# MIDG II DISPLAY AND CONFIGURATION PROGRAM

MIDG II
Inertial Navigation System
with GPS Aiding

June 12, 2007

MICROBOTICS, INC.

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# CONTENTS

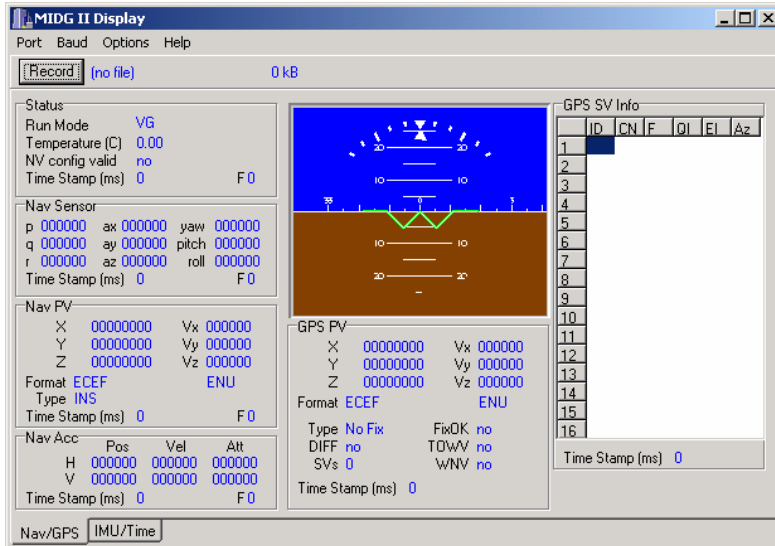# Chapter 1.  Introduction

## 1.1    Overview

The MIDG II is provided with the MIDG II Display and Configuration Program which facilitates immediate access to the MIDG II data for evaluation and testing without requiring the user to write software.  All MIDG II messages and configuration options are supported by the program.



## 1.2    System Requirements

To use the MIDG II Display and Configuration Program, the following are needed:
- A MIDG II
- A PC running Microsoft Windows (98 SE, 2000, and XP are supported).
- A cable with appropriate connectors and an RS-422 to RS-232 Converter (such as the Microbotics' SLC22232), to connect the MIDG II to the PC.
- A power supply providing 9 VDC to 36 VDC and minimum 2 Watts output.
- A GPS antenna with SMA connector. If an active antenna is used, it must be capable of operating at 5 VDC. The GPS antenna may be omitted for limited testing.

## 1.3    Getting Started

The MIDG II is shipped with a CD and a connector cable assembly. The CD contains documentation, the Display and Configuration Program, implementation code samples in "C", and MIDG II data parsing programs.

## 1.4    Software Installation

The Display and Configuration Program must be installed on the PC's hard drive.  Locate MIIDisplay_v2_0_4.exe on the accompanying CD and execute it.  Then, follow the instructions provided by the installation program.

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## 1.5    Connecting the MIDG II to the PC

The MIDG II uses RS-422 for communication due to its robustness in industrial environments.  Connection to a standard PC requires a serial converter that translates the RS-422 signals into RS-232 signals that are common for PC serial ports.  Typical connection to a PC is shown in the figure below.  A GPS Antenna is optional for evaluation, but is recommended.  Using the MIDG II without GPS will result in reduced accuracy and lack of

position and velocity information.  If an active antenna is used, it must be compatible with the 5 VDC that the MIDG II provides at the antenna connector.  Note that, in the figure, each transmit and receive identifier indicates the direction from the local pin.  For example, the PCs Tx pin (pin 3 on 9 pin connector) would send data to the Rx pin on the serial converter.  The PCs Rx pin (pin 2 on a 9 pin connector).  Ground is pin 5 on the 9 pin PC connector.  Also, note that RS-422 uses a differential pair to transmit and send data.  The 'a' and 'b' suffixed refer to the negative (inverted) and positive (non-inverted) signals, respectively.
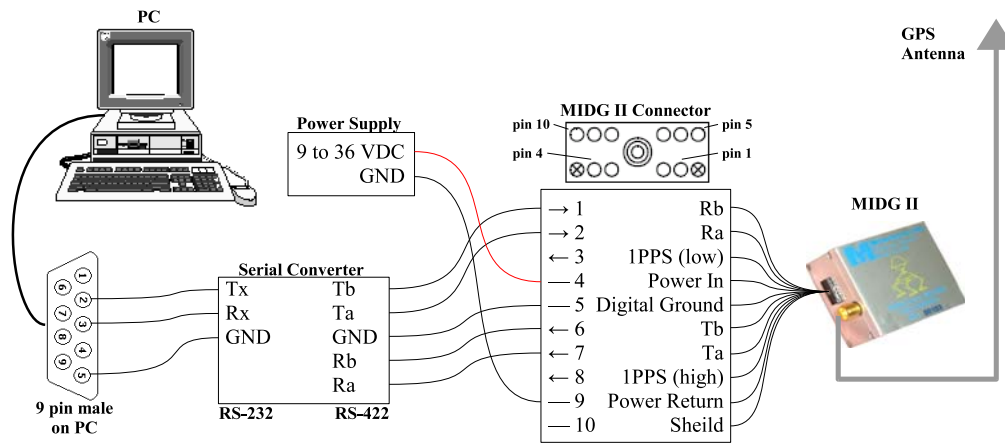


**Typical Connection to a PC**

**ALERT regarding antenna connection**

**5 VDC power for active antennas is supplied via the MIDG II GPS SMA connector.  The GPS antenna must never be connected or disconnected while the MIDG II is powered.  Connecting or disconnecting the GPS antenna with power applied to the MIDG II may damage the GPS receiver, and will void the MIDG II warranty.**

## 1.6    Starting the MIDG II

With the MIDG II Display and Configuration Program running and the MIDG II connected to the PC as outlined in the previous section, select the appropriate port and baud rate (default is 115200) from the program menus.  At this point, the program is ready to receive data from the MIDG II.  Turn on the power supply to start the MIDG II.  If the power supply is equipped with a current meter, monitor the current draw  to make sure that it is appropriate for the connected devices.  The MIDG II will nominally draw about 1 Watt (e.g., 83mA at 12VDC).  If the current draw is too high, turn off the power supply and check for shorts or wrong connections in the wiring.  If everything is wired correctly, the displayed fields will begin to update with data from the MIDG II.

# Chapter 2.  MIDG II Display

## 2.1    Establishing Communications with MIDG II

Once the Display Utility is running, the Baud rate and PC communications port must be set.
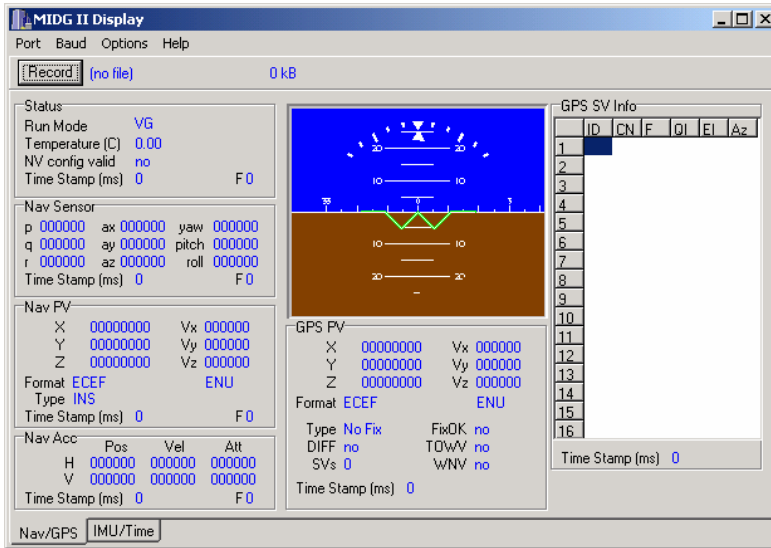


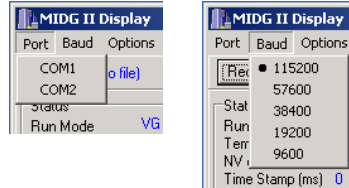Click on the **Baud** menu button at the top of the screen, and select the correct baud rate for your computer connection.  The default MIDG II baud rate is 115200.

Click on the **Port** menu button at the top of the screen and choose the communications port to which the MIDG II is connected.  If the MIDG II is powered, data will begin to update the fields on the screen.



## 2.2    Nav/GPS Display Windows

The initial MIDG II Display and Configuration Program screen is the Nav/GPS screen, which is divided into seven areas, consisting of an Artificial Horizon and six Message Windows.  Each message window corresponds to a message from the MIDG II as defined in the MIDG II Message Specification document.  Values displayed in the message windows may have different scaling than what is presented in the message specification.  Displayed values are intended to have representation that is familiar to the user where the values in the messages are intended to have simple representation from a software integration standpoint.  For example, on the display, the attitude angles (yaw, pitch, and roll) are displayed in degrees, but in the NAV_SENSOR message, they are sent in units of hundredths of degrees.  These discrepancies between the display of data in its representation in the Message Specification document will be noted wherever they occur.

Many of the message windows have a parameter 'F' followed by a value.  These are the message flags.  The value is a hexadecimal representation of the flag information of the message.  In some cases, the flag data is also represented in more explicit forms.  For example, the NAV_PV message flag value indicates the position format and type of position fix.  Those items are repeated in text form for convenience.

Every MIDG II data message has a timestamp that indicates the time at which the data sample was initiated.  This time value initially represents the time in milliseconds from power-on.  When GPS becomes available, the time

value indicates the GPS time in milliseconds. Whether the timestamp is startup time or GPS time is indicated by the message flag value.
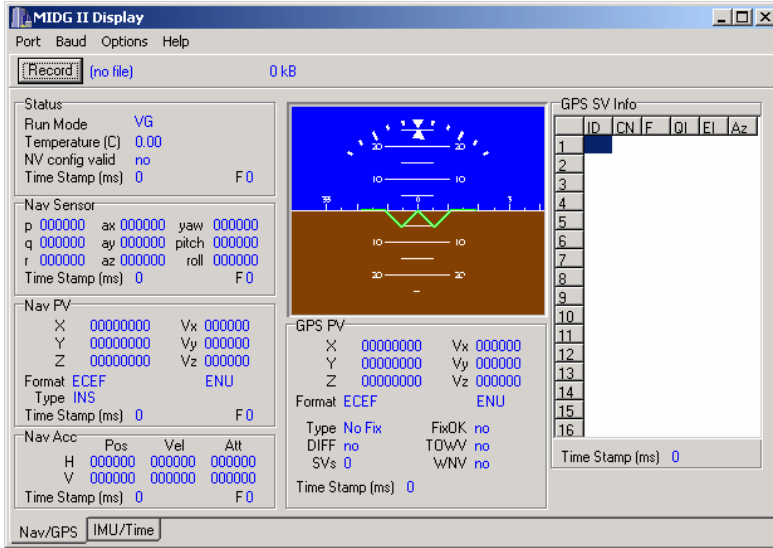


MIDG II messages are presented at up to 50Hz. Also, they may be disabled. Disabled message may be queried. In the MIDG II Display And Configuration program, messages are queried by double-clicking in the corresponding message window. By default, all of the messages on the Nav/GPS screen are enabled and the messages on the IMU/Time screen are disabled. These defaults may be changed by user configuration.

### 2.2.1    Artificial Horizon

The Artificial Horizon is a pictorial representation of the attitude of the MIDG II. It displays:

- **Pitch**: The area of "Sky" (blue) will increase if the MIDG is aimed up, while the "Ground" (brown) area will increase if the MIDG is aimed down.
- **Roll** is shown on the curved scale at the top of the display window, in 10° increments.
- **Yaw** is listed on the horizon. Note that each large tick represents a 10° increment; thus, "12" equals 120°.

The data that drives the artificial horizon is taken from the NAV_SENSOR message.
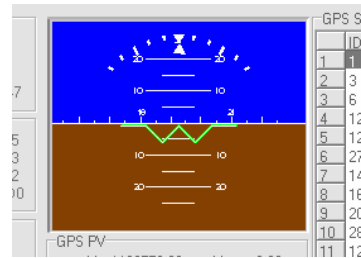


### 2.2.2    Status Window

This window displays data from the STATUS message, including the current mode of operation, internal temperature in °C, and whether or not there is valid user configuration data stored in non-volatile memory.
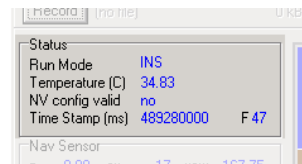


### 2.2.3    Navigation Sensor Data (Nav Sensor) Window

This windows displays data from the NAV_SENSOR message. The angular rates p, q, and r are displayed in degrees per second. The accelerations ax, ay, and az are displayed in milli-g. The attitude angles are displayed in degrees.
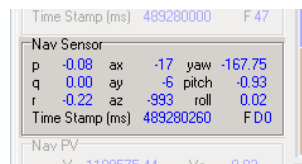
### 2.2.4 Navigation Position and Velocity (Nav PV) Window

This window displays data from the NAV_PV message, namely the estimated position and velocity of the MIDG II.  Position is displayed in met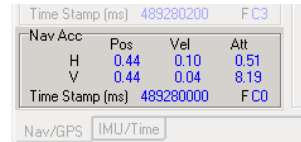ers (ECEF or ENU coordinates) or degrees (LLA coordinates) and velocity in meters per second.  Based on the current configuration settings, position may be presented in ECEF coordinates, ENU coordinates, or LLA.  Velocity may be presented in either ECEF or ENU coordinates.  The current coordinate system in use is displayed below the position and velocity values.  This data will either be the best current estimate derived from the INS solution or a direct copy of the GPS receiver data.  The type of sample, either INS or GPS, is displayed along with the data.

### 2.2.5 Navigation Accuracy Estimate (Nav Acc) Window

This window displays data from the NAV_ACC message.  It shows the estimated accuracy for position, velocity, and attitude in both horizontal and vertical directions.     All of the accuracy values represent the estimated standard deviation of error of the associated parameter(s).  Position accuracy is presented in meters.  Velocity accuracy is presented in meters per second.  Attitude accuracy is presented in degrees.  Horizontal attitude accuracy indicates the probable tilt error of the solution.  Vertical attitude accuracy indicates the probable heading error of the solution.

### 2.2.6 GPS Position and Velocity Solution (GPS PV) Window

This window displays data from the GPS_PV message.  This is data directly from the GPS receiver.  It includes position, velocity, and relevant solution information.  The position and velocity are displayed just as they are for the NAV_PV message.  Position is displayed in meters (ECEF or ENU coordinates) or degrees (LLA coordinates) and velocity in meters per second.  Based on the current configuration settings, position may be presented in ECEF coordinates, ENU coordinates, or LLA.  Velocity may be presented in either ECEF or ENU coordinates.  The current coordinate system in use is displayed below the position and velocity values.
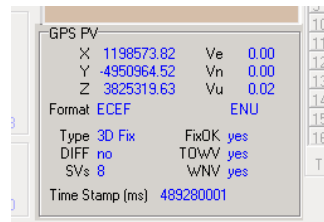
In addition to position and velocity, the GPS_PV message provides information regarding the details of the GPS fix.  This includes the type of fix, whether the fix uses differential corrections, how man SVs (satellite vehicles) were used to generate the fix, and whether the fix, time of week, and week number are valid.

### 2.2.7 GPS Satellite Vehicle Information (GPS SV Info) Window
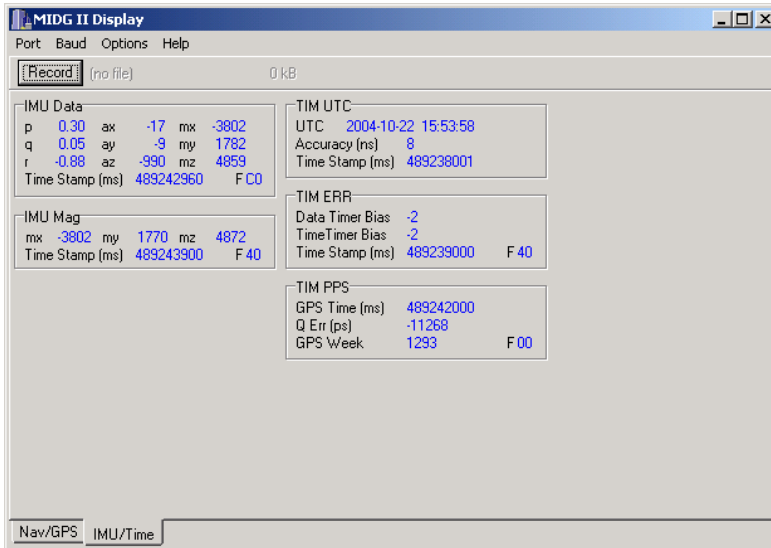
This window displays data from the GPS_SVI message.  This data is directly from the GPS receiver and includes status information for each SV (satellite vehice), including the satellite number being tracked on each receiver channel, the carrier to noise ratio, satellite health flags, a data quality indicator, and the elevation and azimuth of each satellite in degrees.
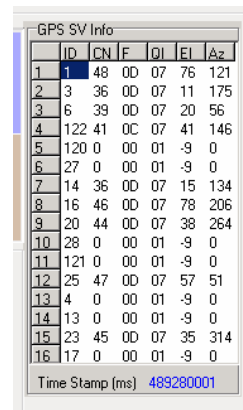
## 2.3 IMU/Time Display Windows

Clicking on the IMU/Time tab at the bottom of the screen will display the following initial IMU/Time data screen, divided into four message windows. As with the Nav/GPS screen, each message window corresponds to a message from the MIDG II as defined in the MIDG II Message Specification document.



### 2.3.1 Inertial Measurements (IMU Data) Window

This window displays data from the IMU_DATA message. IMU data is taken directly from the inertial sensors with only static calibration applied. The angular rates p, q, and r are displayed in degrees per second. The accelerations ax, ay, and az are displayed in milli-g. The magnetic field values are in units such that a vector of length 5000 is equivalent to the field strength at calibration.
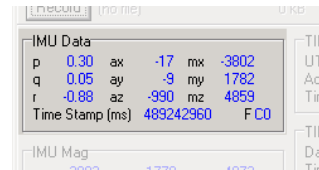


### 2.3.2 Magnetometer Measurements (IMU Mag) Window

This window displays data from the IMU_MAG message, which is provided in the event that the user is interested in the magnetic field values without the additional information of the IMU_DATA message (angular rates and accelerations). The magnetic field values are in units such that a vector of length 5000 is equivalent to the field strength at calibration.
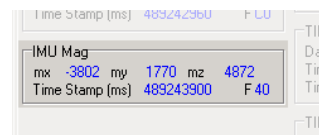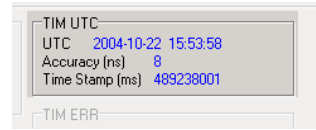
### 2.3.3 UTC Time (TIM UTC) Window

This window displays data from the TIM_UTC message. It includes UTC time displayed in year (1999...2099), month (1...12), day (1...31), hour (0...23), minute (0...59), and second (0...59).
For example, a valid UTC display string would be:
   "2004-10-12  20:23:48".

### 2.3.4 Time Error Information (TIM ERR) Window

This window displays data from the TIM_ERR message. It is a debug message that shows the bias values of clocks inside the MIDG II.
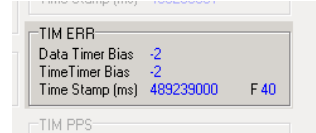
### 2.3.5 Time of One Pulse Per Second (TIM PPS) Window

This windows displays data from the TIM_PPS message. For units equipped with the 1PPS signal at the main connector, this message indicates what the GPS time will be at the next pulse.

# Chapter 3. Configuration Dialog

The MIDG II provides configuration options to support a wide variety of user requirements. Interface options support different baud rates, message rates, and legacy protocols. Operational options allow for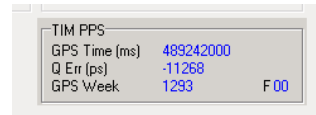 selectable run-modes and output formats for position and velocity. Installation options support non-standard mounting of the MIDG II, and magnetometer bias removal.

Configuration is carried out using the configuration message outlined in the MIDG II Message Specification document. The CFG_SET and CFG_QUERY messages are used to set and retrieve configuration information, respectively. These configuration messages work by accessing the configuration subsystem of the MIDG II, which responds to requests for specific configuration items.

This chapter introduces the configuration dialog of the MIDG II Display and Configuration Program. The configuration dialog provides simplified access to the configuration subsystem through a graphical interface. The dialog has tabs that correspond to the configuration subsystem messages.

## 3.1  Opening the Configuration Dialog

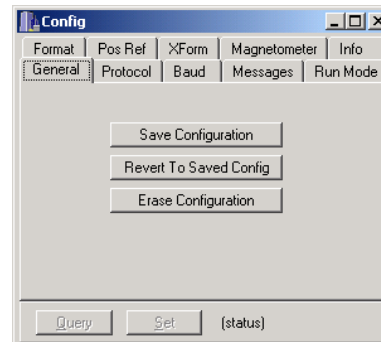The configuration dialog is accessed from the Options menu of the MIDG II Display and Configuration Program.
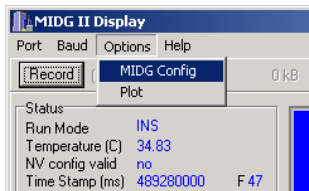
## 3.2  General Configuration

Configuration information is held in non-volatile memory onboard the MIDG II. Upon startup, the non-volatile memory is checked for valid configuration information. If present, this information is loaded into volatile memory as the working configuration. If no valid configuration information is found in non-volatile memory at startup, defaults are used. The configuration messages CFG_SET and CFG_QUERY access the working configuration. The configuration information stored in non-volatile memory is unaffected by all configuration requests except:

- CFG_SAVE, which stores the working configuration into non-volatile memory.
- CFG_LOAD, which overwrites the working configuration with the information in non-volatile memory. This is the operation that is performed by the MIDG II during startup. However, unlike startup, if no valid configuration information is present in non-volatile memory, the current working configuration is unchanged.
- CFG_ERASE, which erases any configuration information stored in non-volatile memory. This allows the default configuration to be loaded at the next startup. The CFG_ERASE request does not change the working configuration.

The General tab of the configuration dialog provides access to these functions.

> **IMPORTANT**
>
> The *Query* and *Set* buttons appear at the bottom of each page of the configuration dialog along with a status string that indicates the status of requests and replies from the MIDG II. A query operation occurs automatically each time a new tab is selected in the dialog. When changes are made to fields in the dialog, the *Set* button must be pressed to send the corresponding CFG_SET request. If no CFG_SET request is sent to the MIDG II, then no configuration information will be changed. Further, CFG_SET requests only make changes to the working configuration in volatile memory. The *Save Configuration* button on the General page must be pressed to store the working configuration into non-volatile memory so that it will be loaded on startup.

## 3.3    Protocol Configuration

The Protocol tab corresponds to the PROTOCOL configuration message. It allows selection of the primary communication protocol used by the MIDG II. This capability is provided to support users of MIDG I. It should not be used unless MIDG I compatibility is required. Please be advised that if the protocol is changed to a MIDG I protocol (AsciiHex or ZNBin), MIDG I software tools will be required to return the MIDG II to its default state. Contact Microbotics if you need to acquire the MIDG I software tools.
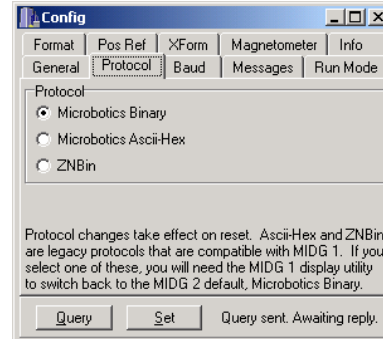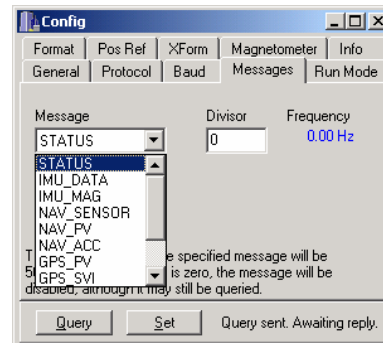
## 3.4    Baud Configuration

The Baud tab corresponds to the BAUD configuration message. It allows the baud rate of the MIDG II to be changed. The change request will fail if the currently enabled output messages require more bandwidth than is provided by the new baud selection. When a baud change is successful, and is saved into non-volatile memory, the new baud rate will be used at the next startup.
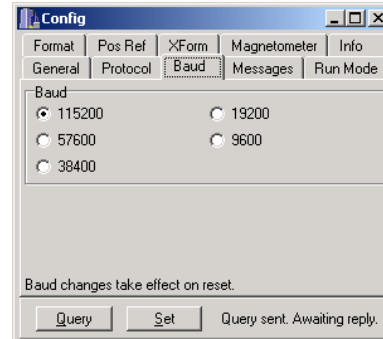
## 3.5    Messages Configuration

The Messages tab corresponds to the MSG_DIV configuration message. It allows the selection of output rate for each of the MIDG II-to-Host messages. The selection of message output rate is accomplished by choosing a divisor. The output frequency of the message will be equal to 50 divided by the divisor value. If the divisor value is zero, then the message is disabled, but may still be queried. For more information in querying messages, see the MIDG II Message Specification document.

## 3.6    Run Mode Configuration

The Run Mode tab corresponds to the MODE configuration message. This message allows the user to select the different modes of operation supported by the MIDG II. The default mode is INS.
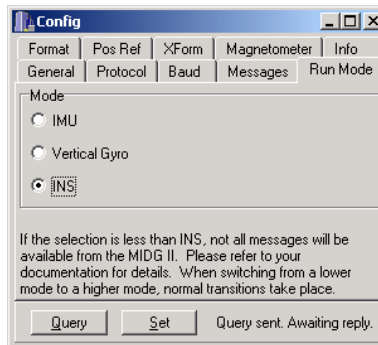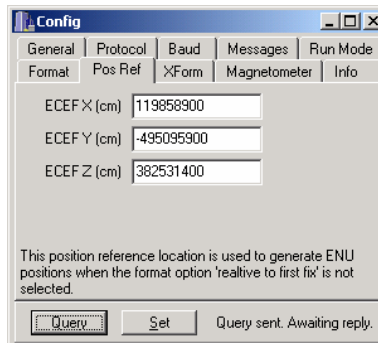
## 3.7    Format Configuration

The Format tab corresponds to the FORMAT configuration message. It allows selection of different coordinate systems in which position and velocity can be provided. Position may be provided in ECEF, ENU, or LLA coordinates. Velocity may be provided in ECEF or ENU coordinates. Both the INS position and velocity (NAV_PV) and the GPS position and velocity (GPS_PV) messages are affected by this selection. If ENU is selected for position output, then the position will be reported in meters East, North, and Up from a reference location on the Earth. The reference location can be either the first GPS fix achieved after startup or a preprogrammed location (see Position Reference Configuration). If the *ENU Relative to First Fix* checkbox is selected, then the reference point for ENU position will be the first GPS fix achieved after startup.
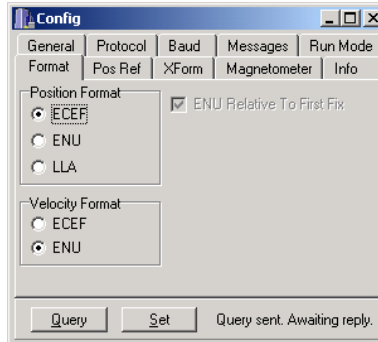
## 3.8    Position Reference (Pos Ref) Configuration

The Pos Ref tab corresponds to the POS_REF configuration message. It allows the user to specify a reference point on the Earth from which ENU positions will be measured. This reference point will only be used if the position format *relative to first fix* option is not selected. The position reference must be provided in ECEF coordinates in centimeters.

## 3.9    Transform (XForm) Configuration

The XForm tab corresponds to the XFORM configuration message. It allows the MIDG II to be mounted in the host vehicle in any orientation and yet still provide data in the host vehicle coordinate frame. The yaw, pitch, and roll values are the Euler angles that define a rotation from the MIDG II sensor axis coordinate frame to the host vehicle coordinate frame.

Note that the values must be specified in hundredths of degrees. For example, if the MIDG II were to be installed upside down, the **Roll** setting would be changed to 18000 (180°/0.01) .
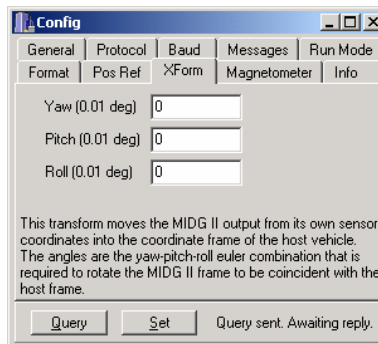
## 3.10  Magnetometer Configuration

The Magnetometer tab corresponds to the MAG configuration message.  It allows for compensation of magnetometer biases and control of magnetometer operation in INS mode.  The bias values are the magnetometer biases that occur when installed in the vehicle due to local ferrous or magnetic material.  The supplied values will be subtracted from the magnetometer readings before they are used by the MIDG II.

When the MIDG II is operating in INS mode, it can determine heading from GPS and inertial measurements alone with sufficient vehicle maneuvering.  When the level of maneuvering is not sufficient to maintain accurate heading, the MIDG II filter will begin to use the magnetometer for heading measurements if the *Enable mag measurements in INS mode* box is checked.  This is the default behavior.

## 3.11  System Information (Info)

The Info tab corresponds to the INFO configuration message (query only).  It allows the user to see the product information for the MIDG II as well as the current firmware version.

## 3.12  Save The Settings

Configuration changes will be lost at reset (power-down) *unless* they are saved in non-volatile memory by clicking the *Save Configuration* button on the General page.  It is not necessary to click *Save Configuration* after every setting change, but it must be done before exiting the configuration screens if the new settings are to be retained after reset.
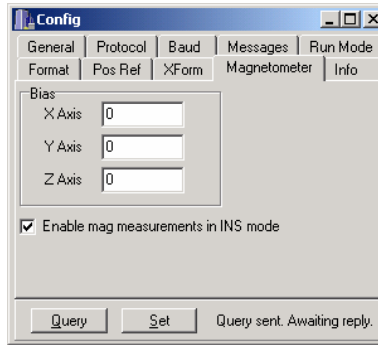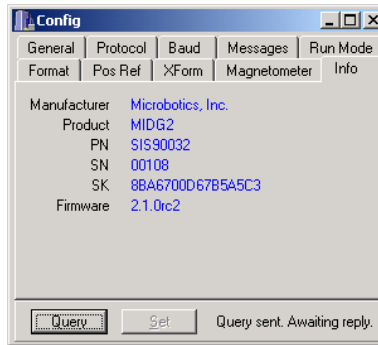
# Appendix A.  Coordinate System Overview

The MIDG II operates using several frames of reference.  Of interest to the user are the Earth-Centered, Earth-Fixed (ECEF) coordinate frame, the East-North-Up (ENU) coordinate frame, the North-East-Down (NED) coordinate frame, the Host Vehicle Coordinate (HVC) frame, and the Sensor Coordinate (SC) frame.  A simplified overview of each frame follows; detailed treatment of these frames can be found in any navigation text.

## A.1   ECEF

The Earth-Centered, Earth-Fixed frame is a right-handed, Cartesian frame in which:
- the origin is fixed at the mass center of the Earth
- the frame rotates with the Earth
- the Z axis points out of the north pole
- the X axis points out through the intersection of the prime meridian and the equator

GPS makes use of this frame, as defined by the World Geodetic System 1984 (WGS84) reference ellipsoid, to represent the position and velocity of a user relative to the Earth.
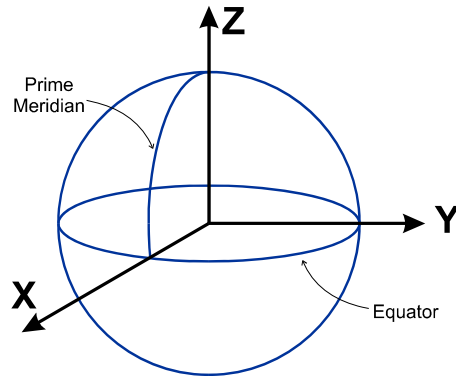


## A.2   ENU

The East-North-Up frame is a right-handed, Cartesian frame in which the Z (up) axis is perpendicular to the surface of the Earth underneath the frame (coincident to the local gravity vector).  The X-Y plane is tangent to the local Earth surface.  The X axis points eastward and the Y axis points northward.

The ECEF and ENU frames are related by the common geodetic coordinates of latitude ($\phi$), longitude ($\lambda$).

| ECEF frame | Z rotation of $\lambda$ | -> | Intermediate frame |
| Intermediate frame | Y rotation of $-\phi$ | -> | ENU frame |
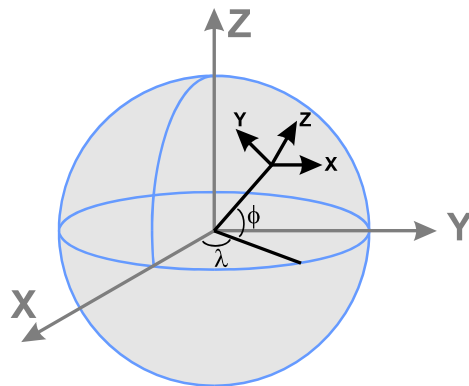
### A.3 NED

The North-East-Down frame is similar to the ENU frame except that the X, Y, and Z axes point northward, eastward, and down, respectively. The NED frame is used for convenience as yaw, pitch, and roll are defined as the Z,Y,X Euler rotations from the NED frame to the vehicle frame.

### A.4 HVC

The Host Vehicle Coordinate frame is the right-handed, Cartesian frame of the vehicle on which the MIDG II is mounted. A convention typically used for aircraft defines the coordinate frame with the X axis out the nose, the Y axis out the right wing, and the Z axis down.

### A.5 SC

The Sensor Coordinate frame is the right-handed, Cartesian frame of the MIDG II. By default, this is the coordinate frame in which the MIDG II presents its data. If installation in the host vehicle requires that the SC frame be non-coincident with the HVC frame, the XFORM configuration item may be used to cause the MIDG II output to be referenced to the HVC frame instead of the SC frame.
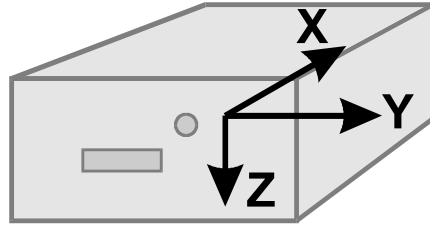
# Appendix B.  Typical Conversions

Several conversions that might be useful when dealing with the MIDG II are provided.  Note that the trigonometric function *atan2* is the same as is defined by the standard C programming language library.

## B.1   Quaternion To Euler Angles

The quaternion provided by the MIDG II is a four element vector that described the attitude of the MIDG II relative to the NED coordinate frame.  The data items of the quaternion field are the components of the complex number w + xi + yj + zk, where i, j, and k are the unit vectors representing the imaginary axes.  The following conversion can be used to generate Euler angles (yaw, pitch, roll):

$$yaw = atan2\left(2 \cdot (x \cdot y + z \cdot w), (x^2 - y^2 - z^2 + w^2)\right)$$
$$pitch = asin\left(- 2 \cdot (x \cdot z - y \cdot w)\right)$$
$$roll = atan2\left(2 \cdot (y \cdot z + x \cdot w), (- x^2 - y^2 + z^2 + w^2)\right)$$

## B.2   LLA To ECEF

Often it is desirable to generate latitude, longitude, and altitude from ECEF coordinates.  In order to proceed, a few WGS84 parameters must first be defined.

$$a = 6378137$$
$$b = 6356752.3142$$
$$e1 = \frac{a^2 - b^2}{a^2}$$
$$e2 = \frac{a^2 - b^2}{b^2}$$

Where a and b are the semi-major and semi-minor axes of the WGS84 reference ellipsoid, respectively, and e1 and e2 are the first and second eccentricity, respectively.

Now, to convert LLA (radians and meters) to ECEF (meters)

$$N = \frac{a^2}{\sqrt{a^2 \cos^2 \phi + b^2 \sin^2 \phi}}$$
$$X_{ECEF} = (N + Altitude) \cos \phi \cos \lambda$$
$$Y_{ECEF} = (N + Altitude) \cos \phi \sin \lambda$$
$$Z_{ECEF} = \left(\frac{b^2}{a^2} N + h\right) \sin \phi$$

Where $\phi$ is latitude, $\lambda$ is longitude, and h is the altitude above the reference ellipsoid.

## B.3   ECEF To LLA

See the LLA To ECEF conversion for the WGS84 parameters a,b,e1, and e2.  The conversion from ECEF (meters) to LLA (radians and meters) is as follows.

$$p = \sqrt{X^2 + Y^2}$$

$$\theta = \arctan\left(\frac{Z \cdot a}{p \cdot b}\right)$$

$$\phi = \arctan\left(\frac{Z + e2 \cdot b \cdot \sin^3 \theta}{p - e1 \cdot a \cdot \cos^3 \theta}\right)$$

$$\lambda = \arctan\left(\frac{Y}{X}\right)$$

$$h = \frac{p}{\cos \phi} - N$$

Where $\phi$ is latitude, $\lambda$ is longitude, and h is the altitude above the reference ellipsoid.