cable is typically copper or aluminum with a copper coating. Copper is a good electrical conductor with relatively low DC resistance per meter. This is important in the event a preamplifier needs to be powered via the center conductor for extra system gain.

Cable Dielectric

The dielectric material is the key to the characteristic impedance of a cable. RF applications generally use a cable with a polyethylene dielectric material. Polyethylene has a low dielectric constant that provides low capacitance and low electrical loss. This material is also lightweight and water-resistant. The outer conductor plays a role in the characteristic impedance of the cable, as well as its shielding effectiveness.

Cable Shielding

There are numerous outer conductor (shield) designs. The outer conductor can be made of braided mesh, a solid foil, or a solid shell. Braided shields of copper or aluminum are ideal for minimizing low frequency interference and exhibiting a low DC resistance. This type of shield provides good structural integrity and flexibility. As a rule, higher braid coverage yields a more effective shield.

Foil shields are made of aluminum and are laminated to a polypropylene film to provide mechanical strength to the foil. The DC resistance of a foil shield is not as low as a braided shield, but the foil shield provides 100 percent coverage of the center conductor. This shield is more cost effective, but has less structural integrity than a braided shield. Solid shields afford the best performance, but are inflexible and expensive.

Shields can be arranged in many different combinations. Combination shields consist of more than one layer of shielding. Typical combinations can include a braid or a braid with foil. A braid-type shield significantly lowers the DC resistance of the overall shield, while a braid-foil type shield provides the low DC resistance and structural strength of the braid plus 100 percent shielding of the foil.

The outside jacketing of a cable does not provide any EMI/RFI shielding to a cable. The jacket provides resistance to weather deterioration, mechanical abuse, and heat.

For most C-MIGITS III applications where the cable runs are relatively short, a cable can be selected with any of the characteristics previously described. If an application requires extensive lengths of cable (> 30 ft) from the antenna to C-MIGITS III, other types of cable commonly larger in diameter with solid copper outer conductors should be considered. These types of cables exhibit very low attenuation and excellent shielding, but tend to be larger, costing more per linear meter.

Installation Considerations

When installing C-MIGITS III, the following areas are of primary concern: *GPS Signal Obscuration, GPS Selective Availability, Multipath Interference,* and *EMI.* Additional areas of concern are *Feedlines and Preamplifiers*, *RF Signal Levels*, and the *Noise Floor*.

GPS Signal Obscuration

Normal operation of C-MIGITS III requires undisturbed reception of signals from four satellites as discussed earlier in *Chapter 2-INS/GPS Concepts.* The signals propagating from the satellites cannot penetrate water, soil, walls, dense foliage, or other similar obstacles.

Antennas and satellites are required to be in a "line of sight" with each other.

C-MIGITS III cannot be used for underground navigation in tunnels, mines, or subsurface marine navigation. In surface navigation, the signal can be obscured by buildings, bridges, trees, and other matter that might block an antenna's line of sight from the GPS satellites in view. In airborne applications, the signal can be shaded by the aircraft's body during high banking or pitching maneuvers.

For moving vehicles, signal shading or temporary outages will likely be transitory and will minimally degrade the overall positioning solution. However, a common case of signal blockage occurs in urban areas lined with skyscrapers.

In these cases, the signals can be obstructed for long periods of time resulting in accuracy degradation. In aircraft applications, transitory outages may occur due to the location of the antenna on the aircraft. In some instances, the motion of an aircraft can temporarily obstruct the line-of-sight due to its own structure, or can induce dynamics that exceed the capabilities of the C-MIGIT III’s tracking loop.

C-MIGITS III uses twelve channels to minimize the effects of obscuration. During normal operation, four channels track the four primary GPS satellites while the fifth channel tracks the remaining visible satellites and recovers the ephemeris data on each one. Therefore, if any of the primary satellites are obscured, C-MIGITS III contains the data to support rapid acquisition of alternate satellites.

Selective Availability

On March 25, 1990, the United States Department of Defense (DoD) formally implemented *Selective Availability* (SA). This is a method to deny unauthorized, non-military GPS users high precision accuracy with C/A code. SA introduces errors by adding slowly varying components into the pseudoranges. SA also affects the satellite position data contained within the ephemeris data message. The deliberate introduction of errors into satellite orbital information leads to a degradation of accuracy in the computed orbital position. The introduced orbital errors vary at a slow rate as do user position errors.

According to DoD SA policy, the nominal position accuracy for horizontal coordinates (latitude and longitude) is 100 meters at a probability level of 95 percent. The corresponding accuracy for the vertical coordinate is 156 meters 95 percent of the time.

Standard Positioning Service (SPS) Policy:

SPS is a positioning and timing service available to all GPS users on a continuous, worldwide basis with no direct charge. SPS is provided on the *GPS Ll frequency*, which contains a C/A code and a navigation data message. SPS provides the capability to obtain horizontal positioning accuracy within 100 meters 2-Drms (95 percent probability) and 300 meters (99.99 percent probability).

GPS Ll frequency also contains a P-Code that is not part of SPS, and is not available with the C-MIGITS III product.

Precise Positioning Service (PPS) Policy:

PPS is a highly accurate military positioning, velocity, and timing service available on a continuous, worldwide basis to users authorized by the DoD. It is not currently available with C-MIGITS III and such an upgrade is not envisioned for this product.

PPS is the data transmitted on GPS Ll and L2 frequencies. PPS was designed primarily for U.S. and Allied military use. It is denied to unauthorized users by use of cryptography. The encrypted P-code is called *Y-code*. PPS is available to U.S. Federal and Allied Government (civilian and military) users through special agreements with the DoD.

Limited civilian use of PPS, both domestic and foreign, is considered upon request and authorized on a case-by-case basis provided that:

- It is in the U.S. national interest to do so.
- Specific GPS security requirements can be met by the applicant.
- A reasonable alternative to the use of PPS is not available.

Multipath Interference

Multipath errors result when data is combined from more than one propagation path. This distorts the signal characteristics from which the range measurements are made, resulting in pseudorange errors. These errors are dependent on the nature and location of a reflective surface peculiar to each user location. The effects are less detrimental for a moving user, since small antenna movements can completely change the multipath characteristics.

In general, multipath interference is caused by signal reflection from buildings or other large objects interfering with a direct signal from a satellite. The effects of surface-replicated multipath interference can be minimized by using an antenna with a sharp gain roll-off near the horizon. A *patch* antenna exhibits this type of pattern while providing nominal gain for the primary satellite signal and attenuation for the undesired multipath signal. Circular antenna polarization also serves to minimize reflected multipath effects.

Electromagnetic Interference (EMI)

A common source of EMI is the operation of a nearby transmitting RF facility, such as a radio station, television station, or airport. Operation near a facility such as these can result in front-end overload or intrusion into Intermediate Frequency (IF) stages. United States television channels 10, 23, and 66 often have harmonics in the GPS signal band.

The GPS receiver circuitry contains onboard filters to help reject out-of-band signal interference.

EMI can be emitted from black boxes, or electronic systems around the C-MIGITS III system. An example of this type could be a switching power supply or other circuits operating nearby without proper shielding.

C-MIGITS III is susceptible to EMI around 1575 MHz. This arises from the high sensitivity required by the GPS receiver to selectively capture the Ll signal at -160 dBW. Interference degrades the C/No density ratio of the C-MIGITS III system. The C/No density ratio directly relates to the ability of the GPS receiver to acquire and track the GPS signal.

Non-GPS, continuous wave (cw) signals within a ±2-MHz bandwidth of 1575 MHz can cause interference to C-MIGITS III. The effect on C/No, with the introduction of continuous wave interference, can be characterized by the following equation:

$$C / No(eff) = \frac{C}{No + \left(\frac{Pi}{Rc}\right)}$$

where: *C/No* = the carrier-to-noise density without interference

Pi = the power in Watts of the interfering signal

Rc = the coding rate of 1.023 Mbps

No = the typical system noise in W/Hz

The system noise in dBW/Hz can be estimated by:

10 LOG (antenna noise temperature) + cable loss in dB + cascaded receive system Noise Figure (NF) in dB - Boltzmann's Constant where Boltzmann's Constant equals -228.6 dBW/Kelvin-Hz and the cascaded receiver system NF is as demonstrated in the *Mechanical Interface* section.

If the system integrator's application requires the C-MIGITS III system to operate in a signal environment where in-band interference may occur, the GPS receiver should be tested for EMI susceptibility in the unique environment targeted by the system.

C/No data from C-MIGITS III should be closely monitored during testing of EMI susceptibility to determine the effects of different interference levels and frequencies.

Feedlines and Preamplifiers

When undertaking the design and layout of a system using C-MIGITS III, careful consideration should be given to using a passive antenna and a short length of low loss feedline. This configuration will yield good results at minimum cost. If a preamp is required to overcome feedline losses or noise sources at the receiver, use the lowest gain device that will set the system NF to the required level.

C-MIGITS III is equipped with a very sensitive Galium-Arsenide (GaAs) front-end. Under most circumstances, no preamplifier is required. A passive patch antenna is most frequently used which provides approximately 0 dBiC of gain, and 5 to 15 feet of low loss coaxial cable can be used, representing about 0.5 dB of loss. Figure 5-11 provides a schematic representation of C-MIGITS III in its basic configuration.

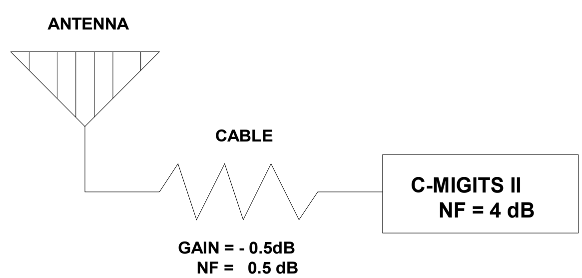


Figure 5-11. Basic Configuration

Carrier-to-Noise Ratio

To predict the Carrier-To-Noise (C/No) density ratio in the C-MIGITS III system, a link budget analysis of the available signal compared to the existing noise must be performed. This is accomplished by first determining the available signal from the satellites and then comparing it to the noise floor of the receiver. This yields the C/No density ratio.

The signals received from GPS satellites are a function of the transmission power of the satellites, the gain of the satellite antennas, the free space path loss of the signal, and the gain of the receiving antennas. According to the specifications, the U.S. military guarantees the signal power from GPS satellites to GPS receivers to be at least -160 dBW. This signal level can then be amplified (or attenuated) by the receiving antenna as a function of antenna gain.

RF Signal Levels

The unobstructed L1 C/A power incident on a user from any Block II satellite is a minimum of -160 dBW. The minimum input signal level of C-MIGITS III is -163 dBW, providing the systems integrator an additional 3 dB for design margin with GPS antennas and other system components.

This is the minimum free space signal power from the satellite. For the past several years, the satellites have been transmitting signals that are 3 to 6 dB higher than the guaranteed figure. However, good engineering practice dictates that the minimum specified signal power be used for all equipment design and link studies. Table 5-7 shows the link margins for 90 percent probability of acquisition for a system with 4 dB of composite NF, 0 dB of antenna spatial loss, and satellites at a 10-degree elevation angle.

Table 5-7. Typical GPS Link Margins		
GPS Signal Level at Antenna	Acquisition	Track
-160 dBW (guaranteed minimum)	3 dB	10 dB
-156 dBW (current typical levels)	9 dB	16 dB

C-MIGITS III is designed to operate with low-cost passive antennas, exhibiting -3 dBiC or greater gain at 5 degrees elevation, and a reasonable length of cable. This feature allows the overall system cost to be minimized. The system integrator should always calculate a link budget for the system.

Most commercial and military users of GPS use a Patch type or Helical antenna, with the Patch antenna being somewhat more popular. In general, the patch antenna exhibits about 2 to 3 dBiC of gain on zenith, and between -4 to 0 dBiC on the horizon. For most "quick" calculations, it is convenient to assume a gain of 0 dBiC.

The Noise Floor

GPS signals are spread spectrum, so noise power spectral density is used in establishing a signal-to-noise power ratio figure of merit. This important figure is *C/No*, or the total carrier power-to-noise power spectral density. The resulting units of this ratio are in Hertz (Hz).

Noise power is typically modeled as a thermally generated white noise source. The simple model for thermally generated noise power spectral density is expressed by the following equation:

$$Np = K \times T^{\circ} \times B$$

where:

K = Boltzman's Constant (1.38×10^{-23} Watts/Kelvin-Hz)

T°= The equivalent noise temperature in degrees Kelvin (typical assumption is T = 290 degrees K)

B = The bandwidth in Hz

In a 1-Hz system at 290°K, the noise power can be seen to be -204 dB W/Hz (4.002×10^{-21} Watts per Hz). This figure represents the absolute noise floor in a 1-Hz bandwidth at room temperature.

The next contributor to the noise floor is the noise generated internally by the C-MIGITS III system. This noise is the sum of the noise generated by C-MIGITS III, attenuation of the feedline, noise of the preamp (if used), and external noise received by the antenna.

There is a general assumption that the antenna, the feed system, any preamplifiers, and the receiver are all properly impedance matched. The standard gross assumption is a 50-Ohm characteristic impedance and *Voltage Standing Wave Ratio* (VSWR) of less than 2:1 (1.6:1 or less is preferred) at each interface.

Noise Factor is defined as the signal-to-noise ratio at the input divided by the signal-to-noise ratio at the output. The result is always greater than or equal to one. *Noise Figure* is defined as the noise factor converted to decibels 10log (NF). The determination of a noise figure is made assuming an input noise source of 290 degrees Kelvin. A noise figure generally is an approximation, and is usually acceptable when receiver noise is the dominant contributor.

The system noise factor (NF_{SYS}) of several cascaded receiver elements is determined by the following equation:

$$NF_{sys} = NF1 + \frac{NF2-1}{G1} + \frac{NF3 - 1}{G1 \times G2} + \ldots\ldots \frac{NFn - 1}{G1 \times G2 \times \ldots\ldots \times G(n-1)}$$

where:			
	NFl	=	Noise Factor of Stage 1
	G1	=	Gain (or loss) factor of Stage 1
	NF2	=	Noise Factor of Stage 2
	G2	=	Gain (or loss) factor of Stage 2
	NF3	=	Noise Factor of Stage 3
	G3	=	Gain (or loss) factor of Stage 3
	NF*n*	=	Noise Factor of the *nth* stage
	G*n*	=	Gain factor of the *nth* stage

As shown by this formula, the primary contributor of the system noise figure is the noise factor of the first stage (NFl). If the first stage is a low loss feedline, the attenuation of the line will directly add to the system NF. The loss must be entered as a gain term (G or loss) , but will be a gain of less than one.

The formula's calculation usually becomes asymptotic after the first couple of stages in a good system design. Typically, the system integrator only needs to be concerned with antenna gain, preamplifier gain if used, coaxial losses, and the specified noise figure of the receiver.

An analysis of C-MIGITS III in the basic configuration (see Figure 5-11) yields a system NF of 4.5 dB at the junction of the antenna and the coaxial feedline, as shown by the following:

- NF_{db} of the receiver = 4 dB
- NF of the receiver = 2.51
- NF_{db} of the cable = 0.5 dB
- NF of the cable = 1.122
- Gain of the cable = –0.5 dB
- Gain factor of the cable = 0.891

Note: For lossy medium such as cable, Gain is always <1, in other words, less than or equal 0 db.
Noise factor = 1/Gain Factor, Noise figure= -Gain db.

$$NF_{SYS} = 1.122 + \frac{2.51 - 1}{0.891}$$

NF = 2.817

NF_{db} = 10log (2.817) = 4.5 dB

The last contributor to the noise floor of C-MIGITS III is *implementation loss*. Implementation losses are the degradation in the C/No density ratio resulting from imperfect A/D converters, filters, and quantization errors.

In C-MIGITS III the implementation losses have been observed to be approximately 2 dB. Therefore, the system noise floor in the basic configuration is as follows:

Noise power in 1 Hz	=	-204.0 dBW/Hz
NF of system	=	+4.5 dB
Implementation losses	=	+2.0 dB
Noise floor	=	-197.5 dBW/Hz

When the noise figure must be below 2 dB, it may be wise to do a thorough analysis of actual system noise temperature, because the noise figure becomes an inaccurate measure of merit. This would be the case when a very low-noise preamplifier is used ahead of the receiver. In such cases it is common to use a system level figure called *G/T,* which is the ratio of a system antenna's *Gain* to system noise *Temperature*. If this type of condition occurs during your system analysis, contact a SDI applications engineer.

Link Calculations

Through analysis and field trials at SDI, it was determined that a 34 dBHz C/No density ratio is required for satellite acquisition. Once C-MIGITS III has acquired the satellite and recovered navigation data, the "track" mode requires as little as a 26 dBHz C/No density ratio.

At this point, the signal power available, the system noise floor, and the required C/No for acquisition are known. A link budget can then be calculated as follows:

Carrier power guaranteed	= -160 dBW
Antenna gain	= 0 dBi
Noise floor ("Basic" configuration)	= -197 dBW/Hz
C/No	= -160 - (-197) = 37 dBHz
C/No required	= 34 dBHz
C/No margin	= 37 - 34 = 3 dB

With a 3-dB margin, C-MIGITS III is quite useable with a passive antenna and a short run of low loss feedline. Outside factors such as foliage or building blockage may reduce the available signal.

It is advised not to significantly reduce the gain of the antenna or increase the feedline loss. As a rule, the feedline losses should be kept to less than 2.5 dB to 3 dB total, when used with a standard passive GPS patch antenna .

Preamplifiers

Under some circumstances, a preamplified antenna system may be desirable. This configuration is illustrated in Figure 5-12. However, it should be emphasized that a preamplifier will not compensate for a poorly located or inferior antenna. The preamp can only amplify what it receives from the antenna.

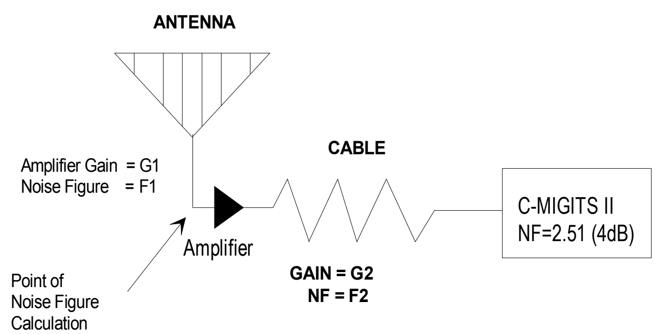


Figure 5-12. C-MIGITS III With Preamplifier

In addition, the preamp will amplify the noise as well as the signal, and will contribute some internally generated noise of its own. Poor preamp selection may actually decrease the C/No density ratio of the receiver's system.

The main reason for selecting a preamp is to optimize the signal-to-noise ratio of a receiver system. As demonstrated by the cascaded NF_{SYS} equation (discussed earlier), the system NF is set primarily by the first active or passive stage encountered after the antenna.

However, if the first stage encountered is a low noise preamp, the system NF can be set and optimized at this point. After thorough analysis, it may be more convenient to think of a preamp as a device that lowers the total system noise rather than raises the signal level.

The preamplifier should be selected to give similar or superior system performance to that of the basic configuration. In other words, the preamp should be selected to set the system NF at 4 dB or better. For example, if the feedline from the Patch antenna to the receiver was measured to have 6 dB of loss, a preamplifier with 10 dB of gain would need an NF of 2.07 dB to maintain the system NF at 4 dB as follows:

Desired system NF	= 4 dB
	= 2.51 NF
Amplifier gain	= 10 dB
	= 10 Gain Factor
Cable gain (loss)	= -6 dB
	= 0.251 Gain Factor
Cable NF	= 6 dB
	= 3.981 NF
Receiver NF	= 4 dB
	= 2.51 NF

$$2.51 = NF1 + \frac{3.981 - 1}{10} + \frac{2.51 - 1}{10 \times 0.251}$$

NF1	= 1.61
NF	= 10*log(1.61) = 2.07

The graphs shown in Figures 5-13 and 5-14 represent the gain and NF of a preamplifier required to maintain a system NF of 3 and 4 dB, respectively. For example, to maintain a system NF of 3 dB with 6 dB of cable loss, a preamp with 15 dB of gain would require an NF of 2.3 dB. This is certainly an achievable combination with available technology.

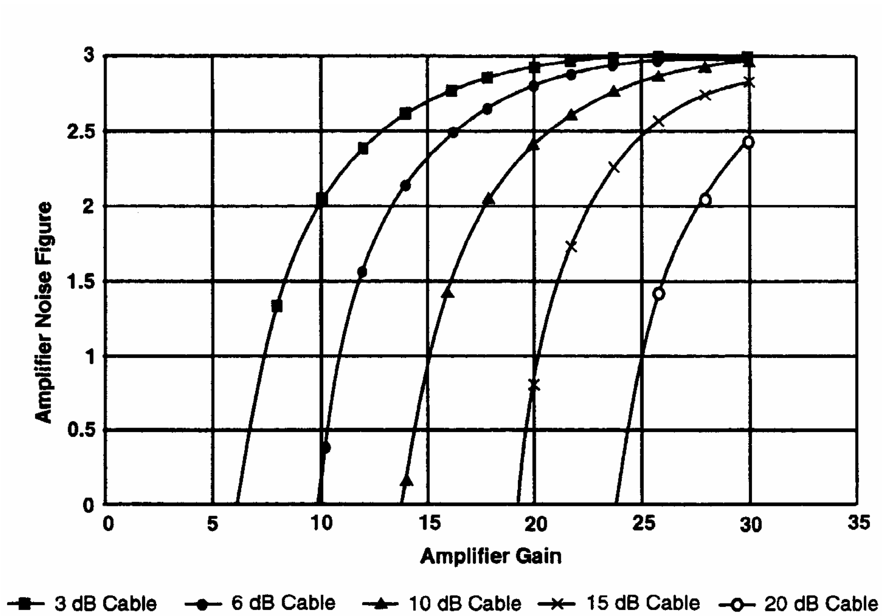


Figure 5-13. Preamplifier Gain And NF for a 3 dB System NF

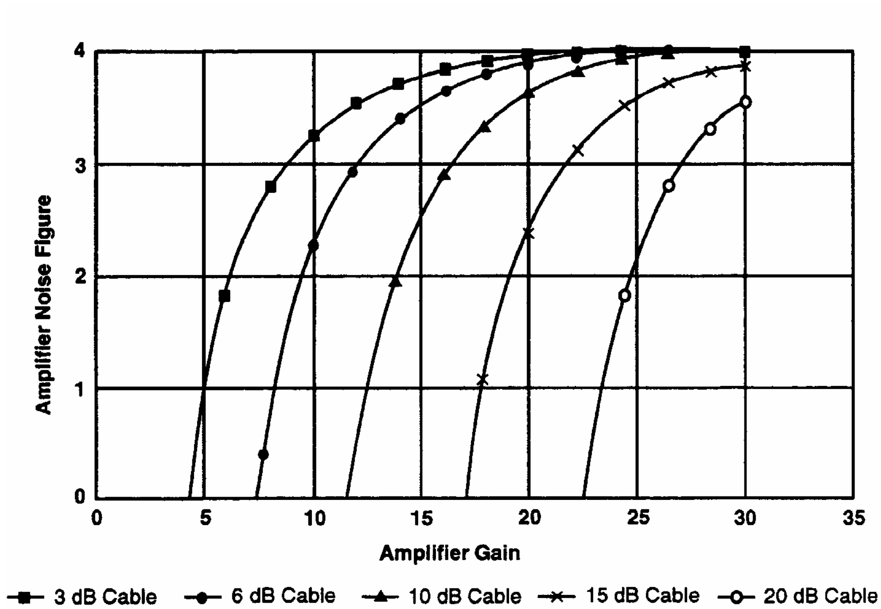


Figure 5-14. Preamplifier Gain and NF for a 4 dB System NF

Maximum Preamp Gain

Improving preamp specifications can be considered; however, there are a few parameters to address. C-MIGITS III has a very sensitive front end. Acceptable C/No density ratios are obtained with -163 dBW into a 4 dB system NF (the basic configuration). If a preamp is used, the GPS signal power delivered to C-MIGITS III must be kept under -130 dBW.

As a rule of thumb, select the minimum preamp gain that will provide the desired performance. Amplifier gains of 10 to 20 dB are easily obtainable and should be adequate to set the desired system NF. This maximizes the performance of C-MIGITS III and minimizes preamp costs. If an amplifier is required, but the overall gain available exceeds the -100 dBm GPS signal limit, an attenuator can be used. The attenuator then must be placed between the amplifier and the receiver.

In conclusion, remember that a preamp will not make up for a poor antenna installation. Adding an amplifier with +10 dB of gain will not compensate for an antenna with -10 dB of gain. Optimum performance from C-MIGITS III can be achieved by using the best available antenna and good quality feedline.

Preamplifier Power

The C-MIGITS III was designed for use with a passive antenna and does not provide power to an active antenna. However, should the application dictate an amplified antenna, the input is protected from DC voltages. Therefore it is acceptable for the DC antenna power to be superimposed on the RF input.

In most instances, to supply power to the antenna, it will be necessary to supply an inexpensive in-line "Bias-Tee" that allows the required supply voltage (typically 5 or 12 Vdc) to be added to the center conductor without attenuating the output signal.

There are several suppliers that offer a "Bias-Tee".

One example is: Minicircuits PN: ZFBT-4RG-FTB.

Amplifier Manufacturers

If an amplifier is needed for systems integration and application, below is a list of amplifier manufacturers to contact for procurement.

Hewlett Packard Company
1421 South Manhattan Avenue
Fullerton, CA 92631
Telephone (714) 758-5592

JCA Technology, Inc.
1090 Avenida Acaso
Camarillo, CA 93012
Telephone (805) 445-9888

Mini-Circuits
P.O. Box 350166
Brooklyn, NewYork 11235
Telephone (718) 934-4500

Miteq
100 Davids Drive
Hauppauge, NY 11788
Telephone (516) 436-7400

This page left intentionally blank.

Chapter 6- Software Integration

C-MIGITS III to Host Vehicle Data Interface/Definitions

The C-MIGITS III provides a bi-directional RS-232 serial port to support serial interface between C-MIGITS III and the *Host Vehicle* (*HV*). This allows the user to receive *output messages* describing the C-MIGITS III status and navigation state, send *input messages* to the C-MIGITS III to initialize it, and change its processing state.

The HV *Input/Output (I/O)* consists of various *data messages* that are identified by data message numbers. The detailed content and structure (definitions) of these data blocks will be specified in this chapter.

The default transmit rate (data from the C-MIGITS III) is 38400 baud, and the default reception rate (data from the HV) is 38400 baud. Data messages are transferred across this interface at any of five selectable baud rates: 9600, 19200, 38400, 57600, and 115200. Refer to Message 3504 in this chapter for more information on selecting/reprogramming the C-MIGITS III–HV baud rate.

Message Format

The data and commands transmitted over the C-MIGITS III-to-HV interface are formatted into *messages*. Each type of message is identified by a unique identification (ID) number. Messages contain a header portion and may or may not contain a data portion. *Header-only-messages* do not contain a data portion.

The maximum number of words a message can contain is 134 (five header words and 129 data words). The message header contains four header words, plus one header checksum word (Words 1 through 5). The message data portion contains a variable number of data words (Words 6 through 5+N ($0 < N \leq 128$)), plus one data checksum word (Word 6+N). For a header-only message, only the header portion (no data checksum) is sent.

A message word length is 16 bits on the C-MIGITS III–HV interface. However, the C-MIGITS III–HV protocol, which uses a standard *Universal Asynchronous Receiver Transmitter* (UART), transmits data in 8-bit groups (bytes). This means that two bytes are required in order to make up one message word.

A byte of information is transmitted as a sequence of 11 bits: one start bit, 8 bits of data (least significant bit (LSB) first), one parity bit (odd), and one stop bit. For each 16-bit data word, the least significant byte is transmitted first, followed by the most significant byte. Integer and floating point data types consisting of more than one word are transmitted from the lowest numbered word to the highest numbered word. The one exception to this rule is the time tag, which is output in words 6-9 of each HV output message. The four 16-bit data words are in the following order: 2,1,4,3, where 1 represents the most significant word and 4 the least significant word. Each word is separately byte-reversed.

Message Header Format

The five message words of the header portion of a message are summarized in Table 6-1.

Table 6-1. Message Header Word Definitions

Word Number	Description
1	Synchronization word (Value = DEL/SOH = $81FF_{16}$)
2	Message ID number
3	Word count (number of 16-bit words in data portion of message, excluding data checksum; legal range = 0 - 128; value = 0 for header-only messages)
4	Flags word (see description below)
5	Header checksum (2's complement of 16-bit sum of header words 1 - 4)

Word 4 of the message header is a bit-coded *flags word* containing protocol and message-related flags. The word's bit definitions are defined in Table 6-2.

Table 6-2. Flag Word Bit Definitions

Bit	Description	Input to C-MIGITS III	Output to HV
0 (LSB)	Spare	Ignored	Always 0
1	Spare	Ignored	Always 0
2	Reserved	Reserved	Reserved
3	Reserved	Reserved	Reserved
4	Reserved	Reserved	Reserved
5	Disconnect	Commands the C-MIGITS III "disconnect", i.e. discontinue transmitting, the specified message. In addition, this flag, sent with a message ID (header word 2) of 0, causes the C-MIGITS III to output only the default messages.	Always 0
6	Connect	Commands the C-MIGITS III to "connect", i.e., begin transmitting, the specified message to the HV at the scheduled update rate.	Always 0

(continued next page)

Flag Word Bit Definitions (cont.)

7	Invalid Data	Ignored	Indicates that an error has rendered the data contained in the data portion of the C-MIGITS III transmitted message to be questionable.
8	Command Reject	Ignored	Indicates that a command to the C-MIGITS III from the HV has been rejected (“1”) or accepted (“0”).
9	Handshake	Indicates that the C-MIGITS III must generate a handshake command accept/reject response to an input message.	Indicates that the C-MIGITS III-transmitted-message is a response to the HV command. The state of the Reject Flag indicates whether the command has been accepted or rejected.
10	NAK Message	Indicates that a C-MIGITS III-transmitted-message, with the Acknowledge Request Flag set, has been received by the HV with data errors. Receipt of a Negative Acknowledge Flag by C-MIGITS III will cause C-MIGITS III to re-transmit the message in error.	Indicates that the HV-transmitted-message, with the Acknowledge Request Flag set, has been received by the C-MIGITS III with data errors.
11	ACK Message	Indicates that a C-MIGITS III transmitted message, with the Acknowledge Request Flag set, has been received by the HV correctly.	Indicates that the HV-transmitted-message, with the Acknowledge Request Flag set, has been received by the C-MIGITS III correctly.
12	ACK Request	Indicates that the message being transmitted by the HV requires acknowledgment from the C-MIGITS III.	Indicates that the message being transmitted by the C-MIGITS III requires acknowledgment from the HV.
13	Reserved	Reserved	Reserved
14	Reserved	Reserved	Reserved
15 (MSB)	Ready	Indicates that the HV is ready to operate under the constraints of the C-MIGITS III–HV protocol. Whenever the HV is ready to receive a message, the Ready Flag is set to one (Ready = “1”, Not Ready = “0”).	Always 1

Message Data Format

The data portion may contain a maximum of 128 data words, plus one data checksum word (Words 6 through 134). These 16-bit data field message words are completely transparent to the protocol and have no restrictions on bit patterns or character groupings.

The number of data message words "N", is the same number of words specified in the message word count (message Word 3 in the header portion). When the message word count is zero, this field does not exist.

The 16-bit checksum field is used to validate the data portion of the message. It is transmitted as the last message word of any message containing data message words. It is computed as the 2's complement of the 16-bit sum of all message data words (words 6 to 5+N).

The data in the C-MIGITS III messages is encoded in a variety of numerical data formats. These are summarized in Table 6-3 below.

Table 6-3. Numerical Data Formats

Data Format	Description
I	Integer (16 bits)
DI	Double integer (32 bits)
BIT	Bit-coded 16-bit value
F	Single-precision binary-scaled fixed-point number (32 bits)
DF	Double-precision binary-scaled fixed-point number (64 bits)

For the binary-scaled fixed-point data formats, the encoding is described as F@S or DF@S, where S is the binary scaling. For both formats, the integer representation is a signed binary fraction (MSB = sign, binary point to the right of the sign bit) of the number 2^S.

For a single-precision binary-scaled number, the LSB is 2^{S-31}, and the range is from:
-2^S (= 80000000_{16}) to 2^S - 1 LSB (= $7FFFFFFF_{16}$).

For a double-precision binary-scaled number, the LSB is 2^{S-63}, and the range is from:
-2^S (= 8000000000000000_{16}) to 2^S -1 LSB (= $7FFFFFFFFFFFFFFF_{16}$).

Example Illustrating Sample Message Data Byte Ordering and Data Conversion

The table below contains a sample message 3500 as transmitted to the Host Vehicle by C-MIGITS III. The byte number represents the time order of data bytes received by the Host Vehicle (i.e. byte 1 is the first byte received, byte 2 is the second byte received, etc.).

Examples of message header and data verification, and data conversion for the various types of numeric data follow.

BYTE #	MESSAGE DATA BYTES							
1	FF	81	AC	0D	10	00	00	80
9	45	F0	2D	78	BA	33	A0	FD
17	7F	D5	02	00	2B	04	00	00
25	00	00	00	00	31	19	34	24
33	00	00	99	19	00	00	F5	6C
41	37	00	A3	B8				

Integer and BIT coded data are sent byte-reversed: the message header data words are as follows:

Word 1 = $81FF_{16}$ (message synchronization value)

Word 2 = $0DAC_{16}$ (message identification = 3500_{10})

Word 3 = 0010_{16} (word count for data portion of message, not including the data checksum word = 16_{10})

Word 4 = 8000_{16} (flag word, indicating 'ready')

Word 5 = $F045_{16}$ (The 16-bit twos complement checksum of words 1-4 = 0 - LSW [$81FF_{16}$+ $0DAC_{16}$+ 0010_{16}+ 8000_{16}]).

Single-precision (32 bit) fixed-point quantities are sent in byte-reversed order. For example, the horizontal position error contained in the example message 3500, (words 16-17, bytes 31-34) is 00002434_{16} scaled at 15 (0.141418457) meters.

Double-precision (64 bit) fixed-point quantities are output byte-reversed, and the most significant 32 bits of the double-precision quantity output first. For example, the time tag contained in this message 3500, (words 6-9, bytes 11-18) is $33BA782DD57FFDA0_{16}$ scaled at 20 (423759.0223798751140) seconds.

The message data checksum is $B8A3_{16}$ (The 16-bit twos complement checksum of message words 6 - 21 = 0 - LSW [+ $782D_{16}$ + $33BA_{16}$ + $FDA0_{16}$ + $D57F_{16}$ + 0002_{16} + $042B_{16}$ + 0000_{16} + 0000_{16} + 0000_{16} + 1931_{16} + 2434_{16} + 0000_{16} + 1999_{16} + $6CF5_{16}$ + 0037_{16}]).

Message Acknowledgment/Acceptance Protocol

Messages are grouped according to whether or not they must be *acknowledged* (ACKNOWLEDGE REQUEST flag, in header message word 4, is set or cleared). Commands are a subset of messages that must be acknowledged (since the ACKNOWLEDGE REQUEST flag is always set for commands). Any message not requiring acknowledgment is considered complete by the transmitting device as soon as it has been sent over the C-MIGITS III–HV interface.

The receiving device considers the message complete when it arrives successfully. If the message is received in error, it is ignored by the receiving device. Any message transaction requiring an acknowledgment is not considered complete by the transmitting device until a *message acknowledgment* is received.

The protocol for *acknowledge* (ACK) and *negative acknowledge* (NAK) messages are specified in the following paragraphs.

Acknowledge (ACK)

This message is a header-only message with a message ID that is the same as that of the message being acknowledged. The ACK bit is set in the flags word. The ACK message is transmitted in response to a message requiring acknowledgment which was received without word count or checksum errors. If the message is received without word count errors or checksum errors (the header and data checksums produce zero sums) the message is acknowledged within 100.0 ms. If the header checksum results in a non-zero sum, or the message had a framing or parity error, then the header will be assumed invalid (i.e., no flag information is available) and is not acknowledged.

Negative Acknowledge (NAK)

This message is a header-only message with a message ID that is the same as that of the message being acknowledged. The NAK bit is set in the flags word. The NAK message is transmitted in response to a message requiring acknowledgment whose header was received correctly but has a word count error or checksum error in the data portion of the message. If the message is received without word errors in the header, and the header checksum results in a zero sum (i.e., there are no checksum errors in the header or any framing or parity errors which would mean that the message would be ignored), and if there is a non-zero sum for the data checksum, then the message is negatively acknowledged within 100.0 ms.

Command Acceptance

All commands require acknowledgment (ACK or NAK*).* The receiving device must always ACK or NAK the command to notify the transmitting device, whether or not the command was received in error. In addition to acknowledgment, any commands with the connect/disconnect/request flags or the handshake flag set require additional handshaking. The handshake needs to be performed for command completion.

If the handshake bit is set in a received command, the receiving device will indicate acceptance or rejection of the command by clearing or setting the command reject bit ("1"-- rejected, "0" -- accepted). C-MIGITS III may reject a command because of the following system constraints:

- Additional messages requested by the command would cause the data rate of the interface to be exceeded.
- The C-MIGITS III's operations at the time of receipt of command do not allow the requested operation to be performed.
- The data content of the message had values that are out of range, or not allowed in current C-MIGITS III operational mode.

For 300 ms following C-MIGITS III transmission of a command accept message, specific data messages being transmitted from C-MIGITS III are not constrained to fall within the previous data output configuration or the requested data output configuration. In other words, the C-MIGITS III is not required to output the previous sequence of messages nor the requested sequence of messages for a period of up to 300 ms. This condition occurs only after a command has been accepted by the C-MIGITS III and the command modifies the current message output.

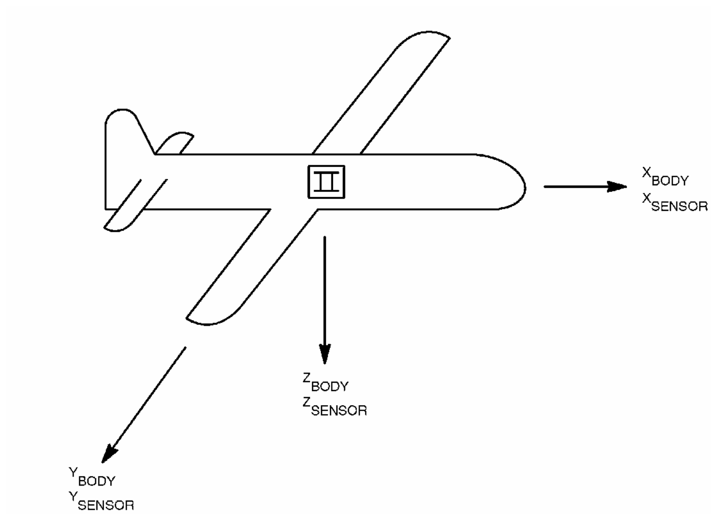
C-MIGITS III Coordinate Frames

C-MIGITS III utilizes several different coordinate reference frames.

The *IMU* or *sensor coordinate frame* is fixed to the body of the C-MIGITS III, and its axes are nominally along the directions defined by the decal affixed to the can. The raw incremental inertial data received from the DQI is resolved along these axes, as is the output AMRAAM data, but none of the C-MIGITS III HV output messages contain data resolved in this frame.

The *body coordinate frame* is also fixed to the body of the C-MIGITS III, but its orientation may be changed by user input (Message 3511). This is useful in making the C-MIGITS III attitude outputs (pitch, roll, heading) meaningful for different orientations of the C-MIGITS III within a host vehicle.

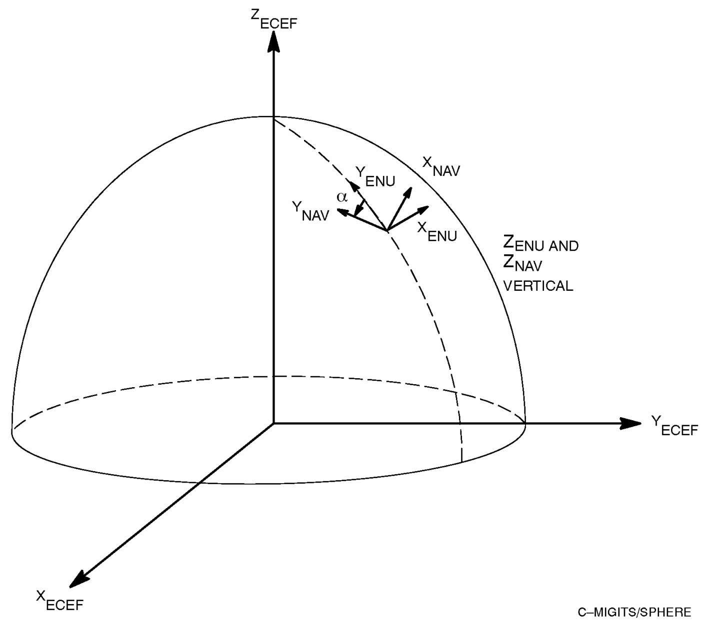
If body axes are defined such that the X_{BODY} axis points out the front end of the vehicle, the Y_{BODY} axis points out the right side, and the Z_{BODY} axis points downward through the floor, then the attitude angles will have their familiar meanings: i.e. pitch is a right-handed rotation about Y_{BODY}, roll is a right-handed rotation about X_{-BODY}, and heading is a right-handed rotation about Z_{BODY}. See illustration below.



The default orientation of the body frame is coincident with the sensor frame, so the default orientation of C-MIGITS III (i.e. the orientation for which no message 3511 command is necessary to yield meaningful attitude outputs) has the decal X axis pointing out the nose of the vehicle and the decal Z axis pointing down.

Note: Message 3511 does not change the axis resolution of the AMRAAM data; it is still resolved in the sensor coordinate frame.

The *Earth-Centered Earth-Fixed (ECEF) coordinate frame* is fixed to the earth and rotates with it. The Z_{ECEF} axis is along the north polar axis of the earth, and the X_{ECEF} and Y_{ECEF} axes are in the equatorial plane, with the X axis pointing outward through the Greenwich meridian. The latitude and longitude angles output by the C-MIGITS III are measured relative to the ECEF coordinate system. See illustration below.



The *locally-level east-north-up (ENU) coordinate frame* is centered at the C-MIGITS III location and has its X_{ENU} axis pointing east, its Y_{ENU} axis pointing north, and its Z_{ENU} axis pointing up. The vehicle velocity is output in this coordinate system.

The *navigation coordinate frame* is also a locally level system centered on the C-MIGITS III with its Z axis pointing vertically. It is displaced from the ENU coordinate system by an angular rotation about the Z axis by an angle α, called the *wander angle*. The wander angle is initialized to the negative of the initial heading of the vehicle, and in general changes very slowly during navigation, so that the navigation and ENU systems have a roughly constant orientation with respect to each other.

The navigation coordinate system is the fundamental system in which the C-MIGITS III performs navigation, but none of the C-MIGITS III output messages contain data resolved in this frame.

C-MIGITS III-HV Messages

Default Messages

Upon transition to *Initialization* mode, C-MIGITS III will begin outputting the following default data messages on the HV interface automatically. Additional messages may be connected by issuing connect commands (described earlier in this chapter).

- C-MIGITS III System Status (Message 3500). This message is output at 1 Hz.
- C-MIGITS III Navigation Solution (Message 3501). This message is output at 10 Hz.
- GPS Processor Timemark Message (Message 36x3). This passthrough message is output at 1 Hz as explained below.

C-MIGITS III-to-HV Data Messages

The messages output from the C-MIGITS III to the HV fall into two categories: messages containing C-MIGITS III status and navigation data, and "passthrough" messages from the GPS processor, which contain status and navigation data.

Transmission of these messages may be enabled (connected) or disabled (disconnected) as described earlier in this chapter, and the output rate of some messages may be changed by HV input command. The data messages are summarized in Tables 6-4 and 6-5.

Table 6-4. C-MIGITS III- to- HV Data Messages

Message ID	Message Name	Description	Rate
3	C-MIGITS III Timemark Message	System status and navigation data	1 Hz
3500	C-MIGITS III System Status	System mode and processing status information	1 Hz
3501	C-MIGITS III Navigation Solution	Position, velocity, attitude	10 Hz or 1 Hz
3502	C-MIGITS III Delta Velocity and Delta Theta	Raw delta velocity and delta attitude data from the IMU	100 Hz, 10 Hz, or 1 Hz
3503	C-MIGITS III Built-In Test Results	Built-In-Test results	Once at startup and at 1 Hz if requested
3512	C-MIGITS III Flight Control	Delta velocity and delta attitude data compensated for IMU error estimates	100 Hz, 10 Hz, or 1 Hz

GPS Passthrough Messages

GPS messages may be passed through to the host vehicle as received or selected messages may be passed through, with the data translated into the numerical formats used by C-MIGITS III. By default, passthrough translation is enabled, but this may be changed via message 3504.

When passthrough translation is enabled, generally only the GPS timemark message will be passed through To avoid conflicts, timemark messages from different GPS sets are assigned different message ID numbers. These messages can be connected and disconnected in the same way as other HV messages.

When passthrough translation is disabled, a larger subsection of the GPS message traffic will be passed through. Again, to avoid conflicts, the message ID's are changed, so even for these "untranslated" messages, the message ID and header checksum are changed from the data transmitted by the GPS processor. Different GPS sets are assigned a block of 100 message ID numbers for their untranslated messages. Untranslated messages cannot be disconnected.

The translation of GPS message ID numbers is summarized in Table 6-5 below.

Table 6-5. GPS Message Passthrough ID Numbers

GPS Set	Raw Timemark ID	Translated Timemark ID	Untranslated Timemark ID	Untranslated Message ID Range
Jupiter LP	(1)	3623	3903	3900-3999
PLGR	3	3613	3803	3800-3899

(1) The raw time message for the Jupiter receiver is available on the GPS monitor port at pin 33 of the JI connector.

HV-to-C-MIGITS III Data Messages

The HV-to-C-MIGITS III data messages are summarized in Table 6-6.

Table 6-6. HV-to-C-MIGITS III Data Messages		
Message ID	**Message Name**	**Description**
0	Universal Reset	Reset C-MIGITS III output to default messages
3504	C-MIGITS III Parameter Control	Set system baud rates; set message output rates and configuration; control loading of program and storage of program data in EEPROM
3510	C-MIGITS III Control and Initialization	Mode commands and position/velocity/time initialization
3511	C-MIGITS III Configuration Control	Set system configuration data: IMU orientation, lever arms

C-MIGITS III Message Formats

The formats of the C-MIGITS III messages are specified in the tables that follow.

Message 0 - Universal Reset

MSG NAME : Universal Reset (See Note)	
MSG ID : 0	
INVALID FLAG: Never set	Data Word Count: 0
I/O: Input	XMIT RATE: As Required

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a

Note to Message 0 - Universal Reset

To command C-MIGITS III to output default messages only, Message 0 should be transmitted with the Disconnect Message Flag set to 1.

Message 3 - C-MIGITS III Timemark Message

MSG NAME : C-MIGITS III Timemark Message	
MSG ID : 3	
INVALID FLAG: Set when no nav solution	Data Word Count: 52 + (2 × Number of GPS Channels) (See Note 11)
I/O: Output	XMIT RATE: 1 Hz

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
GPS Time	(Note 1)	6-9	DF@20	sec
UTC Time	(Note 2)	10-13	DF@17	sec
Latitude	(Note 3)	14-15	F@0	semicircles
Longitude	(Note 3)	16-17	F@0	semicircles
Altitude, Absolute	(Note 3)	18-19	F@15	meters
ECEF Position X	(Note 4)	20-21	F@23	meters
ECEF Position Y	(Note 4)	22-23	F@23	meters
ECEF Position Z	(Note 4)	24-25	F@23	meters
Velocity, East	(Note 5)	26-27	F@10	m/sec
Velocity, North	(Note 5)	28-29	F@10	m/sec
Velocity, Up	(Note 5)	30-31	F@10	m/sec
Acceleration, East	(Note 6)	32-33	F@6	m/sec/sec
Acceleration, North	(Note 6)	34-35	F@6	m/sec/sec
Acceleration, Up	(Note 6)	36-37	F@6	m/sec/sec
Attitude, Pitch	(Note 7)	38-39	F@0	semicircles
Attitude, Roll	(Note 7)	40-41	F@0	semicircles
True Heading	(Note 7)	42-43	F@0	semicircles
Current Mode	(Msg 3500, Note 2)	44	I	n/a
System Status Validity	(Msg 3500, Note 3)	45	BIT	n/a
Number Current SVs Tracked	(Msg 3500, Note 4)	46	I	n/a
Number of Position Measurements Processed	(Msg 3500, Note 5)	47	I	n/a

(continued next page)

C-MIGITS III Timemark Message (cont.)

Number of Velocity Measurements Processed	(Msg 3500, Note 6)	48	I	n/a
FOM Information	(Msg 3500, Note 7)	49	BIT	n/a
Expected Horizontal Position Error	(Note 8)	50-51	F@15	meters
Expected Vertical Position Error	(Note 8)	52-53	F@15	meters
Expected Velocity Error	(Note 8)	54-55	F@10	m/sec
Equipment Available	(Note 9)	56	BIT	n/a
Equipment Used	(Note 10)	57	BIT	n/a
Channel 1 Measurement State	(Note 11)	58	BIT	n/a
Channel 1 C/No	(Note 11)	59	BIT	n/a
Channel 2 Measurement State	(Note 11)	60	BIT	n/a
Channel 2 C/No	(Note 11)	61	BIT	n/a
¦	¦	¦	¦	¦
¦	¦	¦	¦	¦
Channel N Measurement State	(Note 11)	56 + 2N	BIT	n/a
Channel N C/No	(Note 11)	57 + 2N	BIT	n/a
Data Checksum	-	58 + 2N	I	n/a

Notes to Message 3 - C-MIGITS III Timemark Message

1. GPS TIME - GPS Sensor time (time of week in seconds, starting at Saturday 2400 hours/ Sunday 0000 hours) if GPS Time Valid Message 3500 is set to 1, otherwise C-MIGITS III system time since power up is reported. Data words are in the order 2, 1 (MSW), 4 (LSW), 3.

2. UTC TIME - Universal Coordinated Time (seconds of day).

3. LATITUDE/LONGITUDE - These words contain the C-MIGITS III present position output in Latitude/Longitude coordinates referenced to WGS-84 map datum.

4. ECEF POSITION X, Y, and Z - These words contain the C-MIGITS III present position output in WGS-84 Earth-Centered, Earth-Fixed (ECEF) coordinates.

Notes to Message 3 - C-MIGITS III Timemark Message (cont.)

5. VELOCITY EAST, NORTH, UP - These words contain the C-MIGITS III present velocity in local tangent plane coordinate referenced to the WGS-84 ellipsoid.

6. ACCELERATION EAST, NORTH, UP - These words contain the C-MIGITS III present acceleration. Compensated sensor delta velocity values are used.

7. ATTITUDE, PITCH and ROLL; TRUE HEADING - These words contain the C-MIGITS III present attitude. Positive Pitch values represent nose up. Positive Roll values represent right wing down. Positive Heading values represent clockwise angles relative to North.

8. EXPECTED ERRORS - The expected horizontal and vertical position errors and velocity error are derived by taking the square root of the corresponding Kalman filter variances.

9. EQUIPMENT AVAILABLE - This word is structured as follows: (Not presently implemented)

10. EQUIPMENT USED - This word is structured as follows: (Not presently implemented)

11. GPS CHANNEL MEASUREMENT STATE and C/No - These words are provided for each channel of the GPS Receiver, so the length of the timemark block is dependent on the type of GPS receiver. These words are structured as follows:

Channel Measurement State Word

DATA ITEM	DATA BIT	DEFINITION
Satellite PRN Code	0-4	Range 0-31
Channel Activity	5-7	000=idle
		001=C/A code search
		101=C/A code tracking
Code Type	8	0= P-code, 1= C/A code
Encryption Type	9	0= P-code, 1= Y-code
	10	RESERRVED
Reserved	11-14	n/a
Channel Fault	15	1=Fault, 0=No Fault

Channel C/No Word

DATA ITEM	DATA BIT	DEFINITION
Reserved	0-7	n/a
C/No	8-13	Integer value of signal-to-noise ratio, range= 1 to 63 dB-Hz
Reserved	14-15	n/a

Message 3500 - C-MIGITS III System Status

MSG NAME : C-MIGITS III System Status	
MSG ID : 3500	
INVALID FLAG: Never set	Data Word Count: 16
I/O: Output	XMIT RATE: 1 Hz

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
Time Tag	(Note 1)	6-9	DF@20	sec
Current Mode	(Note 2)	10	I	n/a
System Status Validity	(Note 3)	11	BIT	n/a
Number Current SVs Tracked	(Note 4)	12	I	n/a
Number of Position Measurements Processed	(Note 5)	13	I	n/a
Number of Velocity Measurements Processed	(Note 6)	14	I	n/a
FOM Information	(Note 7)	15	BIT	n/a
Expected Horizontal Position Error	(Note 8)	16-17	F@15	meters
Expected Vertical Position Error	(Note 8)	18-19	F@15	meters
Expected Velocity Error	(Note 8)	20-21	F@10	m/sec
Data Checksum	-	22	I	n/a

Notes to Message 3500 - C-MIGITS III System Status

1. TIME TAG - Contains GPS Sensor time if valid (GPS Sensor has valid GPS time); otherwise, C-MIGITS III system time since power-up is reported. Data words are in the order 2, 1 (MSW), 4 (LSW), 3.

2. CURRENT MODE - The value of the CURRENT MODE word has the following definitions:

Value	Mode
1	Test
2	Initialization
3	(Not Used)

Notes to System Status (cont.)

4	Fine Alignment
5	Air Alignment
6	Transfer Alignment
7	Air Navigation
8	Land Navigation
9	GPS Only

3. SYSTEM STATUS VALIDITY - The bits of this word are defined as follows (where bit 0 = LSB):

- bit 0 GPS Measurements Available

Set to 1 if GPS Sensor time is valid and GPS Sensor indicates that at least 4 SVs are being used.

- bit 1 INS Measurements Available

Set to 1 when INS sensor data is being received from the INS.

- bit 2 GPS Data Late

Set to 1 when GPS measurement data is not received for the current second.

- bit 3 GPS Time Valid

Set to 1 when valid UTC data has been received from the GPS receiver.

- bit 4 Timemark Timeout

Set to 1 when the 1-PPS timemark pulse from the GPS receiver is not detected.

- bit 5 BIT Failure

Set to 1 when a failure of Built-In Test has occurred.

- bit 6 Constellation Change

Set to 1 when the constellation (current set of SVs) has changed.

- bit 7 Time Bias Repartition

Set to 1 when the GPS receiver resets the partitioning between the time bias estimate and the pseudorange values.

Notes to System Status (cont.)

- bit 8 Coarse Air Alignment submode indicator

Set to 1 when the system is in Coarse Air Alignment submode;

Set to 0 when the system is not in Coarse Air Alignment submode.

- bit 9 Reserved

- bits 10-12 GPS Receiver Type

  The following GPS receiver types are defined:

Value	Type
0	Unknown
1	Jupiter
2	PLGR
3	Jupiter

- Bits 13-15 Reserved

4. NUMBER CURRENT SVs TRACKED - Number of SVs providing usable measurements during the current second. This is not necessarily the number of measurements processed. The following two words indicate how many measurements were actually used.

5. NUMBER OF POSITION MEASUREMENTS PROCESSED - Number of position measurements processed this second by the C-MIGITS III Kalman filter.

6. NUMBER OF VELOCITY MEASUREMENTS PROCESSED - Number of velocity measurements processed this second by the C-MIGITS III Kalman filter.

7. FOM INFORMATION - The following figure of merit (FOM) bit definitions have been defined for FOM information:

bits 0-3: Position FOM	
Value	$\sqrt{Variance}$ (meters)
1	< 25
2	< 50
3	< 75
4	< 100
5	< 200
6	< 500
7	< 1000
8	<5000
9	≥ 5000

bits 4-7: Velocity FOM	
Value	$\sqrt{Variance}$ (m/sec)
1	< 0.2
2	< 1
3	< 5
4	< 25
5	< 50
6	< 80
7	< 150
8	< 300
9	≥ 300

bits 8-11: Heading FOM	
Value	$\sqrt{Variance}$ (milliradians)
1	< 0.5
2	< 1
3	< 1.73
4	< 5
5	< 8.66
6	< 10
7	< 17.3
8	< 86.6
9	≥ 86.6

bits 12-15: Time FOM	
Value	$\sqrt{Variance}$ (μsec)
1	< 0.001
2	< 0.01
3	< 0.1
4	< 1
5	< 10
6	< 100
7	< 1000
8	< 10000
9	≥ 10000

8. EXPECTED ERRORS - The expected horizontal and vertical position errors and velocity error are derived by taking the square root of the corresponding Kalman filter variances.

Message 3501 - C-MIGITS III Navigation Solution

MSG NAME : C-MIGITS III Navigation Solution	
MSG ID : 3501	
INVALID FLAG: Never set	Data Word Count: 22
I/O: Output	XMIT RATE: 1,10 Hz (Note 1)

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
Time Tag	(Note 2)	6-9	DF@20	sec
Latitude	(Note 3)	10-11	F@0	semicircles
Longitude	(Note 3)	12-13	F@0	semicircles
Altitude	(Note 3)	14-15	F@15	meters
Velocity North	-	16-17	F@10	m/sec
Velocity East	-	18-19	F@10	m/sec
Velocity Up	-	20-21	F@10	m/sec
Pitch	(Note 4)	22-23	F@0	semicircles
Roll	(Note 4)	24-25	F@0	semicircles
True Heading	(Note 4)	26-27	F@0	semicircles
Data Checksum	-	28	I	n/a

Notes to Message 3501 - C-MIGITS III Navigation Solution:

1. Transmission rate programmable via Message 3504.

2. TIME TAG - Contains GPS Sensor time if GPS Time Valid (Message 3500) is set to 1; otherwise, C-MIGITS III system time since power-up is reported.. Data words are in the order 2, 1 (MSW), 4 (LSW), 3.

3. LATITUDE, LONGITUDE, ALTITUDE - Referenced to WGS-84 map datum.

4. PITCH, ROLL, TRUE HEADING - Positive pitch values represent nose up. Positive roll values represent right wing down. Positive heading values represent clockwise angle relative to North.

Message 3502 - C-MIGITS III Delta Velocity and Delta Theta

MSG NAME : C-MIGITS III Delta Velocity and Delta Theta	
MSG ID : 3502	
INVALID FLAG: Never set	Data Word Count: 16
I/O: Output	XMIT RATE: 1,10, 100 Hz (Note 1)

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
Time Tag	(Note 2)	6-9	DF@20	sec
Delta Theta X	(Note 3)	10-11	F@0	radians
Delta Theta Y	(Note 3)	12-13	F@0	radians
Delta Theta Z	(Note 3)	14-15	F@0	radians
Delta Velocity X	(Note 3)	16-17	F@10	m/sec
Delta Velocity Y	(Note 3)	18-19	F@10	m/sec
Delta Velocity Z	(Note 3)	20-21	F@10	m/sec
Data Checksum	-	22	I	n/a

Notes to Message 3502 - C-MIGITS III Delta Velocity and Delta Theta:

1. Transmission rate programmable via Message 3504. The selected rate affects the data time interval. For example, if the message is requested at 10 Hz, the data represents 100 ms of ΔV and $\Delta\theta$.

Overflows may occur if high-dynamics data is output at low rates.

2. TIME TAG - Contains GPS Sensor time if GPS Time Valid (Message 3500) is set to 1; otherwise, C-MIGITS III system time since power-up is reported.. Data words are in the order 2, 1 (MSW), 4 (LSW), 3.

3. Delta values are incremental sums reported in HV body axis coordinate system where the default orientation is as follows: X = nose, Y = right wing, Z = down. Sensor errors and gravity have not been compensated.

Message 3503 - C-MIGITS III Built-In-Test Results

MSG NAME : C-MIGITS III Built-In Test Results	
MSG ID : 3503	
INVALID FLAG: Never set	Data Word Count: 100
I/O: Output	XMIT RATE: Once at startup or completion of a commanded Built In Test, and at 1 Hz if connected for output. (Note 1)

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
Time Tag	(Note 2)	6-9	DF@20	sec
BIT Summary	(Notes 3,A)	10	BIT	n/a
Reserved 1	-	11	n/a	n/a
BIT Validity	(Notes 4,A)	12	BIT	n/a
BIT Results	(Notes 4,A)	13	BIT	n/a
Memory Test Results	(Note 5)	14	BIT	n/a
Hardware Test Results	(Note 6)	15	BIT	n/a
Reserved 2	-	16-31	n/a	n/a
Reserved 3	-	32-33	n/a	n/a
C-MIGITS III Software Version Identification	(Notes 9,B)	34-35	DI	n/a
C-MIGITS III Software Checksum	(Notes 10,B)	36-37	DI	n/a
C-MIGITS III Software Load Module Name	(Notes 11,B)	38-41	ASCII	n/a
C-MIGITS III Software Load Module Load Information Checksum	(Notes 12,B)	42-43	DI	n/a
Parameter Memory Area Checksum	(Notes 13,B)	44-45	DI	n/a
System Parameter File Name	(Notes 14,B)	46-49	ASCII	n/a

C-MIGITS III Built-In Test Results (cont.)

System Parameter Load Information Checksum	(Notes 15,B)	50-51	DI	n/a
Calibration Parameter File Name	(Notes 16,B)	52-55	ASCII	n/a
Calibration Parameter File Load Information Checksum	(Notes 17,B)	56-57	DI	n/a
Instrument Data Processor Parameter File Name	(Notes 18,B)	58-61	ASCII	n/a
Instrument Data Processor Parameter File Load Information Checksum	(Notes 19,B)	62-63	ASCII	n/a
Instrument Data Processor Software Checksum	(Notes 20,B)	64-65	DI	n/a
Instrument Data Processor Load Module Name	(Notes 21,B)	66-69	ASCII	n/a
Instrument Data Processor Load Module Load Information Checksum	(Notes 22,B)	70-71	DI	n/a
GPS Receiver Self Test Results	(Notes 23,B)	72-87	n/a	n/a
Reserved 2	-	88-105	n/a	n/a
Data Checksum	-	106	I	n/a

Message 3503 contains the results of all self test processing performed by ***C-MIGITS III***: Power-On Self Test (POST), Commanded Built-In Test (BIT), and background BIT processing. Refer to the notes below for individual data items to determine when a particular message field is updated.

Notes to Message 3503 - C-MIGITS III Built-In Test Results:

1. Message 3503 is transmitted once at start-up, after completion of Power-On Self Test (POST) and once upon each completion of a commanded Built In Test (BIT). It may be also be connected for output in order to monitor the continuous background BIT processing, in which case it will be transmitted at a 1-Hz rate. In general, it is not necessary to have message 3503 connected for continuous output, as the system status message 3500 System Status Validity word, bit 5 indicates the BIT summary pass/fail status.

Notes to Message 3503 - C-MIGITS III Built-In Test Results (cont.)

2. TIME TAG - Contains GPS Sensor time if GPS Measurements Available (Message 3500) is set to 1; otherwise, C-MIGITS III system time since power-up is reported.

3. BIT SUMMARY - Contains the overall pass/fail status and type of the current test. The overall test pass/fail status represents the arithmetic AND of the BIT VALIDITY word and the BIT RESULTS word. It is also reported in System Status message 3500, word 11 (System Status Validity), bit 5. The format of this word is as follows.

BIT	Note	Description
0 (LSB)-12	-	Reserved
13-14	(Note A)	Type of current BIT test: 0 - Background BIT 1 - Commanded BIT 2 - Power-On Self Test (POST)
15 (MSB)	(Note A)	Test pass/fail flag (0 = PASS, 1 = FAIL)

4. BIT VALIDITY and BIT RESULTS words - Bits in the BIT VALIDITY word are Boolean indicators of whether the corresponding bits in the BIT RESULTS word contain valid data. This word is updated each time message 3503 is output. A bit is set to ‘1’ to indicate that this particular subsystem test has been performed, or that this element contains valid data from a previous test. The BIT RESULTS word contains summary test results for various subsystem tests, where a bit is set to ‘1’ to indicate a failure in a particular subsystem test. The bits in this word are updated as indicated by their respective notes. The individual tests that comprise each summary bit are indicated in a note accompanying the description of the summary bit. These detailed test results may be examined to determine the exact nature of any failure noted by a subsystem summary test indicated in the BIT RESULTS word.

The format of the BIT VALIDITY and BIT RESULTS words are detailed in the following table.

BIT	Note	Description
0 (LSB)	(Note A)	EEPROM test
1	(Note B)	RAM test
2	(Note A)	Hardware BIT
3	(Note A)	Analog MUX data limit test
4	(Note A)	Instrument data limit test
5	(Note B)	Discrete input data test
6	-	Reserved
7	-	Reserved
8	-	Reserved
9	(Note C)	GPS receiver BIT
10	(Note A)	Timemark Synchronization test
11-15 (MSB)	-	Reserved

Notes to BIT VALIDITY and BIT RESULTS Summary Test Descriptions:

4.0 EEPROM test summary results represent the composite test results of 1) C31 code section of EEPROM, 2) Instrument data processor section of EEPROM, and 3) Parameter storage area of EEPROM. See detailed description of Memory Test Results (word 14), bits 3, 4, and 5.

4.1 RAM test summary results represent the composite test results of 1) C31 processor internal RAM, 2) C31 processor external RAM, and 3) Instrument data processor RAM. See detailed description of Memory Test Results (word 14), bits 0, 1, and 2.

4.2 Hardware BIT summary results represent the composite test results of 1) Instrument data processor selftest results, 2) X QRS selftest results, 3) Y QRS selftest results, and 4) Z QRS selftest results. See detailed description of Hardware Test Results (word 15), bits 0, 1, 2, and 3.

4.3 Analog Multiplexer (AMUX) test summary results represent the composite test results of 1) AMUX temperature limit test results, 2) AMUX digital voltage limit test results, 3) AMUX analog voltage limit test results. See detailed description of Hardware Test Results (word 15), bits 4, 5, and 6.

4.4 Instrument Data Limit summary results represent the composite test results of 1) Accelerometer data error test results, 2) Instrument data processor data error test results, 3) AMRAAM data limit test results. See detailed description of Hardware Test Results (word 15), bits 7, 8, and 9.

4.5 Discrete Input Data Test indicates the status of the discrete input reliability test. A failure indicates that the state of the Test Mode and BIT discrete inputs could not be reliably determined. See detailed description of Hardware Test Results (word 15), bits 10 and 11.

4.7 GPS Receiver BIT indicates the summary pass/fail status of the GPS receiver subsystem built-in test. This testing is performed by the GPS receiver subsystem when a built in test is command is sent to the C-MIGITS III. See GPS Receiver BIT Summary (word 72), bit 0 for details.

5. DQI MEMORY TEST RESULTS - This word gives the detailed test results of the system memory tests. The format of the DQI Memory Test results word is as follows:

BIT	Note	Description
0 (LSB)	(Note A)	C31 internal RAM test result
1	(Note A)	C31 external RAM test result
2	(Note A)	Instrument Data Processor RAM test result
3	(Note B)	C31 flash memory test (code section)

4	(Note B)	C31 flash memory test (Instrument Data Processor code section)
5	(Note B)	C31 flash memory test (system parameters section)
6	(Note C)	Saved initialization data validity
7-15	-	Reserved

Notes to DQI Memory Test Results:

5.0 C31 Internal RAM - Indicates the result of the C31 internal RAM test performed at power application. A failure indicates that an error was detected in the C31 internal RAM during RAM pattern testing.

5.1 C31 External RAM - Indicates the result of the C31 external RAM test performed at power application. A failure indicates that an error was detected in the C31 external RAM during RAM pattern testing.

5.2 Instrument Data Processor RAM - Indicates the result of the RAM test performed at power application on the Instrument Data Processor area of RAM. A failure indicates that an error was detected RAM pattern testing.

5.3 C31 Flash Memory (Code Section)- Indicates the most recent result of the C31 background checksum test performed on the program code area of C31 memory. A failure indicates that the checksum for this area of memory did not match the pre-stored value, indicating that this area of memory is corrupt.

Notes to DQI Memory Test Results (cont.)

5.4 C31 Flash Memory (Instrument Data Processor Section)- Indicates the most recent result of the C31 background checksum test performed on the instrument data processor code area of C31 memory. A failure indicates that the checksum for this area of memory did not match the pre-stored value, indicating that this area of memory is corrupt.

5.5 C31 Flash Memory (System Parameter Section)- Indicates the most recent result of the C31 background checksum test performed on the system parameter area of C31 memory. A failure indicates that the checksum for this area of memory did not match the pre-stored value, indicating that this area of memory is corrupt.

5.6 C31 Flash Memory (Saved Initialization Data Validity)- Indicates the state of the user configuration data area of memory. When this bit is ‘0’, no data has been saved by the user, or the saved data has failed checksum verification and is not usable. When this bit is ‘1’, data has been saved by the user, passed validity tests, and will be used for system initialization.

6. DQI HARDWARE TEST RESULTS - This word gives the detailed test results of the system hardware tests. The format of the DQI Hardware Test results word is as follows:

BIT	Note	Description
0	(Note B)	Instrument Data Processor BIT results
1	(Note A)	X QRS hardware BIT result
2	(Note A)	Y QRS hardware BIT result
3	(Note A)	Z QRS hardware BIT result
4	(Note A)	Analog MUX temperature out of limits
5	(Note A)	Analog MUX digital voltage out of limits
6	(Note A)	Analog MUX analog voltage out of limits
7	(Note A)	VQA count error
8	(Note A)	Instrument Data Processor timetag error flag
9	(Note A)	AMRAAM data range error
10	(Note A)	BIT discrete error
11	(Note B)	Test Mode discrete error
12-15 (MSB)	-	Reserved

Notes to DQI Hardware Test Results:

6.0 Instrument Data Processor BIT Results - Indicates the status of the Instrument Data Processor Power On Self Test. A ‘1’ indicates that a failure has been detected during this test.

6.1 - 6.3 X,Y,Z QRS Hardware BIT- Indicates the current status of the hardware internal diagnostic checks made in the gyro data processing firmware.

6.4 AMUX Temperature Out Of Limit - One of the system temperature monitors has indicated an out of limit condition.

6.5 AMUX Digital Voltage Out Of Limit - One of the system digital voltage monitors has indicated an out of limit condition.

Notes to DQI Hardware Test Results (cont.):

6.6 AMUX Analog Voltage Out Of Limit - One of the system analog voltage monitors has indicated an out of limit condition.

6.7 VQA Count Error - Checks made on the raw accelerometer instrument data have indicated an error.

6.8 Instrument Data Processor Timetag Error Flag - Indicates the current status of the Instrument Data Processor timetag verification that is performed each time that data is read from this processor. A failure indicates that an error has occurred in the processing of this data.

6.9 AMRAAM Data Error - Indicates that an AMRAAM data quantity could not be created at the required fixed point scaling.

6.10 BIT Discrete Error - Indicates that the state of the AMRAAM BIT discrete input signal could not be reliably determined.

6.11 Test Mode Discrete Error - Indicates that the state of the Test Mode discrete input signals could not be reliably determined at power turn on.

Notes to Message 3503 - C-MIGITS III Built-In Test Results (cont.)

9. C-MIGITS III Software Version Identification - Contains a double precision integer number whose hexadecimal value represents a software version code of the form XXYYMMDD, where XX is reserved, YY is the last 2 digits of the year, MM is the month (01 - 12), and DD is the day (01-31). This identification code uniquely identifies the C31 software that is loaded.

10. C-MIGITS III Software Checksum - Contains a double precision integer number that is the checksum for the C31 code portion of memory. This number can be used to uniquely identify the C31 software that is loaded, and is used in testing the C31 code section of memory.

11. C-MIGITS III Software Load Module Name - Contains the first eight ASCII characters of the C31 software load module name.

12. C-MIGITS III Software Load Module Load Information Checksum - Contains a checksum number identifying the load module name, file creation time and date, and file load time and date.

13. Parameter Memory Area Checksum - Contains a double precision integer number that is the checksum for the C31 parameter portion of memory. This number is used in testing the C31 parameter portion of memory.

14. System Parameter File Name - Contains the first eight ASCII characters of the system parameter file name.

15. System Parameter Load Information Checksum - Contains a checksum number identifying the system parameter file module name, file creation time and date, and file load time and date.

Notes to Message 3503 - C-MIGITS III Built-In Test Results (cont.)

16. Calibration Parameter File Name - Contains the first eight ASCII characters of the calibration parameter file name.

17. Calibration Parameter File Load Information Checksum - Contains a checksum number identifying the calibration parameter file name, file creation time and date, and file load time and date.

18. Instrument Data Processor Parameter File Name - Contains the first eight ASCII characters of the instrument data processor parameter file name.

19. Instrument Data Processor Parameter File Load Information Checksum - Contains a checksum number identifying the instrument data processor parameter file name, file creation time and date, and file load time and date.

20. **C-MIGITS III** Instrument Data Processor Software Checksum - Contains a double precision integer number that is the checksum for the C31 instrument data processor code portion of memory. It is used in testing this section of memory.

21. Instrument Data Processor Load Module Name - Contains the first eight ASCII characters of the instrument data processor software load module name.

22. Instrument Data Processor Load Module Load Information Checksum - Contains a checksum number identifying the instrument data processor load module name, file creation time and date, and file load time and date.

23. Words 72-87 reflect the results of the GPS receiver subsystem selftest performed by the Jupiter when a built in test command is received by the **C-MIGITS III**. These words are the data portion of the Jupiter BIT results message 1100, exactly as reported by the GPS receiver. It is defined in the following table:

Data	Notes	Word No	Data Type	Units
Set Time	(Note 24)	72-73	UDI	10 ms ticks
Sequence Number	(Note 25)	74	I	n/a
ROM Failure	(Note 26)	75	UI	n/a
RAM Failure	(Note 26)	76	UI	n/a
EEPROM Failure	(Note 26)	77	UI	n/a
Dual Port RAM Failure	(Note 26)	78	UI	n/a
Digital Signal Processor (DSP) Failure	(Note 26)	79	UI	n/a
Real-Time Clock (RTC) Failure	(Note 26)	80	UI	n/a
Serial Port 1 Receive Error Count		81	UI	# errors detected
Serial Port 2 Receive Error Count		82	UI	# errors detected
Serial Port 1 Receive Byte Count		83	UI	# errors detected
Serial Port 2 Receive Byte Count		84	UI	# errors detected
GPS Receiver Software Version		85	UI	0.01 resolution
Reserved		86	n/a	n/a
Reserved		87	n/a	

24. Set Time - This is an internal 10 ms count since power-on initialization enable the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time count references the receiver's internal time at which the message was created for output. The range is approximately 71 weeks.

25. Sequence Number – This is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.

26. Failure indications - A value of zero indicates a test has passed. A non-zero value indicates a device failure. Missing devices will be reported as failures. Therefore, the OEM's BIT pass/fail should ignore words for components that are not in the system under test.

Notes on update rates:

A. The data item in this field is updated continuously by background Built-In Test processing. The last update of this field is reported whenever message 3503 is output.

B. The data item in this field is updated once during Power On Self-Test. Subsequent output of message 3503 report the results of this test.

C. The data item in this field is updated every time that a Built-In Test is commanded. Subsequent output of message 3503 report the results of the last commanded Built-In Test.

This page left intentionally blank.

This page left intentionally blank.

Message 3504 - C-MIGITS III Parameter Control

MSG NAME : C-MIGITS III Parameter Control	
MSG ID : 3504	
INVALID FLAG: Never set	Data Word Count: 5
I/O: Input	XMIT RATE: As Required

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
Data Validity	(Note 1)	6	BIT	n/a
Host Vehicle Baud Rate	(Note 2)	7	BIT	n/a
GPS Receiver Baud Rate	(Note 2)	8	BIT	n/a
Message Control	(Note 3)	10	BIT	n/a
Data Checksum	-	11	I	n/a

Notes to Message 3504 - C-MIGITS III Parameter Control:

1. DATA VALIDITY - This word is structured as follows:

DATA ITEM	DATA BIT	DEFINITION
Host Vehicle XMIT Rate Valid (See Note 2)	0	0=No data specified 1=Valid XMIT baud rate data
Host Vehicle RCV Rate Valid (See Note 2)	1	0=No data specified 1=Valid RCV baud rate data
GPS Receiver XMIT Rate Valid (See Note 2)	2	0=No data specified 1=Valid XMIT baud rate data
GPS Receiver RCV Rate Valid (See Note 2)	3	0=No data specified 1=Valid RCV baud rate data
	4	Reserved
Message 3501 XMIT Rate Valid	5	0=No data specified 1=Valid XMIT rate for Message 3501
Message 3502 XMIT Rate Valid	6	0=No data specified 1=Valid XMIT rate for Message 3502

Notes to Message 3504 - C-MIGITS III Parameter Control (cont.)

Message 3512 XMIT Rate Valid	7	0=No data specified 1=Valid XMIT rate for Message 3512
Message 3512 Configuration Specification Valid	8	0=No data specified 1=Valid configuration for Message 3512
GPS Set Specification Valid	9	0=No data specified 1=Valid GPS set specification
Reserved	10-12	Set to zero
Load Program Command Valid	13	0=No action 1= Commence program load
Passthrough Control Valid	14	0=No data specified 1=Valid passthrough control data
Save Configuration Command Valid	15	0=No data specified 1=Save configuration command valid

Refer to Chapter 8, Frequently Asked Questions, for explanation of the Save Configuration command. Refer to Appendix A, Getting Started, for explanation of the Load Program command.

Notes to Message 3504 - C-MIGITS III Parameter Control (cont.)

2. BAUD RATE - Baud rate changes are only processed when the CURRENT MODE (Message 3500) is Initialization. This word is structured as follows:

DATA ITEM	DATA BIT	DEFINITION
XMIT Baud Rate	0-3	0=No Change
		1=115200
		2=57600
		3=38400
		4=19200
		5=9600
Reserved	4-5	Set to zero
XMIT Parity	6-7	0=No Change
		1=No parity
		2=Even parity
		3=Odd parity
RCV Baud Rate	8-11	0=No Change
		1=115200
		2=57600
		3=38400
		4=19200
		5=9600
Reserved	12-13	Set to zero
RCV Parity	14-15	0=No Change
		1=No parity
		2=Even parity
		3=Odd parity

The default setting for the Host Vehicle interface is 38400 baud, odd parity. The default setting for the GPS interface is 9600 baud, odd parity.

Notes to Message 3504 - C-MIGITS III Parameter Control (cont.)

3. MESSAGE CONTROL - This word is structured as follows:

DATA ITEM	DATA BIT	DEFINITION
Message 3501 Transmit Rate	0-1	0=No Change 1=1 Hz 2=10 Hz (Default)
Message 3502 Transmit Rate	2-3	0=No Change 1=1 Hz 2=10 Hz (Default) 3=100 Hz
Message 3512 Transmit Rate	4-5	0=No Change 1=1 Hz 2=10 Hz (Default) 3=100 Hz
Message 3512 Configuration	6-9	Bit 6=Delta attitude Bit 7=Delta velocity Bit 8=Attitude Bit 9=Velocity
GPS Set Specification	10-12	0=Unknown 1=Microtracker LP 2=PLGR 3=Jupiter
Reserved	13	Set to zero
Passthrough control	14	0=Pass raw GPS messages 1=Pass translated GPS messages
Save configuration command	15	0=Erase 1=Save

Message 3510 - C-MIGITS III Control and Initialization

MSG NAME : C-MIGITS III Control and Initialization	
MSG ID : 3510	
INVALID FLAG: Never set	Data Word Count: 21
I/O: Input	XMIT RATE: As Required

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
Data Validity	(Note 1)	6	BIT	n/a
Mode Command	(Note 2)	7	I	n/a
Latitude - Degrees	(Note 3)	8	I	degrees
Latitude - Minutes	(Note 3)	9	I	minutes
Latitude - Seconds	(Note 3)	10	I	seconds
Longitude - Degrees	(Note 3)	11	I	degrees
Longitude - Minutes	(Note 3)	12	I	minutes
Longitude - Seconds	(Note 3)	13	I	seconds
Altitude	(Note 3)	14-15	DI	meters
Ground Speed	(Note 4)	16	I	m/sec
Ground Track	(Note 4)	17	I	degrees
Year	(Note 5)	18	I	years
Day of Year	(Note 5)	19	I	days
Hours	(Note 5)	20	I	hours
Minutes	(Note 5)	21	I	minutes
Seconds	(Note 5)	22	I	seconds
True Heading	(Note 6)	23	I	degrees/100
Auto Align/Nav Sequence	(Note 7)	24	BIT	n/a
Reserved	Set to zero	25-26	n/a	n/a
Data Checksum	-	27	I	n/a

Notes to Message 3510 - C-MIGITS III Control and Initialization:

1. DATA VALIDITY - The bits of this word are defined in the table below. A mode command may be issued in any mode, subject to the limitations of Table 4-1.

Refer to *Chapter 8, Frequently Asked Questions*, for an explanation of various initialization options. The other initialization data will be acted upon only in initialization mode.

DATA ITEM	DATA BIT	DEFINITION
Mode Command Data	0	0=invalid, 1=valid
Position Data (lat/long/altitude)	1	0=invalid, 1=valid
Velocity Data	2	0=invalid, 1=valid
Date/Time Data	3	0=invalid, 1=valid
Heading Data	4	0=invalid, 1=valid
Auto Align/Nav Sequence Data	5	0=invalid, 1=valid
Auto GPS Init Valid	6	0=invalid, 1=valid
Reserved	7-15	Set to zero

2. MODE COMMAND - A value of zero enables automatic mode sequencing through alignment into navigation mode, as defined by the Auto Align/Nav sequence word. A value corresponding to a valid mode (see notes for message 3500) will cause a transition to that mode, if necessary through intervening modes as specified by the Mode Transition Table, Table 4-1.

A commanded mode will remain in effect until another mode command is processed. The special mode command values -99 and +99 allow enabling of an "INS-Only" mode where GPS measurements processing is disabled and navigation is performed using only INS data. The value -99 enables INS-Only mode, and the value +99 disables it, i.e. returns to INS/GPS operation.

3. LATITUDE, LONGITUDE, ALTITUDE - For latitude, northern hemisphere values are indicated with positive degree, minute, second values; southern hemisphere values are represented with negative degree, minute, and second values. For instance, a southern latitude of 34 degrees, 15 minutes, 25 seconds would be input with a degrees value of -34, a minutes value of -15, and a seconds value of -25. Similarly, for longitude, eastern hemisphere values are indicated with positive degree, minute, and second values; western hemisphere values are represented with negative degree, minute, and second values.

Notes to Message 3510 - C-MIGITS III Control and Initialization (cont.)

Latitude, longitude, and altitude are geodetic values referenced to WGS-84 datum. The default location at turn-on is the position saved in EEPROM by the Save Configuration command of Message 3504, or, if this does not exist, the location is Anaheim, CA (Lat = 33:51:24, Lon = -117:50:51, Alt = 42).

4. VELOCITY - A vertical velocity of 0 (level flight) is assumed. Ground track is measured clockwise relative to North. The default is a velocity of zero.

5. DATE, TIME - UTC (Paris) date and time. The year is encoded as years since 1900 (1=1901). The day of year starts at one (1=Jan 1). The hour is encoded in 24-hour time (0=midnight; 13=1 pm).

6. TRUE HEADING - Represents actual pointing direction of HV, measured clockwise from North. The value must be specified in the range -180 to +180 degrees in units of deg/100, so the input integer must be between -18000 and +18000. The default heading is zero.

7. AUTO ALIGN/NAV SEQUENCE - This word is used to define default sequencing through an alignment mode and into a navigation mode after initialization. If this data is not provided, default sequencing is through Fine Alignment mode into Air Navigation mode. The bit definitions (where 0=LSB for this word are shown in the table below. The numerical definitions of the modes are found in the notes for message 3500.

DATA ITEM	DATA BITS	DEFINITION
Auto Alignment Sequence	0-3	Alignment mode for automatic sequencing
Auto Navigation Sequence	4-7	Navigation mode for automatic sequencing
Auto GPS Initialization	8	0 = Initialize from user-provided data (default)
		1 = Initialize from GPS processor nav solution as soon as GPS processor enters navigation mode
Reserved	9-15	Set to zero

Message 3511 - C- MIGITS III Configuration Control

MSG NAME: C-MIGITS III Configuration Control	
MSG ID : 3511	
INVALID FLAG: Never set	Data Word Count: 22
I/O: Input	XMIT RATE: As Required

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
Data Validity	(Note 1)	6	BIT	n/a
Sensor-to-Body Transformation Cbs (1,1)	(Note 2)	7-8	F@1	Unitless
Sensor-to-Body Transformation Cbs (1,2)	(Note 2)	9-10	F@1	Unitless
Sensor-to-Body Transformation Cbs (1,3)	(Note 2)	11-12	F@1	Unitless
Sensor-to-Body Transformation Cbs (2,1)	(Note 2)	13-14	F@1	Unitless
Sensor-to-Body Transformation Cbs (2,2)	(Note 2)	15-16	F@1	Unitless
Sensor-to-Body Transformation Cbs (2,3)	(Note 2)	17-18	F@1	Unitless
Sensor-to-Body Transformation Cbs (3,1)	(Note 2)	19-20	F@1	Unitless
Sensor-to-Body Transformation Cbs (3,2)	(Note 2)	21-22	F@1	Unitless
Sensor-to-Body Transformation Cbs (3,3)	(Note 2)	23-24	F@1	Unitless
Lever Arm X	(Note 3)	25	I	cm
Lever Arm Y	(Note 3)	26	I	cm
Lever Arm Z	(Note 3)	27	I	cm
Data Checksum	-	28	I	n/a

Notes to Message 3511 - C-MIGITS III Configuration Control:

1. DATA VALIDITY - The bits of this word are defined in the table below:

DATA ITEM	DATA BIT	DEFINITION
Sensor-to-Body Transformation Data	0	0=invalid, 1=valid
Lever Arm Data	1	0=invalid, 1=valid
Reserved	2-15	Set to zero

Notes to Message 3511 - C-MIGITS III Configuration Control (cont.)

2. SENSOR-TO-BODY TRANSFORMATION - This matrix provides the means of transforming delta-velocity and delta attitude data from IMU axes to host-vehicle body axes. This affects the incremental data reported in messages 3502 and 3512 and the attitude data (pitch, roll, heading) reported in messages 3501 and 3512. It does not affect the AMRAAM data, which is resolved in IMU coordinates.

3. LEVER ARM - The lever arm is the distance to the GPS antenna from the C-MIGITS III center of gravity along the C-MIGITS III body axes.

Message 3512 - C-MIGITS III Flight Control

MSG NAME : C-MIGITS III Flight Control	
MSG ID : 3512	
INVALID FLAG: Never set	Data Word Count: Note 3
I/O: Output	XMIT RATE: 1,10, 100 Hz (Note 1)

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	-	5	I	n/a
Time Tag	(Note 2)	6-9	DF@20	sec
Configurable Flight Control Data	(Note 3)	10 - N		
Data Checksum	-	N+1	I	n/a

Notes to Message 3512 - C-MIGITS III Flight Control:

1. Transmission rate programmable via Message 3504. The selected rate affects the data time interval. For example, if the message is requested at 10 Hz, the data represents 100 ms of ΔV and $\Delta\Theta$.

Overflows may occur if high-dynamics data is output at low rates.

2. TIME TAG - Contains GPS Sensor time if GPS Time Valid (Message 3500) is set to 1; otherwise, C-MIGITS III system time since power-up is reported. Data words are in the order 2, 1 (MSW), 4 (LSW), 3.

3. The format of Message 3512 is configurable via Message 3504. Message 3512 may be specified to contain any or all of the following data items.

Notes to Message 3512 - C-MIGITS III Flight Control (cont.)

DATA	NUMBER OF 16-BIT WORDS	DATA TYPE	UNITS
Compensated Delta Theta (Body coordinates - X,Y,Z)	6	F@0	radians
Compensated Delta Velocity (Body coordinates - X,Y,Z)	6	F@10	m/sec
Attitude (Pitch, roll, heading)	6	F@0	semicircles
Velocity (North, east, up)	6	F@10	m/sec

Included data items appear in the order shown. The size of the data block will vary with the included data items. The default content of message 3512 is the delta-attitude and delta-velocity data. Unlike message 3502, the delta-attitude and delta-velocity values are compensated for estimated IMU errors.

Message 3623 - Jupiter Timemark Message

MSG NAME: Jupiter Timemark Message (Note 1)	
MSG ID : 3623	
INVALID FLAG: Never set	Data Word Count: 117
I/O: Output	XMIT RATE: 1 Hz

Data	Notes	Word No	Data Type	Units
Message Header	-	1-4	n/a	n/a
Header Checksum	(Note 1)	5	I	n/a
GPS Time of Week	-	6-9	DF@20	sec
UTC Time	-	10-13	DF@17	sec
Reserved	-	14	n/a	n/a
Number of SV's Used	-	16	I	n/a
Reserved	-	17-21	n/a	n/a
Latitude	(Note 3)	22-23	F@0	semicircles
Longitude	(Note 3)	24-25	F@0	semicircles
Altitude	(Note 3)	26-27	F@15	meters
Velocity, East	(Note 4)	28-29	F@10	m/sec
Velocity, North	(Note 4)	30-31	F@10	m/sec
Velocity, Up	(Note 4)	32-33	F@10	m/sec
Expected Horizontal Position Error	-	34-35	UDI	cm
Expected Vertical Position Error	-	36-37	UDI	cm
Expected Time Error	-	38-39	UDI	cm
Expected Horizontal Velocity Error	-	40	UI	cm/sec
Clock Bias	-	41-42	DI	cm
Clock Drift	-	43-44	DI	cm
Channel 1 CSW	(Note 5)	45	I	n/a
Channel 2 CSW	(Note 5)	46	I	n/a
Channel 3 CSW	(Note 5)	47	I	n/a
Channel 4 CSW	(Note 5)	48	I	n/a
Channel 5 CSW	(Note 5)	49	I	n/a
Channel 6 CSW	(Note 5)	50	I	n/a
Channel 7 CSW	(Note 5)	51	I	n/a
Channel 8 CSW	(Note 5)	52	I	n/a

Channel 9 CSW	(Note 5)	53	I	n/a
Channel 10 CSW	(Note 5)	54	I	n/a
Channel 11 CSW	(Note 5)	55	I	n/a
Channel 12 CSW	(Note 5)	56	I	n/a
Channel 1 Measurement State Info	(Note 6)	57	BIT	n/a
Channel 2 Measurement State Info	(Note 6)	58	BIT	n/a
Channel 3 Measurement State Info	(Note 6)	59	BIT	n/a
Channel 4 Measurement State Info	(Note 6)	60	BIT	n/a
Channel 5 Measurement State Info	(Note 6)	61	BIT	n/a
Channel 6 Measurement State Info	(Note 6)	62	BIT	n/a
Channel 7 Measurement State Info	(Note 6)	63	BIT	n/a
Channel 8 Measurement State Info	(Note 6)	64	BIT	n/a
Channel 9 Measurement State Info	(Note 6)	65	BIT	n/a
Channel 10 Measurement State Info	(Note 6)	66	BIT	n/a
Channel 11 Measurement State Info	(Note 6)	67	BIT	n/a
Channel 12 Measurement State Info	(Note 6)	68	BIT	n/a

(continued next page)

Jupiter Timemark Message (cont.)

Channel 1 Pseudorange	(Note 7)	69-70	F@26	meters
Channel 1 Deltarange	(Note 8)	71-72	F@14	m/sec
Channel 2 Pseudorange	(Note 7)	73-74	F@26	meters
Channel 2 Deltarange	(Note 8)	75-76	F@14	m/sec
Channel 3 Pseudorange	(Note 7)	77-78	F@26	meters
Channel 3 Deltarange	(Note 8)	79-80	F@14	m/sec
Channel 4 Pseudorange	(Note 7)	81-82	F@26	meters
Channel 4 Deltarange	(Note 8)	83-84	F@14	m/sec
Channel 5 Pseudorange	(Note 7)	85-86	F@26	meters
Channel 5 Deltarange	(Note 8)	87-88	F@14	m/sec
Channel 6 Pseudorange	(Note 7)	89-90	F@26	meters
Channel 6 Deltarange	(Note 8)	91-92	F@14	m/sec
Channel 7 Pseudorange	(Note 7)	93-94	F@26	meters
Channel 7 Deltarange	(Note 8)	95-96	F@14	m/sec
Channel 8 Pseudorange	(Note 7)	97-98	F@26	meters
Channel 8 Deltarange	(Note 8)	99-100	F@14	m/sec
Channel 9 Pseudorange	(Note 7)	101-102	F@26	meters
Channel 9 Deltarange	(Note 8)	103-104	F@14	m/sec
Channel 10 Pseudorange	(Note 7)	105-106	F@26	meters

Channel 10 Deltarange	(Note 8)	107-108	F@14	m/sec
Channel 11 Pseudorange	(Note 7)	109-110	F@26	meters
Channel 11 Deltarange	(Note 8)	111-112	F@14	m/sec
Channel 12 Pseudorange	(Note 7)	113-114	F@26	meters
Channel 12 Deltarange	(Note 8)	115-116	F@14	m/sec
ECEF Position X	(Note 10)	117-118	F@23	meters
ECEF Position Y	(Note 10)	119-120	F@23	meters
ECEF Position Z	(Note 10)	121-122	F@23	meters
Data Checksum	-	123	I	n/a

Notes to Message 3623 - Jupiter Timemark Message:

1. Message 3623 represents a re-packaging of various Jupiter messages (Jupiter Messages 1000, 1002, 1007, 1009, and 1102) internal to the C-MIGITS III. Passthrough translation is enabled, i.e., data formats have been changed to those used by C-MIGITS III. The message size and checksum values differ from those of any Jupiter message.

2. LATITUDE, LONGITUDE, ALTITUDE - Referenced to WGS-84 map datum. WGS-84 coordinates are ellipsoidal coordinates, hence given in latitude, longitude and altitude above the ellipsoid. Note: In some locations, a WGS-84 altitude of 0 meters above the ellipsoidal surface can differ by as much as 100 meters from actual sea level.

3. VELOCITY EAST/NORTH/UP - Local tangent plane coordinates referenced to the WGS-84 ellipsoid, where velocities are referenced clockwise with respect to true North.

4. CHANNEL STATUS WORD
These words have the following structure:

Channel Status Word

DATA ITEM	DATA BIT	DEFINITION
Weak Signal	0	1 = Weak

High $\Delta\theta$	1	1 = High
Parity Error(s)	2	1 = Errors
Pre-Position Data (not used)	3	1 = Data propositioned
Propagated Track	4	1 = Propagated
Bit Sync Flag	5	1 = Data bit sync not achieved
Frame Sync Flag	6	1 = Frame sync not achieved
Z Count Flag	7	1 = Z Count not recovered
Reserved	8 - 15	N/a

5. CHANNEL 1, 2, ..., 12 MEASUREMENT STATE INFO These words are structured as follows:

Channel Measurement State Word

DATA ITEM	DATA BIT	DEFINITION
Channel Used	0	1 = Used
Ephemeris Available	1	1 = Available
Measurement Validity	2	1 = Valid
	3	Reserved
SVID	4-9	Satellite PRN, Range 0 to 32
C/No	10-15	Integer value of signal-to-noise ratio, range = 0 to 60 dBHz

Notes to Message 3623 - Jupiter Timemark Message (cont.)

7. CHANNEL 1, 2, ..., 12 PSEUDORANGE - The apparent range from the receiver antenna to a GPS satellite, calculated from the signal transmission time, the time of signal reception, and the speed of light.

8. CHANNEL 1,2, ..., 12 DELTARANGE – The time rate of change of pseudorange.

9. ECEF POSITION X/Y/Z - WGS-84 ECEF coordinates. ECEF coordinates are rectangular, Cartesian and are fixed to the earth, hence a rotating coordinate system.

This page left intentionally blank.

Chapter 7- End Product Applications

Overview

C-MIGITS III can be used for a variety of applications. Use of the various system features and interfaces varies widely from customer to customer. The information presented here is designed to guide the first-time user on what might be required for his/her specific application.

Regardless of the application, *prime power* must be supplied to the C-MIGITS III unit. A *GPS antenna* is a necessity if integrated INS/GPS performance is desired.

The system will operate in *INS only* navigation if a GPS antenna is not present. However, it will not meet specified C-MIGITS III performance, and the system navigation solution will drift over time.

All users will need to communicate with the system's asynchronous RS-232 *serial interface*. This interface provides navigation solution data to the user, and accepts initialization and control data from the user.

Use of other C-MIGITS III interfaces and features beyond those just mentioned requires consideration of specific application needs. The sections that follow provide examples of specific application needs and how they should be addressed by the system integrator.

Specific Application Examples

If an application has a limited capability to supply C-MIGITS III with initialization data, providing *battery power* to the unit may solve this potential problem. Providing external battery input to the C-MIGITS III will allow it to store the last known position and time data.

Presence of this data will improve GPS TTFF. In applications using dynamic alignment, this may reduce the time required to complete alignment and transition to integrated INS/GPS navigation.

Note: The user needs to keep in mind that C-MIGITS III provides internal back-up of the data for up to 4 hours. Providing an external battery makes sense for applications that expect elapsed power-down time to exceed 4 hours.

If an application needs to time-synchronize C-MIGITS III data with other external systems, use of the *Timemark* (RS-232) output is required. This discrete output will provide a pulse that corresponds to valid GPS time in output block 3.

Finally, if an application plans to use C-MIGITS III for vehicle control, use of the IMU *AMRAAM interface* may be required. Many application control loops require data at rates higher than 100 Hz. These applications will need to utilize the AMRAAM 600-Hz autopilot data.

Considerations when using AMRAAM 600-Hz autopilot data include:

- Filtering requirements for the application rates.
- Potential effects of the filtering on the autopilot data transfer function.

If the application control loops can accept 100-Hz data (inertial data), the user may be able to utilize block 3502 on the system serial port. Considerations when using 3502 data at 100 Hz include:

- The system serial port bandwidth, (a function of the user-selected baud rate).
- The number of output data blocks connected and/or requested.

Product Application Examples

The C-MIGITS III can be implemented in many end-product solutions. Some examples of C-MIGITS III use and applications are described below.

Use: Navigation System

- *Applications*: Manned or remote controlled dynamic platforms.
- *Examples*: Airplanes, Helicopters, remote controlled Unmanned Aerial Vehicles (UAVs), Mobile Land Vehicles, and Mobile Marine Vehicles.

Use: Guidance, Navigation, and Control

- *Applications*: Unmanned Vehicles.
- *Examples*: Autonomous UAVs, Missiles, Targets, Drones, Guided Munitions.

Use: Pointing

- *Applications*: Camera and other pointing applications.
- *Examples*: Aerial Photomapping, Radar Pointing/Steering, Land/Sea Launched Weapon Platforms.

Since C-MIGITS III can be integrated into a wide range of end-product solutions, each unique system requires different inputs and outputs to satisfy the application. The system integrator should help the development team determine how to use C-MIGITS III features and software data sets within the specific product or application.

Chapter 8- Frequently Asked Questions

I apply power to the unit and the unit doesn't run. What can I do?

Inspect the power supply and cabling to the unit. Verify the proper voltage level at the power supply and at the unit connector pins.

- The +28 Vdc power supply that you are using may not have an adequate current capacity for the unit. Although the unit draws 0.8 amps steady state current, turn-on inrush current can be as high as 1.5 amps. It's a good idea to use a power supply rated 2 amps at +28 Vdc.
- The power supply that you are using may not support the units' turn-on current timing requirements. The full current from the power supply must be available within 2 msec of power application to the unit. You may have to turn on the power supply separately and then apply power to the unit via an external switch or relay.

When I turn on power, the unit draws an unusually large current and doesn't run, or immediately stops running. What can I do?

Inspect the power supply and cabling for electrical shorts. Check power supply requirements as stated in the previous question above.

I can't communicate with the unit via the RS232 port. Why?

Generally, if you are having trouble communicating with the unit and are sure that your RS232 communications parameters are set correctly, try viewing the data using an RS232 monitor program. This will verify the communications parameters, as well as the message data content, handshaking, and timing. Remember that the data on the RS232 port is binary, not ASCII coded numbers. See chapter 6 for data formats. Also, verify the following:

- Check that the serial data connections are complete in the cable that you are using. (Can you see data on an oscilloscope or via an RS232 monitor program right at the data pins on the unit connector?)
- Verify that a null modem cable configuration is being used (i.e., is your system's transmit data line going to the unit's receive data line and your system's receive data line going to the unit's transmit data line).
- Check that the proper baud rate, data bits, stop bits, and parity are being used. You should be using the proper baud rate, eight data bits, one stop bit, and odd parity.
- Verify that you have set up your UART correctly. On a PC, the UART's OUT 2 signal must be asserted for the UART to function properly.
- If your program is interrupt-driven, verify that the interrupt handling routine functions correctly using a dumb terminal or simulated message input.

Why am I getting unintelligible data over the RS232 port?

The RS232 data is sending byte information in reverse order from the unit. (At your PC, observe the message traffic, or at your printer, if you are using one, get a sample printout.) If you're using a PC to receive data, you must be sure to place the data in memory in the correct order for your program to interpret the data.

- Verify that poor cable connections are not causing RS232 signal degradation. If the received data bytes have parity, break, or framing errors, then you are either using the wrong communications parameters, or there is a problem with the cabling.

My program can't detect the start of a new message block, but there appears to be data being sent by the unit. Why?

The message start identification word "81FF" is sent LSB first, so a program should check that an "FF" is received, then that an "81" is received to indicate the start of an incoming message.

I can receive data from the unit, but I can't send data to the unit. What should I do?

- Verify that the unit transmit cable connection is complete to your processor.
- Verify that the message format for the data that you are sending the unit is proper. (Are the checksums for the header and data portions of the message correct?) If the handshake protocol indicates that your message has been rejected, chances are that your message format is in error.

Messages are output with non-sequential timestamps, or seem to be output sporadically or stop being output altogether. What can I do?

Check to see if the messages that are 'CONNECTED' fit the bandwidth RS232 bus at the baud rate you are using. The unit will behave unpredictably if the data bandwidth is exceeded.

The unit stays in Initialization mode when I turn it on. Why?

When the unit is turned on, it will remain in Initialization mode until it has received a valid initialization data message. If you have sent an initialization message and the unit remains in Initialization mode, the message you are sending the unit may have a data or format error.

The unit exhibits poor performance upon sequencing to INS/GPS Navigation mode. Why?

- The unit may not have been stationary during the Ground Alignment mode. The Ground Alignment mechanization assumes that the unit is stationary, and will behave unpredictably if this is not the case.

- You may be experiencing problems with GPS operation. See the next question regarding GPS operation.

The unit will not sequence into INS/GPS Navigation mode. What should I do?

- Check that the GPS satellite signal strengths (C/No) appear normal in the GPS data message. If all signal strengths indicate 0 or are low (< 30 dB/Hz), then the antenna may not be connected to the unit or the antenna connector, cable, or antenna itself may be broken. Your active antenna may not be powered up properly, the antenna may be indoors or otherwise obscured (buildings, trees, people, improper orientation), or the cable run to the antenna may be too long (unpowered).

- You may have sent erroneous initialization information to the unit. In this case, signal strengths for all channels probably indicate 0. Check that the initialization data you have sent is accurate. The GPS initialization process is very sensitive to errors in time initialization. Be sure that you are using UTC (GMT) and not local time. Position data must be in decimal degrees (not radians), in WGS-84 coordinates (not NAD-27) , and should be within 100 km of your actual location. Remember that west longitudes (e.g. USA) and south latitudes must be entered as negative numbers.

- If the unit has not been run for several months, the GPS almanac data stored by the GPS processor may be too old to provide quick GPS satellite acquisition. In this case, power the unit up with the antenna connected and let the unit remain in Initialization mode for about 15 minutes after the GPS indicates that it is tracking satellites. This will allow time for the GPS almanac to be updated.

The unit sequences to INS-Only Navigation mode, but after a little while the position data starts changing erratically. What's wrong?

The unit is not receiving GPS data or there is a problem with the GPS initialization. The unit depends on receiving GPS data for proper operation. The mode sequencing time line provides adequate time for the GPS subsystem to acquire satellites and begin GPS navigation before Ground Alignment mode is complete.

The unit cannot function as an unaided inertial navigation system for long periods of time. The errors inherent in the inertial instruments will eventually grow unbounded without GPS data available to provide corrections.

What is saved by the Save Configuration command?

The Save Configuration command in message 3504 is used to save a number of system parameters to EEPROM so that the parameters will be initialized to the saved values at subsequent turn-ons. These parameters are:

- *Position (Latitude, longitude, altitude)*
- *IMU parameter estimates (gyro bias and scale factor; accelerometer bias and scale factor)*
- *Sensor-to-body coordinate transformation (see notes on message 3511)*
- *Lever-arm body-frame components*
- *Auto align/nav sequence specifiers*
- *Auto GPS init flag*
- *Baud rates (HV, GPS)*
- *Message 3501, 3502, and 3512 output rates*
- *Message 3512 output configuration*
- *Message connect/disconnect states*
- *GPS set type*
- *Passthrough translation setting*

All of these parameters are saved at once as a group, so it is not possible to save certain parameters while leaving other parameters at their previously saved or default values. In general, it is useful to save the configuration so that the C-MIGITS III comes up in the desired configuration at turn-on. Care should be taken, however, that the state of the system is known when the Save Configuration command is issued.

In particular, the position can become corrupted if the C-MIGITS III is operated for a long period without GPS available, and the IMU parameter estimates can become corrupted if the unit is moved during Fine Alignment mode. The configuration should not be saved in either of these situations. If it is desired to erase a saved configuration, the Save Configuration with the Erase option specified can be used.

What is the difference between the Mode Command and the Auto Align/Nav sequence word in message 3510?

The Mode Command word in Message 3510 is a command to the C-MIGITS III to sequence to the specified mode, if necessary through intervening modes, while the Auto Align/Nav sequence word defines the default sequencing through an alignment mode to a nav mode, but does not trigger this sequencing. The Mode Command tells the C-MIGITS III to sequence to the specified mode and no further, so, if the commanded mode is an alignment mode, the system will go to that mode and stay there, regardless of the alignment mode's exit criteria. A mode command of Automatic (0) tells the C-MIGITS III to go through the mode sequence defined by the Auto Align/Nav sequence word.

Generally, for normal upmoding, it is best to send a 3510 message containing a mode command of Automatic and an Auto Align/Nav sequence word specifying the desired sequencing. Only in special situations would commanded upmoding to specific modes be appropriate.

One such situation would be a case where the C-MIGITS III was to remain stationary for a long period of time; in this case, it would make sense to command Fine Alignment mode to allow the unit to stay in Fine Alignment as long as it was stationary, and then command Automatic mode before start of motion to enable transition to a navigation mode.

Mode commands are also used to command downmoding, either to command Test mode to perform Built In Test, or to return to Initialization mode. It is possible, for instance, after having been in navigation mode, to return to initialization mode, and upmode again through a different sequence.

An alignment/navigation sequencing specified in message 3510 becomes the default for subsequent re-upmodes if power to the unit is not turned off. This sequencing can be saved even across power cycles using the Save Configuration command.

How do I initialize the unit?

Message 3510 offers a number of options for initializing the C-MIGITS III. Presently, the C-MIGITS III software allows two possible paths for sequencing from startup into navigation:

- *Initialization --> Fine Alignment --> Air Navigation*
- *Initialization --> Air Alignment --> Air Navigation*

In general, the Fine Alignment route is the appropriate option to use if C-MIGITS III can be kept stationary for two minutes or more after startup. The Air Alignment route is the appropriate option to use if C-MIGITS III will be moving from the time it is turned on.

One of the parameters which can be specified in the 3510 message is the Auto GPS Initialization flag. This indicator tells C-MIGITS III whether it should get its position and velocity initialization data from the user, or from the GPS receiver when it acquires satellites and begins tracking. In general, the set of data which must be provided by the user to fully initialize C-MIGITS III will depend on whether this flag is set or not.

Position and velocity data may be provided in the 3510 message even if the Auto GPS Initialization flag is set, but they will not be used to initialize C-MIGITS III; they instead will be used to initialize the GPS receiver if it is not already tracking satellites.

The behavior of the initialization sequence is somewhat different for the case in which Auto GPS Initialization is specified and the case in which it is not. If Auto GPS Initialization is not specified, the transition to alignment mode will take place immediately upon acceptance of the 3510 message regardless of whether the GPS is tracking satellites.

If Auto GPS Initialization is specified, the C-MIGITS III will continue to report Initialization mode until the GPS receiver acquires and tracks four satellites, at which time the unit will transition to alignment mode.

1. Fine Alignment Initialization - Fine alignment performs an initial estimation of the IMU parameters, primarily gyro bias and the vertical component of accelerometer bias, using the known fact that the IMU is stationary. In order for this estimation to be valid, the C-MIGITS III must have a reasonably good idea of its position and heading, so these quantities must be provided to it before entry to Fine Alignment.

The initial position should be valid to within about 100 miles, and the initial heading should be good to within about 10 degrees. In general, though, the more accurate these values are, the better the IMU calibration will be. Vehicle heading cannot be estimated during Fine Alignment since it is not observable in a stationary situation, so the heading during Fine Alignment will stay at very nearly the initial value provided by the user. Heading can only be estimated via GPS measurements during subsequent motion.

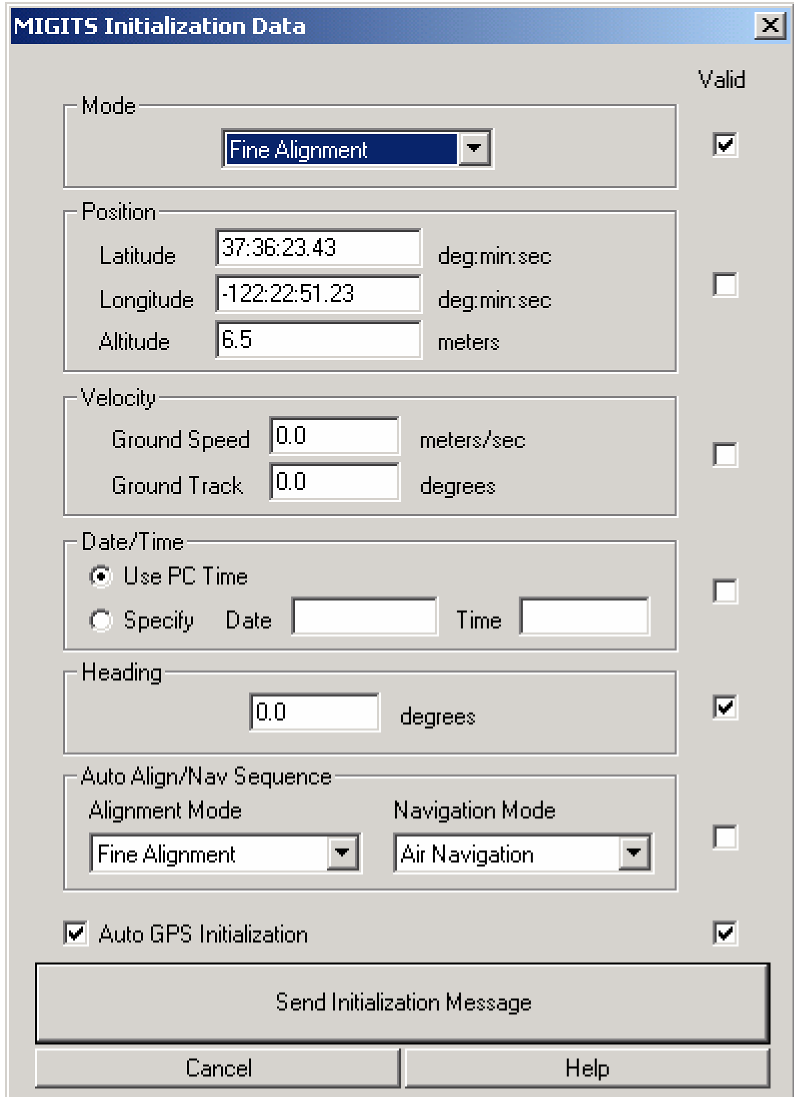
The paragraphs below summarize the data which must be provided for initialization of Fine Alignment both without and with auto-initialization from GPS.

- Without auto-initialization from GPS - In order to initialize Fine Alignment without auto-initialization from GPS, position, time, and heading must be supplied in the 3510 message. Velocity will be ignored even if it is given a non-zero value.

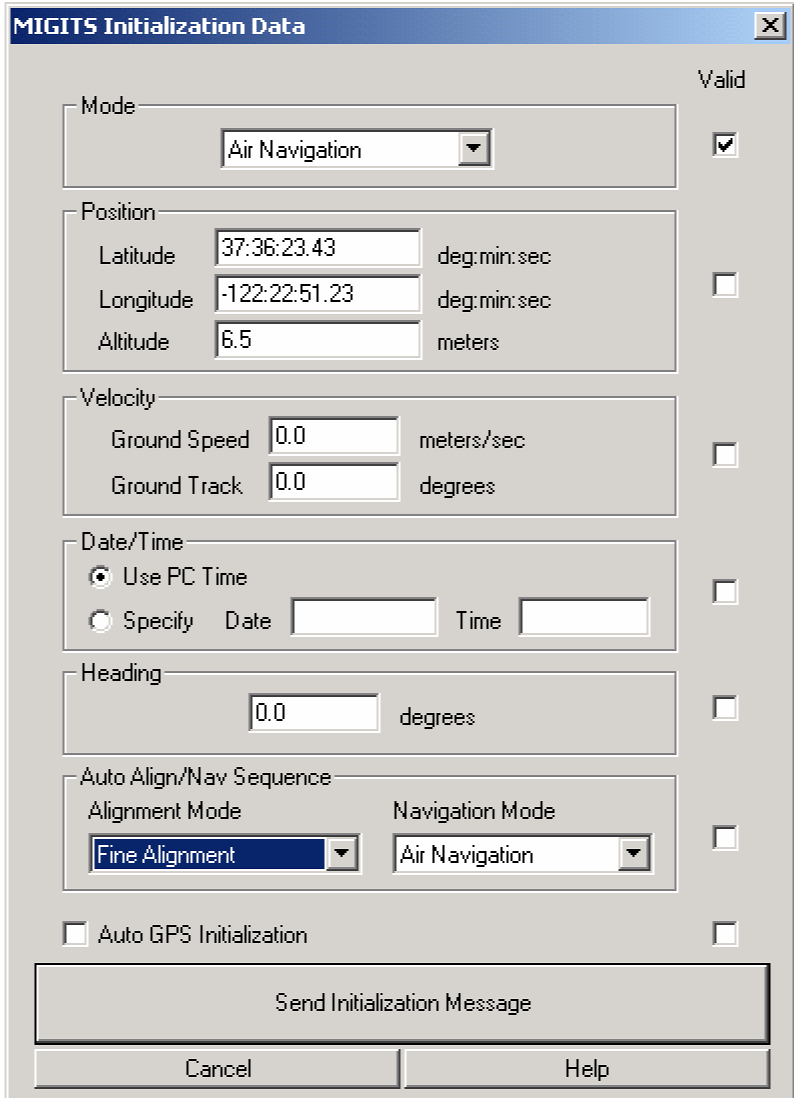
- With auto-initialization from GPS - In order to initialize Fine Alignment with auto-initialization from GPS, only heading must be supplied in the 3510 message. It is helpful to supply position and time also, especially if the GPS receiver has not yet begun tracking satellites. Position will be reinitialized from GPS. Again, velocity will be ignored even if it is given a non-zero value.

If your application requires the longer Fine Alignment time, you can do so as follows. First send a 3510 message commanding the C-MIGIT III to the Fine Alignment mode, then send another 3510 message to the C-MIGIT III commanding the unit to Air Navigation mode when you are ready to navigate. The following shows the two 3510 messages using MIGICOM, which is provided in the user's software CD.

1. Send a 3510 message commanding the unit into Fine Alignmentas shown: (specify the true heading of the unit - the unit will move into Fine Alignment mode after GPS is locked and will stay in Fine Alignment)



2. Send a 3510 message, "command to Air Navigation" when you want to move the unit to Air Navigation mode as shown below. The unit will move to the Air Navigation mode once the 3510 message is received. Keep in mind that the minimum time of the Fine Alignment mode is 2 minutes. If the "Command to Air Navigation" message is sent to the unit within the 2 minutes of the Fine Alignment period, then the unit will move into the Air Navigation mode at the end of 2 minutes of Fine Alignment. If the "Command to Air Navigation" message is sent to the unit after 2 minutes of Fine Alignment, then the unit will move into the Air Navigation mode immediately.



2. Air Alignment Initialization - Air Alignment performs an initial estimate of heading using GPS measurements, and then exits automatically to a navigation mode. Since, as mentioned before, heading is not observable in a stationary situation, movement, in particular acceleration, of the C-MIGITS III is necessary to get out of Air Alignment mode. Either linear acceleration in a straight line or a turn from one course to another is required for exit. Air Alignment generally does not estimate IMU parameters nearly as well as does Fine Alignment; it is left up to subsequent motion during nav mode to do this.

- Without auto-initialization from GPS - In order to initialize Air Alignment without auto-initialization from GPS, position, velocity, time, and heading must be supplied in the 3510 message. In general, this mode of initialization is not recommended since it may give unreliable results depending on the relative timing of the 3510 message and GPS satellite acquisition.

- With auto-initialization from GPS - The parameters which must be supplied in order to initialize Air Alignment with auto-initialization from GPS depend on how fast the C-MIGITS III host vehicle is traveling. If the vehicle speed is less than 5 meters/sec, then at least the heading must be supplied in the 3510 message. If the speed is greater than 5 meters/sec, then no parameters are required for initialization.

If heading is not specified, it is computed from the course over ground of the vehicle as seen by GPS, and position and velocity are also initialized from GPS values. As before, it is helpful to supply position, velocity, and time in the initialization message if the GPS receiver has not yet begun tracking satellites. Use of auto-initialization from GPS is the recommended method of initialization for Air Alignment mode.

Appendix A- Getting Started

Setup

The following information will guide the system integrator in effectively integrating the C-MIGITS III system with the HV. For commonly asked questions regarding system integration, refer to *Chapter 8-Frequently Asked Questions*. For questions concerning your specific application, refer to the *Product Support* section. Otherwise, contact an SDI applications engineer.

Support Equipment Required

Power Supply

C-MIGITS III requires a prime power input voltage between +20.0 and +34.0 Vdc as measured at the input. The typical input voltage is +28 Vdc. The typical start-up current drawn by the unit is 1.5 amps at +28 Vdc. The typical steady-state current drawn by C-MIGITS III is 0.65 amps at +28 Vdc.

The optional battery input to C-MIGITS III accepts a voltage in the range of +3.0 to +5.0 Vdc referenced to digital ground to maintain position, time, and ephemeris data when primary power is removed. If no voltage is applied to the battery input, C-MIGITS III will maintain data for a minimum of 3 hours at 20°C after the primary power is removed.

The typical steady-state current drawn from the battery is 30 micro-amps at +5 Vdc and 16µamps at +3 Vdc. In remote applications where using an unlimited power source is not convenient, a lithium battery is recommended to provide long life and voltage stability. If an unlimited power source is needed or desired, care should be taken to ensure that the supply voltage is free of unwanted noise or transients in excess of the input requirements.

Antenna

C-MIGITS III requires L1 GPS SPS signals (1575.42 MHz), either from a passive or externally powered active antenna. The signal level input shall be between -163 to -130 dBW for normal operation. Signal-to-noise (C/No density measured by C-MIGITS III) should range approximately between 35 to 45 dBHz on all channels. Additional information on the type of antenna to use, and whether a preamplifier is needed is given in Chapter 5.

Connectors/Cables

The J1 I/O connector and cable requirements are defined in Chapter 5. Figure A-1 shows the typical arrangement of C-MIGITS III's cable. If used in a hostile electromagnetic environment, care should be given in selecting the proper backshell and overbraid of the interface cable to obtain the best overall EMI protection.

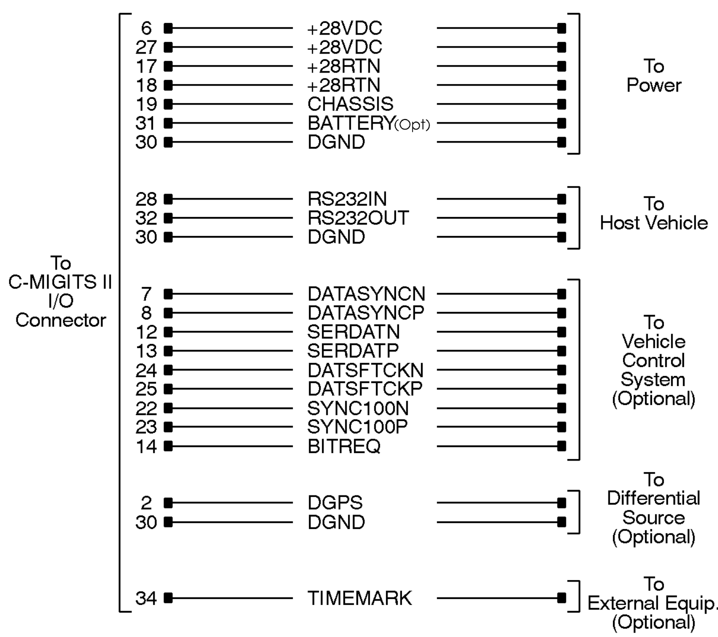


Figure A-1. Typical Cable Arrangement

The straight RF input (J2) mating connector is a standard male SMA type of the MIL-C-39012 series. A 50-ohm coaxial cable and antenna is required for the RF input.

Communication Via RS-232 Asynchronous

Host Vehicle Port

As part of getting started, an AT compatible computer equipped with a standard RS-232 serial port can be used as the host vehicle system. It is recommended that a computer with a 38400 baud rate be used to support the C-MIGITS III's default data rate. The host vehicle software MigiCom (a Windows program) or MBB_COMM (DOS based) can be used to communicate with C-MIGIT. These softwares are available on the C-MIGIT user CD software and manual kit. The host vehicle I/O interface will enable the user to send initialization and control data to C-MIGITS III, as well as display or record its navigation information. Standard personal computer UART baud rates from 9600 to 115200 baud are supported. Refer to the *Digital Interface* section in Chapter 5 for information on the data rates and frame format selection of the serial data.

Communication Via IMU RS-422 Synchronous

Serial Port (optional)

High-speed inertial data is provided via the C-MIGITS III RS-422 synchronous serial port. This data is fixed point "AMRAAM" format. RS-422 serial data, clock, and frame sync signals are provided as shown in Chapter 5. An optional AT compatible computer equipped with a TMS320C3X DSP board can be used to display and record this data with the appropriate software.

Additional Support for Integration

An optional EMI filter can be used to provide protection to the +28 Vdc power lines from conducted noise such as power spikes, and to attenuate any internally generated conducted emissions. The EMI filter is a bolt-on unit that mates to the top of C-MIGITS III. The EMI filter adds approximately 1.78 cm (0.7 in) to the unit's height.

C-MIGITS III provides a Time Mark pulse at one pulse-per-second (PPS) for synchronization of external equipment. The leading edge of the pulse represents the instant in time when the navigation solution is valid. The navigation solution and status at this instant of time is reported in Time Mark output message 3. See Chapter 6 for discussion of time validity at the various solutions.

PC-based integration software, MIGILITE (MS Windows) and MBB_COMM (MS DOS), are available with C-MIGITS III. This software will aid the user in the configuration, initialization, and communication through the host vehicle port. The software serves only as a guide in helping the user get started using C-MIGITS III and to observe the contents of each data message. However, it is the responsibility of the user to develop software to meet their own specific applications.

Installation

It is recommended that C-MIGITS III be mounted using four NAS 1351-C3 socket cap screws, tightened to a torque between 20 to 28 in-lbs. The mounting hole pattern is shown in Figure 3.3.

C-MIGITS III can be initialized in any orientation. In order for its attitude outputs (pitch, roll, heading) to be meaningful in the coordinate reference frame of the host vehicle, the sensor-to-host vehicle transformation may need to be reset, using data message 3511. See Chapter 6 for more details.

Using C-MIGITS III

This section is intended as an operational overview of C-MIGITS III. Examples are provided using the MBB_COMM software, running on a standard AT compatible computer. The following section will provide information necessary to help the user set up their system to make use of the various interfaces and features of C-MIGITS III. A block diagram of a typical C-MIGITS III system setup is shown in Figure A-2.

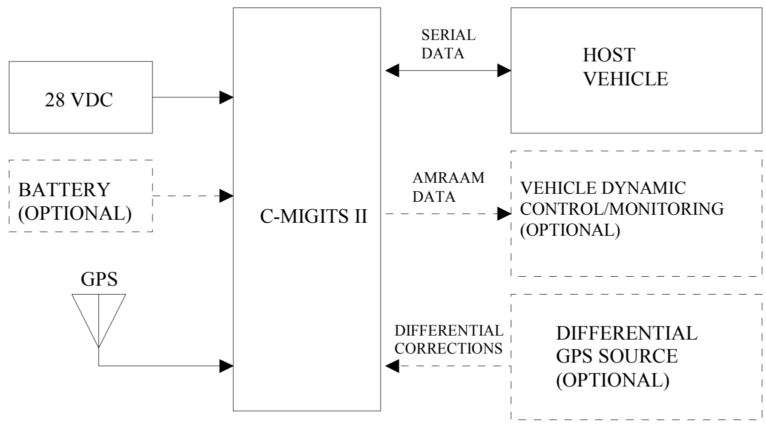


Figure A-2. Typical C-MIGITS III System Setup

C-MIGITS III Operational Overview

Once power is applied, C-MIGITS III will go through power-on initialization, and will sequence up to Initialization mode. This entire process takes approximately 7 seconds to complete.

Also at this time, the GPS receiver subsystem will begin searching for a satellite, based on GPS almanac data stored in the receiver's non-volatile memory, together with time and position data from the optional battery backed RAM. The GPS receiver will sequence up into navigation mode once it can track enough satellites. This can take from 10 seconds to 15 minutes, depending on the condition of the receiver's stored data and RF signal quality. C-MIGITS III will remain in initialization mode until it receives an initialization (message 3510) from the host vehicle.

As a minimum, C-MIGITS III requires time, position, and heading information for initialization. The GPS receiver acquisition time is directly related to the accuracy of data that is provided to C-MIGITS III, which uses the data to initialize the GPS receiver. Proper, repeatable operation of C-MIGITS III depends on reasonable input data.

C-MIGITS III is most sensitive to time initialization data (which should be within 10 minutes), followed by heading initialization data (which should be within 15 degrees). C-MIGITS III is less sensitive to position data, which should be within 100 kilometers of actual location. Once initialized, C-MIGITS III will sequence to one of three possible alignment modes: *Fine Alignment, Air Alignment*, or *Transfer Alignment*. Specification of the alignment mode is done via input message 3510 as described above.

The purpose of each alignment mode is to use a known velocity reference to perform initial estimation of vehicle attitude and of IMU error parameters (biases and scale factor errors of the gyros and accelerometers).

Fine Alignment- The default alignment mode if no mode-up sequence is specified, assumes C-MIGITS III is stationary for the purpose of estimating IMU parameters. It is thus important that the unit be kept stationary during this mode, which has a duration of two minutes. Movement during this time will result in mis-estimation of IMU parameters and erratic subsequent behavior.

Air Alignment - This mode uses GPS measurements as the velocity reference for its estimation process, and it performs estimation of the GPS antenna lever arm (i.e. the distance between the GPS antenna and C-MIGITS III) as well as of the other parameters.

It is advantageous to move C-MIGITS III during this mode. In fact, the exit criteria from air alignment mode is that the heading and the lever arms have been estimated to a particular level of precision. This generally makes it necessary to move through a trajectory with several changes of direction before this mode can be exited.

Transfer Alignment - This mode is similar to air alignment, except that the velocity reference for the alignment process consists of navigation data from a separate inertial navigation system in the host vehicle, rather than the C-MIGITS III GPS receiver.

After completing the alignment mode, sequencing continues to one of two navigation modes: *Air Navigation* or *Land Navigation*. Again, choice of sequencing is made via input message 3510. The navigation modes continue estimating attitude and IMU parameters that begun in alignment, but also estimate position and velocity errors using GPS data as a reference.

If available, measurements can be processed from a heading reference, such as a compass, or an altitude reference such as a barometric altimeter. The errors of these reference instruments may be estimated. Air navigation and land navigation modes differ only in that land navigation mode does not estimate gyro scale factor errors, but allows use of measurements from an odometer and estimation of odometer errors.

In the navigation modes, if the GPS receiver is navigating (GPS Measurements Available bit = 1 in message 3500), the navigation solution will represent a combined INS/GPS navigation solution. Once the *INS/GPS* mode is reached, C-MIGITS III can be moved, tested or flown. If GPS measurements are not available, the navigation solution represents an "INS-only" navigation solution.

The use of INS data allows C-MIGITS III to navigate through temporary GPS outages due to the effects of antenna obscuration, jamming, or loss of GPS. C-MIGITS III is not intended to be operated as an INS-only system over extended periods of time (>5 minutes). As with any unaided inertial system, if C-MIGITS III is left in an INS-only state indefinitely, navigation errors will grow unbounded. The actual performance of C-MIGITS III during INS-only operation depends on the state of the internal navigation filter when the INS-only state is entered.

Assuming that C-MIGITS III is operating properly and in a static position, the user should observe the measurement variances (message 3500) and the system velocities (message 3501) decrease during alignment. During this time, the GPS receiver should also acquire satellites and begin navigating. This can be verified by observing the signal strengths and tracking state information provided in the GPS data block (message 3).

Signal strengths (C/No density ratio) should range from the mid 30's to mid 40's on all channels. If the antenna signals are satisfactory and the initialization data provided was accurate, the GPS receiver should reach navigation mode within 2 minutes more than 95% of the time.

C/No values that are less than 30 dB indicate a problem with signal strength or noise, and will prevent the GPS receiver from acquiring satellites. Types of problems that could cause this result are the wrong type of antenna, excessive cable length, obscuration of antenna, or poor cable connection. If the signal strength measurements are too high (C/No = 46 to 52 dB), then the signal should be attenuated. Strong signal strengths confuse the GPS receiver and will result in very erratic operation.

Once C-MIGITS III is navigating, the system heading will be observed to drift when the unit remains stationary for a period of hours. This happens when the navigation filter cannot accurately estimate heading without changes in motion. The inherent accuracy of the inertial instruments do not allow for unaided heading determination.

Before You Begin

Warning

Improper wiring of the user cable connecting to C-MIGITS III can cause irreversible damage that is not covered under product warranty. Common mistakes include:

1. Incorrectly identifying pin assignments (e.g., mirror image wiring assignments), resulting in power being applied to the wrong pins.
2. Applying power with polarity reversed.

Before applying power, verify that it is being supplied to the correct pins. For customers who purchased the *optional mating connector* (with color coded wires) power connection pins are identified in the table below (pin 1 is connected to the black wire).

Signal	Pin	Color
+28 V	6	Green
+28 V	27	White with black and gray stripes
Power Return (Ground)	17	White with blue stripe
Power Return (Ground)	18	White with purple stripe

For **all** customers (with **or** without purchase of the *optional mating connector*) continue with the following as required:

1. Fabricate a cable similar in design, with those features needed, to that shown in Figure A-1. The cable's RF noise environment and shielding requirements should be taken into consideration prior to fabrication.

2. Verify cable configuration of RS-232 port is correct. Your system's transmit data line should go to the C-MIGITS III receive line and your system's receive line should go to the C-MIGITS III transmit line. (i.e. null modem connection)

For reference, Table A-1 provides the standard pin assignments for the RS-232 port typically found on an AT compatible computer. C-MIGITS III requires only use of the **Transmit** and **Receive** data signals (**TD**, **RD**) and **Signal Ground**. The control lines **DTR**, **DSR**, **DCD**, **RTS**, and **CTS** are irrelevant.

Table A-1. RS-232 Pin Assignments

Description	DTE Pin # (25-Pin)	DTE Pin # (9-Pin)	Abbreviation
Transmit Data	2	3	TD
Receive Data	3	2	RD
Data Set Ready	6	6	DSR
Data Terminal Ready	20	4	DTR
Data Carrier Detect	8	1	DCD
Ring Indicator	22	9	RI
Request to Send	4	7	RTS
Clear to Send	5	8	CTS
Signal Ground	7	5	SG
Protective Ground	1	-	FG

Note: DTE = Data Terminal Equipment (e.g. a personal computer)

3. Verify that the cable configuration of +28 Vdc main power and +5 Vdc battery input (optional) are correct.

4. Insert the available C-MIGIT III user software CD in CDROM drive, and type the following at the root directory command prompt: (It is assumed that CDROM drive is D. If CD drive is different, user can change the setupcm2.bat file to match the drive letter.)

c:\> **D:\mbb\setupcm2** <return>

A default directory called CM2 will be created, along with several subdirectories containing the supplied software, mbb_comm.exe, and various format files. The software will provide the ability to interface between C-MIGITS III and a DOS-based PC simulating the user's host vehicle communication device.

5. Using the **SET** command in MS-DOS, set the following environment variables to operate mbb_comm.exe:

TZ = PST#PDT

Note: PST and PDT are arbitrary values that are part of the time zone variable and stand for Pacific Standard Time and Pacific Daylight Time, respectively. The # is the standard time difference (+/-) from UTC. It is used by mbb_comm to change the PC's local time to UTC time for initialization. In the above example, # would be substituted with 8 for Pacific Time.

FMT = C:\CM2\FORMAT

BLOCKFMT = C:\CM2\BLOCKFMT

MIGITS = C_MIGITS_III

The above variables can be set using a batch file or automatically at startup by modifying the autoexec.bat file. In order for mbb_comm to format the screen correctly, the ANSI.SYS driver must be installed by including the following line in the CONFIG.SYS initialization file:

DEVICE=ANSI.SYS

For optimum operation of mbb_comm, it is best not to have programs running that do periodic processing based on the computer's timer interrupt. Examples of such programs are screensavers and power management programs. These programs can be disabled by modifying the CONFIG.SYS or AUTOEXEC.BAT files.

Configuring Host Vehicle Communication Port

The default I/O configuration of C-MIGITS III as delivered has input and output baud rates set to 38400 bits per second with an odd parity, 8 data bits, one start bit, and one stop bit. These parameters may be changed via message 3504 described in Chapter 6.

Verify that your PC's COM port capability is compatible with the C-MIGITS III I/O baud rate settings.

Powering Up The System

1. Before connecting the cabling and test equipment to C-MIGITS III, apply power to the test setup and verify that the correct voltages are seen at the 37-pin I/O connector. +28 Vdc should only be seen on pins 6 and 27 with respect to pins 17 and 18 (28RTN). If the optional battery input is used, voltage should be seen only on pin 31 with respect to pin 30 (DGND).

   If the above is not the case, troubleshoot the cable and test equipment to resolve the problem before continuing.

2. With power off, connect the 37-pin I/O connector to C-MIGITS III and all required cabling to the test equipment. Apply +28 Vdc to C-MIGITS III.

3. Verify that the correct amount of current is being drawn according to the specifications given by the power supply requirements.

Note: An excessive or inadequate power reading may be due to miswiring; the unit should be shut off immediately to avoid permanent damage.

---

4. From the directory c:\cm2, execute the available test software by typing mbb_comm as shown below:

c:\cm2> **mbb_comm** <return>

5. Message 3500 display should appear with a continuously updating system status display.

6. If no data appears and only parameter labels are shown, then the serial port may need to be reconfigured.

Data Display

By default, C-MIGITS III will display data messages 3500, 3501 and 3623. See Chapter 6 for description of contents. The following function keys are available and will display each of the above messages:

F1 Message ID 3500 - C-MIGITS III System Status

Displayed are the current mode (initialization, fine align, etc.), GPS and INS availability and the current number of satellites tracked. The current mode will be initialization until the unit is properly initialized as demonstrated later in this section.

F2 Message ID 3501 - C-MIGITS III Navigation Solution

Current position, velocity, and attitude are displayed.

F4 Message ID 3623 - Jupiter Timemark message

Navigation information is provided, including position, time, the satellites tracked and the carrier-to-noise ratios.

Note: Message 3623 reports the navigation solution of the GPS processor alone, while message 3501 reports the combined INS/GPS solution.

While viewing any of the data messages, pressing any key will exit the display mode to a $ prompt. At the $ prompt, type **help** to display a list of commands and other function keys that can be used in mbb_comm.exe as shown below:

$ **help** <return>

In addition to the function keys, data messages can be displayed by using the **display** command. To display message 3500, at the $ prompt type the following:

$ **display 3500** <return>

Message ID 3500 will be displayed as seen earlier. The **display** command may be abbreviated as **db.**

To exit the mbb_comm program, press the F10 function key or type **quit** at the $ prompt.

System Initialization

The system initialization is accomplished by transmitting message 3510, C-MIGITS III Control and Initialization. A detailed description of message 3510 can be found in Chapter 6. Using mbb_comm, at the $ prompt, type the following to initialize C-MIGITS III:

$ **send init new** <return>

The system will respond by asking a series of questions regarding the unit's initial conditions as shown below. Answer each question as indicated. The latitude and longitude data is shown as an example only and actual position data should be entered for proper initialization of C-MIGITS III.

```
COMMANDED MODE
  Enter desired Operating Mode (AUTOMATIC, BIT, INIT, FINEALIGN,
  AIRALIGN, TRANSALIGN, AIRNAV, LANDNAV, GPSONLY) or X to skip:
  automatic <return>

POSITION
  Enter Latitude in dd:mm:ss or X to skip:  33:51:24 <return>
  Enter Longitude in ddd:mm:ss:  -117:50:51  <return>
  Enter WGS-84 altitude in meters:  42  <return>

VELOCITY
  Enter ground speed in meters/sec or X to skip:  0  <return>
  Enter ground track (0-360 compass heading) in degrees:  0  <return>

DATE/TIME
  Enter current year, AUTO for PC's time and date, or X to skip:  auto  <return>

HEADING
  Enter True Heading (0.00 - 360.00 degrees) or X to skip:  0  <return>

ALIGN/NAV SEQUENCING
  Enter Align Mode (FINEALIGN, AIRALIGN, TRANSALIGN) or X to skip:
finealign  <return>
  Enter Nav Mode (AIRNAV, LANDNAV) or X to skip:  airnav  <return>

AUTO-GPS-INIT
  Enter 1 to allow initialization from GPS, 0 to disallow:  0  <return>
```

The receiver control and initialization message 3510 will be sent to C-MIGITS III, and the $ prompt will appear, indicating that initialization is complete. If an error message occurs, verify that the information was entered correctly, then initialize once again.

The initialization information can also be entered by creating an input command file, which automatically sequences through the list of initialization conditions with the preselected responses. The file (*filename*.cmd) can then be executed by using the **run** command at the $ prompt. Each response must be sequenced exactly to correspond with the questions asked during the "send init new" process. A sample file created in MS-DOS is shown below:

`send init new`	
`automatic`	***Operating Mode***
`33:51:24`	***Latitude (deg-min-sec)***
`-117:50:51`	***Longitude (deg-min-sec)***
`42`	***Altitude (meters)***
`0`	***Ground Speed (meters/second)***
`0`	***Ground Track (deg)***
`auto`	***Time (PC time)***
`0`	***True Heading (deg)***
`finealign`	***Align Mode***
`airnav`	***Nav Mode***
`0`	***Auto GPS Initialization***
`quit`	***Return to mbb_comm***

Type the following to execute the integration command file:

$ **run *filename*.cmd** <return>

In the above example, time could be entered manually by specifying the year, then the day (1-366) and then UTC time (hh:mm:ss).

Note: The "auto" response to the DATE/TIME inquiry relies on the PC clock being set correctly, and on the TZ environment variable being set to enable conversion of local time to UTC time.

In some responses, “X” can be used, which sets the initialization parameter to a default value. For latitude, longitude, and altitude, C-MIGITS III will default to the position saved in EEPROM if one exists, and if not, to Anaheim, CA. Ground speed, ground track, and true heading will default to zero. Align mode will default to fine alignment, which will be followed by air navigation mode.

A restricted version of the 3510 message, containing just a mode command, may be sent by using the *mbb_comm* command:

$**send control** mode-name <return>

where the mode-name may be any of: test, init, finealign, airalign, transalign, airnav, landnav, or gpsonly. This will cause C-MIGITS III to sequence to the commanded mode, if necessary through intervening modes. One use of this command is to send the C-MIGITS III back to initialization mode after it is in an alignment or navigation mode. Another use is to force C-MIGITS III to remain in a particular mode. For instance, if the system is commanded to Fine Alignment mode from Initialization, it will remain in Fine Alignment until commanded out, possibly beyond the default two minutes.

Message Connection and Disconnection

Host vehicle messages may be connected and disconnected by using the **connect** and **disconnect** commands as shown below:

$**connect 3502 3512** <return>

$**disconnect 3623** <return>

The first command connects messages 3502 and 3512, and the second command disconnects message **3623**. Connecting an already connected message, or disconnecting an already disconnected message, has no effect. Up to seven message numbers may be specified with either command. The **connect** command may be abbreviated as **c**, and the **disconnect** command may be abbreviated as **d**.

Sending Other Commands

Other commands to the system may be issued using the *mbb_comm* command **send file**, which may be abbreviated as **sf**. The syntax for this command is:

$**send file** filename.hex message-number flags-word <return>

By convention, the files which are used with the **send file** command have a DOS filename extension of ".hex", and in the default installation of *mbb_comm* software, they reside in the directory c:\cm2\hex. The message-number parameter of the **send file** command is simply the decimal number of the message to be sent to the C-MIGITS III, generally either 3504, 3510, or 3511. The flags-word parameter is a hexadecimal value to put in the flags word (word 4) of the transmitted message. Generally, this value will be either 8000 (if an acknowledgment is not desired), or 9000 (if n acknowledgment is desired). The hex files are ASCII files containing the successive words of the data portion of the message as four-nibble hexadecimal numbers. The last two parameters of the **send file** command, along with the word count obtained from the number of words in the hex file, give *mbb_comm* enough information to fill in the header of the transmitted message.

The functions of the various hex files which are distributed with the *mbb_comm* software are summarized below.

1. Baud Rate - The following hex files may be sent via the **send file** command with a message-number of 3504 to set the C-MIGITS III HV interface to the indicated baud rates:

Hex File	Baud Rate	Baud Divisor
1152kb.hex	115200 baud	1
576kb.hex	57600 baud	2
384kb.hex	38400 baud	3
192kb.hex	19200 baud	6
9600.hex	9600 baud	12

After transmission of any of these commands, the baud rate at which *mbb_comm* is operating needs to be changed in order to communicate at the new baud rate. This may be done by the *mbb_comm* command:

$**com** port-number baud-divisor <return>

where port-number is the number of the PC COM port, and baud-divisor is a number determining the new baud rate, which is obtained from the table above.

2. Message Rates - Host vehicle output messages 3501, 3502, and 3512 have selectable output rates which may set using the following hex files with a message-number of 3504:

Hex File	Action
Slow3501.hex	Block 3501 @ 1 Hz
med3501.hex	Block 3501 @ 10 Hz
Slow3502.hex	Block 3502 @ 1 Hz
med3502.hex	Block 3502 @ 10 Hz
fast3502.hex	Block 3502 @ 100 Hz
Slow3512.hex	Block 3512 @ 1 Hz
med3512.hex	Block 3512 @ 10 Hz
fast3512.hex	Block 3512 @ 100 Hz

Care should be taken, especially when using the 100-Hz transmissions, that the requested message rates do not exceed the communication channel bandwidth at the current baud rate.

3. Flight Control Message Configuration - The data contained in the flight control message 3512 may be configured using the following hex files with a message-number of 3504:

Hex File	Message 3512 Data
3512_1.hex	Delta-attitude
3512_2.hex	Delta-velocity
3512_3.hex	Delta-attitude and Delta-velocity
3512_7.hex	Delta-attitude, Delta-velocity, and Attitude
3512_f.hex	Delta-attitude, Delta-velocity, Attitude, and Velocity

The other ten possible configurations of the 3512 message may be selected by appropriate modifications to the hex files.

4. Save Configuration Command - The Save Configuration command is used to save a number of system parameters to EEPROM so that the parameters will be initialized to the saved values at subsequent turn-ons. The parameters saved are summarized in Chapter 8. The current set of parameters may be saved by issuing the command:

$**send file** saveeep.hex 3504 9000 <return>

The parameters may be erased by the command:

$**send file** eraseeep.hex 3504 9000 <return>

After either of these commands, the C-MIGITS III program will reboot from a cold start.

5. Message Passthrough Translation - The state of the program flag which determines whether GPS passthrough messages are translated to C-MIGITS III format may be set by the following commands:

$**send file** passtran.hex 3504 9000 <return>

turns passthrough translation on, and

$**send file** notran.hex 3504 9000 <return>

turns it off.

6. Body Frame Orientation - The sensor-to-body coordinate transformation may be changed by message 3511, to whatever orientation is desired. One commonly used transformation is to turn the default transformation "upside down" to accommodate the situation where C-MIGITS III is oriented with the sensor Z axis pointing up (i.e. the plug is facing up). In this orientation, the default coordinate transformation yields a roll value of about 180 degrees. A reorientation of the body axes to yield a roll value of approximately 0 may be accomplished by the command:

$**send file** upside.hex 3511 9000 <return>

7. Lever Arm Specification - The body-frame components of the lever arm from C-MIGITS III to the GPS antenna may also be set using message 3511. Knowledge of the lever arm is important in accounting for the offset and the motion of the antenna relative to the C-MIGITS III. The C-MIGITS III mechanization assumes that the GPS antenna is rigidly attached to C-MIGITS III and rotates with it. If this is not the case (e.g. if a rooftop antenna is being used), it is best to leave the lever arm components at their default value of zero. A sample lever arm specification file [specifying body-frame components of (X,Y,Z) = (100, 49, -84)] is included in the hex directory. It would be invoked by the command:

$**send file** levarm.hex 3511 9000 <return>

8. Auto-initialization from GPS - The ability of the C-MIGITS III to automatically initialize its position and velocity from GPS, which is disabled by default, can be enabled by the command:

$**send file** gpsinit.hex 3510 9000 <return>

See Chapter 8, Frequently Asked Questions, for an explanation of the way in which this capability should be used in system initialization.

9. INS-Only Operation - The C-MIGITS III can be commanded into an "INS-Only" mode in which GPS measurements are not processed even though they may be available from the GPS receiver. This may be useful in assessing the performance of the C-MIGITS III when the GPS signal is lost. This option is more convenient than the alternative of disconnecting the GPS antenna, since the GPS receiver continues to track satellites. This mode is entered by the command:

$**send file** insonly.hex 3510 9000 <return>

and exited by the command:

$**send file** ninsonly.hex 3510 9000 <return>

Program Loading

C-MIGITS III software provides the capability to load upgrades to itself through the HV serial port. Program upgrades are provided as MS-DOS files with a DOS filename extension of ".out". The base name of the file is a date code in the format yymmdd, so a valid program name might be *970220.out*. Program files are loaded through the serial port by an *mbb_comm* command of the form:

$**send prog** 970220.out <return>

During the program loading, mbb_comm will print out a list of the program blocks being loaded. At completion of the program load, the new program will be booted from a cold start.

Using IMU Synchronous Serial Data

IMU data is output as an AMRAAM-formatted serial bus, consisting of autopilot data and inertial data. The autopilot data is output at 600 Hz, providing angular rate and linear acceleration. The inertial data is output at 100 Hz, providing delta velocity and delta attitude information.

The AMRAAM data consists of three RS-422 differential signal output pairs: *serial data out*, *data shift clock*, and *data sync pulse*. Refer to the *IMU Serial Interface* section in Chapter 5 for more detail.

Glossary of Terms

Abbreviations and Acronyms

The following is a list of abbreviations and acronyms used in this guide and their definitions.

$\Delta\theta$
: *Attitude change*

Δv
: *Velocity change*

2-D
: *Two Dimensional*

2-Drms
: *Two-Dimensional root mean square*

3-D
: *Three Dimensional*

3-Drms
: *Three-Dimensional root mean square*

AAMP
: *Advanced Architecture Microprocessor*

AMRAAM
: *Advanced Medium Range Air-to-Air Missile*

A/D
: *Analog-to-Digital*

AFSC
: *Air Force System Command*

AP
: *Application Processor*

AS
: *Anti-Spoofing*

ASIC
: *Application Specific Integrated Circuit*

AWGN
: *Additive White Gaussian Noise*

B
: *Boolean*

BIT
: *Built-In-Test*

bps
: *Bits Per Second*

cg
: *Center of Gravity*

C
: *Celsius*

C/A
: *Coarse/Acquisition*

C-MIGITS III
: *C/A-code Miniature Integrated GPS/INS Tactical System (Digital Quartz Inertial Measurement Unit coupled with a 5-channel C/A code GPS receiver)*

C/No
: *Carrier-to-Noise density ratio*

COMSEC
: *Communications Security*

cw
: *Continuous Wave*

dBm
: *Decibels Milliwatt (measure of power relative to one milliwatt)*

dBW
: *Decibel-Watt (measure of power relative to one watt)*

DC
: *Direct Current*

deg
: *Degrees*

DETF
: *Double Ended Tuning Fork*

DI
: *Double precision Integer*

DIG
: *Digital*

DoD
: *Department of Defense*

DOP
: *Dilution of Precision*

DQI
: *Digital Quartz Inertial Measurement Unit (Systron Donner Inertial trade name)*

DSP
: *Digital Signal Processor*

DTR
: *Data Terminal Ready*

EEPROM
: *Electrically Erasable Programmable Read Only Memory*

EFP
: *Extended Floating Point*

EMC
: *Electromagnetic Compatibility*

EMI
: *Electromagnetic Interference*

EPROM
: *Erasable Programmable Read Only Memory*

EU
: *Electronics Unit*

FFC

Flex Cable

FP

Floating Point

g

Gravity

GaAs

Gallium Arsenide

GDOP

Geometric Dilution of Precision

GHz.

Gigahertz (10^9)

GMT

Greenwich Mean Time

GN&C

Guidance, Navigation and Control

GND

Ground

GPS

Global Positioning System

GPSRE

GPS Receiver Engine

Grms

G's root mean squared

HDOP

Horizontal Dilution of Precision

HVIO

Host Vehicle Input/Output

Hz

Hertz

ICD

Interface Control Document

I

Integer

I/O

Input/Output

IF

Intermediate Frequency

IMU

Inertial Measurement Unit

INIT

Initialization (mode)

INS

Inertial Navigation System

IODE

Issue of Data Ephemeris

ISA

Inertial Sensor Assembly

kbaud

Kilobaud (10^3)

kHz

KiloHertz (10^3)

km

Kilometer

kohms

Kilohms

LD/LR

Line Driver/Line Receiver

LPTS

Low Power Time Source

LRU

Lowest Replaceable Unit, Line Replaceable Unit

LSB

Least Significant Bit

mA

Milliamp (10^{-3})

MFI

Multi-Function Interface

MHz

Megahertz

MR

Master Reset

mrad

Milliradian (10^{-3})

MSB

Most Significant Bit

ms

Millisecond (10^{-3})

m/sec

Meters per Second (units of velocity)

m/sec/sec

Meters per Second per Second (units of acceleration)

m/sec/sec/sec

Meters per Second per Second per Second (units of impulse or "jerk")

MSL

Mean Sea Level

MTBF

Mean Time Between Failure

MTTR

Mean Time to Repair

MUX

Multiplex (bus)

mV

Millivolt

mW

Milliwatt

nS

Nanoseconds

NAV

Navigation

NAVSTAR

Navigation Satellite Timing and Ranging

NF

Noise Factor

NMEA

National Marine Electronics Association

NSA

National Security Agency

nsec

Nanosecond (10^{-9})

OEM

Original Equipment Manufacturer

ρ

Pseudo-range

P/N

Part Number

PDOP

Position Dilution of Precision

PSD

Power Spectral Density

P-P

Peak-to-Peak

ppm

Parts Per Million

PPS

Precise Positioning Service; also, Pulse-Per-Second

PPS-SM

Precise Position Service Security Module

PRN

Pseudorandom Number

PSF

Post Select Filter

psia

Pounds Per Square Inch Absolute

PVT

Position, Velocity, and Time

PWB

Printed Wiring Board

QFS

Quartz Flexure Suspension

QRS

Quartz Rate Sensor

RAM

Random Access Memory

RF

Radio Frequency

RFI

Radio Frequency Interference

rms

Root Mean Squared

ROM

Read Only Memory

RSS

Root Sum of Squares

RTCA

Radio Technical Commission for Aeronautics

rt-hr

Root-Hour

RT

Remote Terminal

RTC

Real-Time Clock

RTN

Return

RTV

Room Temperature Vulcanizing

SA

Selective Availability

SA/AS

Selective Availability, Anti-Spoofing

sec

Seconds

SEP

Spherical Error Probable

SNR

Signal-To-Noise ratio (expressed in decibels).

SPS

Standard Positioning Service

SRAM

Static Random Access Memory

SRU

Shop Replaceable Unit

SV

Space Vehicle

TDOP

Time Dilution of Precision

TSP

Twisted Shielded Pair

TTFF

Time to First Fix

TTL

Transistor -Transistor Logic

TWINAX

Two conductor coaxial cable

TwPr

Twisted Pair

UART

Universal Asynchronous Receiver /Transmitter

μsec

Microsecond (10^{-6})

UBER
: *Undetected Bit Error Rate*

UDRE
: *User Differential Range Error*

URA
: *User Range Accuracy*

UTC
: *Universal Coordinated Time*

VCO
: *Voltage Controlled Oscillator*

Vdc
: *Volts Direct Current*

VDOP
: *Vertical Dilution of Precision*

VQA
: *Vibrating Quartz Accelerometer*

VSWR
: *Voltage Standing Wave Ratio*

ZIF
: *Zero Insertion Force*

Terms

The following is a list of selected terms used in this document, together with their associated meaning.

Algorithm

A set of rules for finding a solution to a problem in a finite number of steps.

Almanac

A set of orbital parameters that allows calculation of approximate GPS satellite positions and velocities. The almanac is used by a GPS receiver to determine satellite visibility and as an aid during acquisition of GPS satellite signals. The almanac is a subset of satellite ephemeris data and is updated weekly by GPS Control.

Analog Sinusoidal

A curve having ordinates proportional to the sine (or cosine) of an angle that is a linear function of time, distance, or both.

Application Processor

The processor connected to the Host Vehicle receiver port which controls C-MIGITS III with command messages and uses data from output messages.

Attenuation

The decrease in amplitude of a signal during its transmission from one point to another. It may be expressed as a ratio, or, by extension of the term, in decibels.

Attitude

A ship, aircraft, or other vehicle's state in terms of pitch, roll and heading.

Baud

bits per second (also referred to as baud rate)

Block I Satellite

Satellites designed and built to support GPS development and testing. A total of 10 Block I satellites were successfully launched between February 1978 and October 1989.

Block II Satellite

Satellites designed and built to support GPS Space Segment operation. A total of 28 Block II satellites have been built and launched.

Block IIR Satellite

Satellites being designed to eventually replace Block II satellites. The first Block IIR satellite was launched in 1997.

Coarse/Acquisition Code

A spread spectrum direct sequence code that is used primarily by commercial GPS receivers to determine the range to the transmitting GPS satellite.

Circular Error Probable

The radius of a circle, centered at the user's true location, that contains 50 percent of the individual position measurements made using a particular navigation system.

Clock Error

The uncompensated difference between synchronous GPS system time and time best known within the GPS receiver.

Cold Start

A condition in which the GPS receiver can arrive at a navigation solution without initial position, time, current ephemeris, and almanac data.

Control Segment

The Master Control Station and the globally dispersed Monitor Stations used to manage the GPS satellites, determine their precise orbital parameters, and synchronize their clocks.

Coriolis Force

An apparent force that as a result of the earth's rotation deflects moving objects (such as missiles) to the right in the northern hemisphere and to the left in the southern hemisphere.

Decibel-Isometric-Circular

Measure of power relative to an isometric antenna with circular polarization.

Dielectric

The insulating (non-conducting) medium between the two plates of a capacitor. Typical dielectrics include air, plastic, mica, and ceramic. A vacuum is the only perfect dielectric.

Doppler Aiding

A signal processing strategy, which uses a measured Doppler shift to help a receiver smoothly track the GPS signal to allow a more precise velocity and position measurement.

Doppler Effect

The observed change of frequency of a wave caused by a time rate of change of the effective distance traveled by the wave between the source and the point of observation.

Doppler Shift

The change observed in the frequency of a wave due to the Doppler effect.

Drift Angle

The angle measured in the horizontal plane between the horizontal velocity projection and the horizontal projection of the vehicle's longitudinal axis. In an example of an aircraft, the drift angle is generated from cross-winds, causing the aircraft to point into the direction of the relative wind, rather than along the ground-referenced velocity direction.

Earth-Centered Earth-Fixed

A Cartesian coordinate system with its origin located at the center of the Earth. The coordinate system used by C-MIGITS III to describe three-dimensional location. For the WGS-84 reference ellipsoid, ECEF coordinates *have the Z-axis aligned with the Earth's spin axis, the X-axis through the intersection of the Prime Meridian and the Equator and the Y -axis is rotated 90 degrees East of the X-axis about the Z-axis.*

Ephemeris

A set of satellite orbital parameters that is used by a GPS receiver to calculate precise GPS satellite positions and velocities. The ephemeris is used to determine the navigation solution and is updated frequently to maintain the accuracy of GPS receivers.

Federal Radio Navigation Plan

The U.S. Government document which contains the official policy on the commercial use of GPS.

Geometric Dilution of Precision

A factor used to describe the effect of the satellite geometry on the position and time accuracy of the C-MIGITS III solution. The lower the value of the GDOP parameter, the less the error in the position solution. Related indicators include PDOP, HDOP, TDOP, and VDOP.

Global Positioning System

A space-based radio positioning system which provides suitably equipped users with accurate position, velocity, and time data. When fully operational, GPS will provide this data free of direct user charge worldwide, continuously, and under all weather conditions. The GPS constellation will consist of 24 orbiting satellites, four equally spaced around each of six different orbital planes.

GPS Time

The number of seconds since Saturday/Sunday Midnight UTC, with time zero being this midnight. Used with GPS Week to determine a specific point in GPS time.

GPS Week

The number of weeks since January 6, 1980, with week zero being the week of January 6, 1980. Used with GPS Time to determine a specific point in GPS time.

Gradient

Change in the value of a quantity (for example, Gravity) with respect to the change in a given variable (for example, Position).

Horizontal Dilution of Precision

A measure of how much the geometry of the satellites affects the position estimate (computed from the satellite range measurements) in the horizontal (East, North) plane.

Interface

The physical terminating points of a data link.

Kalman Filter

Sequential estimation filter which combines measurements of satellite range and range rate to determine the position, velocity, and time at the GPS receiver antenna.

Ll Band

The 1575.42 MHz GPS carrier frequency which contains the C/A code, P-code, and navigation messages used by commercial GPS receivers.

L2 Band

A secondary GPS carrier, containing only P-code, used primarily to calculate signal delays caused by the atmosphere. The L2 frequency is 1227.60 MHz.

Mask Angle

The minimum GPS satellite elevation angle permitted by a particular GPS receiver design.

Measurement Error Variance

The square of the standard deviation of a measurement quantity. The standard deviation is representative of the error typically expected in a measured value of that quantity.

Multipath Errors

GPS positioning errors caused by the interaction of the GPS satellite signal and its reflections.

Obscuration

Term used to describe periods of time when a GPS receiver's line-of-sight to GPS satellites is blocked by natural or man-made objects.

Overdetermined Solution

The solution of a system of equations containing more equations than unknowns. The GPS receiver computes, when possible, an overdetermined solution using the measurements from five GPS satellites, instead of the four necessary for a three-dimensional position solution.

Piezoelectric

A property of crystals which produce a voltage when subject to a mechanical stress, or undergo mechanical stress when subjected to a voltage

Port

Access point for data input or output.

Precision Code

A spread spectrum direct sequence code that is used primarily by military GPS receivers to determine the range to the transmitting GPS satellite.

Parallel Receiver

A receiver that monitors four or more satellites simultaneously.

Position Dilution of Precision

A measure of how much the error in the position estimate produced from satellite range measurements is amplified by a poor arrangement of the satellites with respect to the receiver antenna.

Pi (or π)

The mathematical constant having a value of approximately 3.14159.

Precise Positioning Service

The GPS positioning, velocity, and time service which will be available on a continuous, worldwide basis to users authorized by the DoD.

Pseudorandom Number

The identity of the GPS satellites as determined by a GPS receiver. Since all GPS satellites must transmit on the same frequency, they are distinguished by their pseudorandom noise codes.

Q Factor

A measure of sharpness of resonance or frequency selectivity of a mechanical or electrical system.

Radome

Also called a radar dome. The housing that protects a radar antenna from the elements, but does not block radio frequencies.

Real Time

Refers to Greenwich Mean Time.

Selective Availability

The method used by the DoD to control access to the full accuracy achievable with the C/A code.

Satellite Elevation

The angle of the satellite above the horizon.

Sequential Receiver

A GPS receiver in which the number of satellite signals to be tracked exceeds the number of available hardware channels. Sequential receivers periodically reassign hardware channels to particular satellite signals in a predetermined sequence.

Spherical Error Probable

The radius of a sphere, centered at the user's true location, that contains 50 percent of the individual three-dimensional position measurements made using a particular navigation system.

Standard Positioning Service

A positioning service available to all GPS users on a continuous, worldwide basis with no direct charge. SPS uses the C/A code to provide a minimum dynamic and static positioning capability.

Standby SRAM

Portion of the SRAM that is powered by a "keep-alive" power supply when prime power is removed to preserve important data and allow faster entry into the Navigation Mode when prime power is restored. All of the SRAM in the receiver is "keep-alive" SRAM.

Strapdown Inertial Navigation System

A system in which the accelerometers are directly connected to the vehicle's frame (in the example of an aircraft, the airframe). The accelerometers measure the components of vehicle-specific force acceleration in the body's (in this example, the airframe's) axes.

Time Dilution of Precision

A measure of how much the geometry of the satellites affects the time estimate computed from the satellite range measurements.

Three-Dimensional Coverage (Hours)

The number of hours-per-day with four or more satellites visible. Four visible satellites are required to determine location and altitude.

Three-Dimensional (3-D) Navigation

Navigation mode in which altitude and horizontal position are determined from satellite range measurements.

Time Mark Message

Output message of the receiver that provides the current estimate of position, velocity, and time as well as other data related to the state of the receiver.

Time Mark Pulse

A positive going pulse output by the receiver at the instant to which the next solution output will be referenced. The position, velocity, and time values in the next message were the estimated values at the rising edge of the pulse.

Time-To-First-Fix.

The actual time required by a GPS receiver to achieve a position solution. This specification will vary with the operating state of the receiver, the length of time since the last position fix, the location of the last fix, and the specific receiver design.

User Differential Range Error

A measure of error in range measurement to each satellite as seen by the receiver.

Update Rate

The GPS receiver specification which indicates the solution rate provided by the receiver when operating normally.

Universal Coordinated Time

This time system uses the second defined true angular rotation of the Earth measured as if the Earth rotated about its Conventional Terrestrial Pole. However, UTC is adjusted only in increments of one second. The time zone of UTC is that of Greenwich Mean Time (GMT).

Velocity

A vector quantity indicating both direction of motion and magnitude of speed.

Vertical Dilution of Precision

A measure of how much the geometry of the satellites affects the position estimate (computed from the satellite range measurements) in the vertical (perpendicular to the plane of the user) direction.

WGS-84

World Geodetic System (1984). A mathematical ellipsoid designed to fit the shape of the entire Earth. It is often used as a reference on a worldwide basis, while other ellipsoids are used locally to provide a better fit to the Earth in a local region. GPS uses the center of the WGS-84 ellipsoid as the center of the GPS ECEF reference frame.

This page left intentionally blank.

Notes

Notes

Notes

Notes

Notes

Notes

Index

D

E

J

K

L

M

S

T

U

V

W

Z