AHRS500CA Series User's Manual

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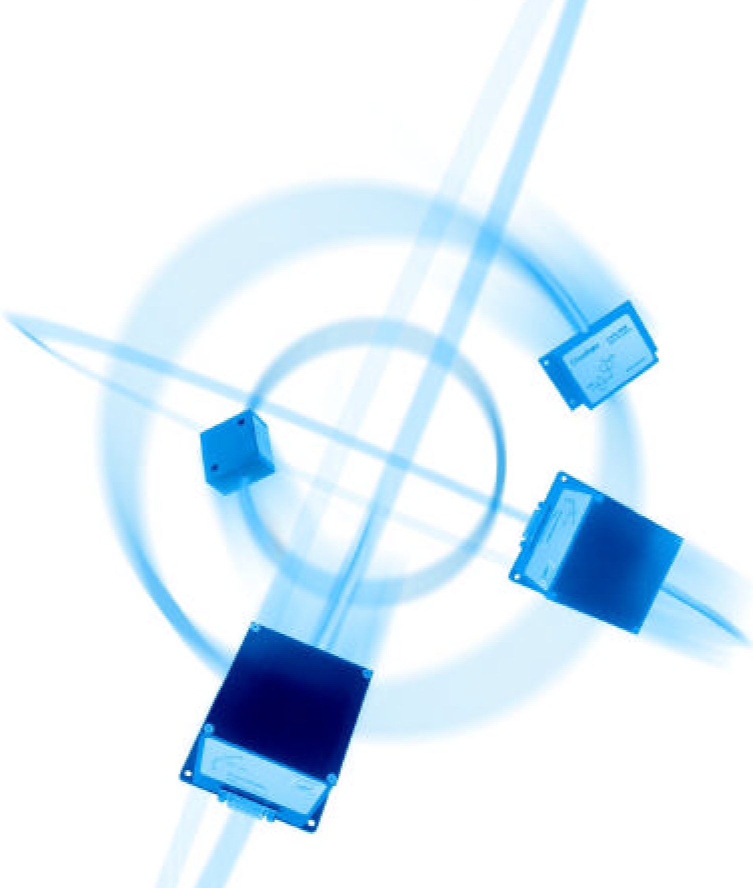

Crossbow

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Table of Contents

About this Manual

The following annotations have been used to provide additional information.

NOTE

Note provides additional information about the topic.

☑ EXAMPLE

Examples are given throughout the manual to help the reader understand the terminology.

IMPORTANT

This symbol defines items that have significant meaning to the user

WARNING

The user should pay particular attention to this symbol. It means there is a chance that physical harm could happen to either the person or the equipment.

The following paragraph heading formatting is used in this manual:

1 Heading 1

1.1 Heading 2

1.1.1 Heading 3

Normal

1 Introduction

1.1 The AHRS500CA Series Motion and Attitude Sensing Units

This manual explains the use of the AHRS500CA Series of products, nine-axis measurement system designed to measure stabilized pitch, roll and yaw angles in a dynamic environment.

The AHRS500CA is a nine-axis measurement system that combines linear accelerometers, rotational rate sensors, and magnetometers. The AHRS500CA uses the 3-axis accelerometer and 3-axis rate sensor to make a complete measurement of the dynamics of your system. The addition of a 3-axis magnetometer also allows the AHRS500CA to make a true measurement of magnetic heading.

The AHRS500CA is the solid-state equivalent of a vertical gyro/artificial horizon display combined with a directional gyro.

The AHRS500CA series units are low power, fast turn on, reliable and accurate solutions for a wide variety of stabilization and measurement applications.

All AHRS500CA products have an RS-232 serial link. Data may be requested via the serial link as a single polled measurement or may be streamed continuously.

Crossbow Technology AHRS500CA units employ onboard digital processing to compensate for deterministic error sources within the unit and to compute attitude information. The AHRS500CA units accomplish these tasks with an analog to digital converter and high performance Digital Signal Processors.

The AHRS500CA uses angular rate sensors and linear acceleration sensors that are micro-machined devices. The three angular rate sensors consist of vibrating ceramic plates that utilize the Coriolis force to output angular rate independently of acceleration. The three MEMS accelerometers are surface micro-machined silicon devices that use differential capacitance to sense acceleration. Solid-state MEMS sensors make the AHRS500CA both responsive and reliable. The magnetic sensors are state-of-the-art miniature fluxgate sensors. Fluxgate sensors make the AHRS500CA sensitive and responsive, with better temperature performance than other technologies such as magneto-resistive sensors.

The AHRS500CA Series of products utilize a sophisticated Kalman filter algorithm to allow the unit to track orientation accurately through dynamic maneuvers. The Kalman filter will automatically adjust for changing dynamic conditions without any external user input. No user intervention or configuration is required at power-up.

The AHRS500CA should not be exposed to large magnetic fields. This could permanently magnetize internal components of the AHRS500CA and degrade its magnetic heading accuracy.

1.2 Package Contents

In addition to your AHRS500CA sensor product you should have:

- **1 CD with GyroView Software**

  GyroView will allow you to immediately view the outputs of the AHRS500CA on a PC running Microsoft® Windows™. You can also download this software from Crossbow's web site at http://www.xbow.com.

- **1 Digital Signal Calibration/Maintenance Cable.**

  This links the AHRS500CA directly to a serial port. Only the transmit, receive, power, and ground channels are used. The magnetometer calibration switch will be visible on the connector.

- **1 AHRS500CA Configuration Sheet**

  This contains the configuration information for the AHRS500CA model type ordered.

2 Quick Start

2.1 GyroView Software

Crossbow includes GyroView software to allow you to use the AHRS500CA right out of the box and the evaluation is straightforward. Install the GyroView software, connect the AHRS500CA to your serial port, apply power to your unit and start taking measurements.

2.1.1 GyroView Computer Requirements

The following are minimum capabilities that your computer should have to run GyroView successfully:

- CPU: Pentium-class
- RAM Memory: 32MB minimum, 64MB recommended
- Hard Drive Free Memory: 15MB
- Operating System: Windows 95, 98, NT4, 2000

2.1.2 Install GyroView

To install GyroView in your computer:

1. Insert the CD "Support Tools" in the CD-ROM drive.
2. Find the GyroView folder. Double click on the setup file.
3. Follow the setup wizard instructions. You will install GyroView and a LabView Runtime Engine. You will need both these applications.

If you have any problems or questions, you may contact Crossbow directly.

2.2 Connections

The AHRS500CA is shipped with a calibration/maintenance cable to connect the AHRS500CA to a PC communications port.

1. Connect the 15-pin female end of the digital signal calibration/maintenance cable to the port on the AHRS500CA.
2. Connect the 15-pin male end of the digital signal calibration/maintainance cable to the cable harness connector that supplies power to the DMU.
3. Connect the 9-pin end of the calibration/maintenance cable to the serial port of your computer.
4. Bolt the base of the unit to a grounded surface. A good ground is required for EMI and lightning over-voltage protection.

WARNING

Do not reverse the power leads! Applying the wrong power to the AHRS500CA can damage the unit; although there is reverse power protection, Crossbow Technology is not responsible for resulting damage to the unit should the reverse voltage protection electronics fail.

2.3 Setup GyroView

With the AHRS500CA connected to your PC serial port and powered, open the GyroView software.

1. GyroView should automatically detect the AHRS500CA and display the serial number and firmware version if it is connected.
2. If GyroView does not connect, check that you have the correct COM port selected. You find this under the "DMU" menu.
3. Select the type of display you want under the menu item "Windows". Graph displays a real time graph of all the AHRS500CA data; FFT displays a Fast-Fourier transform of the data; Navigation shows an artificial horizon display.
4. You can log data to a file by entering a data file name. You can select the rate at which data is saved to disk.
5. If the status indicator says, "Connected", you're ready to go. If the status indicator doesn't say connected, check the connections between the AHRS500CA and the computer; check the power; check the serial COM port assignment on your computer.

2.4 Take Measurements

Once you have configured GyroView to work with your AHRS500CA, pick what kind of measurement you wish to see. "Graph" will show you the output you choose as a strip-chart type graph of value vs. time. "FFT" will show you a real-time Fast-Fourier transform of the output you choose. "Navigation" will show an artificial horizon and the stabilized pitch and roll output of the AHRS500CA.

Let the AHRS500CA warm up for 90 seconds when first turned on. This allows the Kalman filter to estimate the rate sensor biases. Now you're ready to use the AHRS500CA!

3 AHRS500CA Details

3.1 AHRS500CA Coordinate System

The AHRS500CA will have a label on one face illustrating the AHRS500CA coordinate system. With the connector facing you, and the mounting plate down, the axes are defined as:

X-axis – from face with connector through the AHRS500CA

Y-axis – along the face with connector from left to right

Z-axis – along the face with the connector from top to bottom

This is the default configuration for the generic AHRS500CA model. Other coordinate frame orientations are supported given the model type purchased, and these will be reflected in the label as well as through the model configuration number. The axes form an orthogonal right-handed coordinate system. An acceleration is positive when it is oriented towards the negative side of the coordinate axis. For example, with the AHRS500CA sitting on a level table, it will measure zero g along the x- and y-axes and +1 g along the z-axis. Gravitational acceleration is directed downward, and thus will be defined as positive for the AHRS500CA z-axis.

The angular rate sensors are aligned with these same axes. The rate sensors measure angular rotation rate around a given axis. The rate measurements are labeled by the appropriate axis. The direction of a positive rotation is defined by the right-hand rule. With the thumb of your right hand pointing along the axis in a positive direction, your fingers curl around in the positive rotation direction. For example, if the AHRS500CA is sitting on a level surface and you rotate it clockwise on that surface, this will be a positive rotation around the z-axis. The x- and y-axis rate sensors would measure zero angular rates, and the z-axis sensor would measure a positive angular rate.

The magnetic sensors are aligned with the same axes definitions and sign as the linear accelerometers.

Pitch is defined positive for a positive rotation around the y-axis (pitch up). Roll is defined as positive for a positive rotation around the x-axis (roll right). Yaw is defined as positive for a positive rotation around the z-axis (turn right).

The angles are defined as standard Euler angles using a 3-2-1 system. To rotate from the body frame to an earth-level frame, roll first, then pitch, and then yaw.

3.2 Connections

The AHRS500CA500 has a male DB-15 connector. The signals are as shown in Table 1.

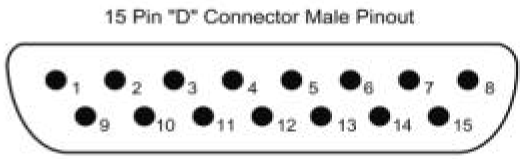


Table 1 Connector Pin Assignments

Pin	Signal	Electrical Specifications
1	RS-232 Transmit	+/- 4.5 VDC min w.r.t. power ground.
2	RS-232 Receive	+/- 25 VDC max w.r.t. power ground.
3	VDC Power Input	10-40 VDC normal, 9VDC emergency
4	Power Input Ground	
5	No connection	Do not connect
6	No connection	Do not connect
7	RS-422 Transmit + A	2.0 VDC differential output (min) into 100 ohms. Common mode output voltage, 3VDC max.
8	RS-422 Transmit – A	
9	Signal Ground	Capacitive coupling to internal system ground. Should be connected to user's system ground to reduce RS232 and RS422 signal noise.
10	Factory mode pin	Factory reserved; do not connect
11	Factory mode pin	Factory reserved; do not connect
12	Magnetometer calibration input (hard and soft iron cal)	Active: Short to power ground. Inactive: Open circuit. (Internally pulled to +3.3VDC through 10Kohm resistor)
13	Hardware BIT Status	Open collector, requires user pull-up resistor. Max pull-up voltage: +15VDC Max current sink: 10ma.
14	RS-422 Receive + A	Common mode input voltage range: 3VDC w.r.t. power ground.
15	RS-422 Receive – A	
N/A	Case Ground	Electrically connected to I/O connector shell

3.2.1 I/O Cable

The user must provide a shielded cable with the shield connected to the I/O connector shell in order to provide the required EMI protection. The cable sent with the unit is intended to provide the user with the ability to perform a magnetometer calibration, and provide routine magnetometer calibration maintenance of the system, and will not provide adequate shielding.

3.2.2 Power Input and Power Input Ground

The AHRS500CA power requirements are described in the table below. It is designed to operate with either a nominal 14VDC or 28VDC aircraft power system.

Table 2 Electrical Power Input Requirements

Item	Requirement	**AHRS500CA specification**
1	Input Supply voltage	10-40 VDC
2	Input Supply Current	1 Amp (max)

3.2.3 Case Ground

The case is electrically connected to the I/O connector shell. The shell should be electrically connected to the user's cable shield. The case is isolated from the Power Input Ground, and should be bolted to a good conducting surface that is grounded.

3.2.4 Serial Data Interface

The serial interface is a factory configurable RS-422 or RS-232, also with factory configurable baud rates (see table below) depending on the model configuration chosen. In the final shipping configuration, the unit will recognize certain commands detailed in Section 3.5. Data output is continuous at a fixed frequency dependant on the baud rate (see Table 3 below).

Table 3 Supported BAUD Rates and Output Rates

BAUD Rate	Output Rate
9600	25
19200	50
38400	100
57600	200

The unit has both an RS-232 and RS422 serial interface. During factory configuration, one port is configured as the user data port while the other is a factory diagnostic port to monitor BIT data. The unit can be configured to allow either port to be the user data port, defaulting the other for BIT diagnostics. The port definition is specified by the model configuration chosen and will be detailed in the model configuration sheet shipped with the unit.

3.2.5 BIT Status Output Pin

The BIT status output pin will become active high if the system is experiencing a failure. The BIT is an open collector signal and requires a pull-up resistor for proper operation.

3.2.6 Magnetometer calibration Input Pin

The AHRS500CA has an input pin to control the magnetometer hard-iron calibration function. When this pin is active (low) the unit will collect the data necessary for magnetometer calibration. When it becomes inactive, the magnetometer calibration data shall be used to compute the hard and soft iron compensation values. During normal operation, no connection should be made to this pin; this pin shall be tied high internally with a pull-up resistor. This feature has been added as a means to perform a Hardiron/Softiron calibration without sending the calibration commands to the unit. Please see Appendix C, for a complete explanation of the Hardiron/Softiron calibration process, and how this pin can be used as a means of implementing the calibration.

3.2.7 No Connection

During normal operation of the AHRS500CA, no connection is made to the factory test pin. This pin has an internal pull-up mechanism and must have no connection for the AHRS500CA to operate properly.

3.2.8 Quick Digital interface connection

On a standard DB-9 COM port connector, make the connections as described in Table 4.

Table 4 DB-9 COM Port Connections

COM Port Connector			AHRS500CA Connector	
Pin #	Signal		Pin #	Signal
2	RxD		1	TxD
3	TxD		2	RxD
5	GND*		4	GND*

*Note: Pin 4 on the AHRS500CA is data ground as well as power ground.

Power is applied to the AHRS500CA on pins 3 and 4. Pin 4 is ground; Pin 3 should have 10-40 VDC unregulated at 275 mA. DO NOT REVERSE THE POWER LEADS.

3.3 Interface

The default serial interface is standard RS-232, model configurable baud rate, 8 data bits, 1 start bit, 1 stop bit, no parity, and no flow control, and will output at a model configurable output rate.

3.4 Measurements

The AHRS500CA Series is designed to operate as a complete attitude and heading reference system. The default system operation is "angle" mode with the packet and output data as described below. The AHRS500CA operates in two other measurement modes that are for factory use only and are not supported for general use.

The AHRS500CA acts as a complete attitude and heading reference system and outputs the stabilized pitch, roll, and yaw angles along with the angular rate and acceleration.

The Kalman filter operates to track the rate sensor bias and calculate the stabilized roll, pitch, and yaw angles.

The AHRS500CA uses the angular rate sensors to integrate over your rotational motion and find the actual pitch, roll, and yaw angles. The AHRS500CA uses the accelerometers to correct for rate sensor drift in the vertical angles (pitch and roll); the AHRS500CA uses the magnetometers to correct for rate sensor drift in the yaw angle. This is the modern equivalent of an analog vertical gyro that used a plumb bob in a feedback loop to keep the gyro axis stabilized to vertical. The AHRS500CA takes advantage of the rate gyros' sensitivity to quick motions to maintain an accurate orientation when accelerations would otherwise throw off the accelerometers measurement of the AHRS500CA orientation relative to gravity; the AHRS500CA then uses the accelerometers to provide long term stability to keep the rate gyro drift in check.

The AHRS500CA uses a sophisticated Kalman filter algorithm to track the bias in the rate sensors. This allows the AHRS500CA to use a very low effective weighting on the accelerometers when the AHRS500CA is moved. This makes the AHRS500CA very accurate in dynamic maneuvers.

The AHRS500CA outputs the stabilized pitch, roll and yaw angles in the digital data packet. To convert the digital data to angle, use the following relation:

$$\textbf{angle} = \textbf{data}*(\textbf{SCALE})/2^{15}$$

where **angle** is the actual angle in degrees (pitch, roll or yaw), **data** is the signed integer data output in the data packet, and **SCALE** is a constant. **SCALE** = 180° for roll, pitch and yaw.

To convert the acceleration data into G's, use the following conversion:

$$\textbf{accel} = \textbf{data}*(\textbf{10} * 1.5)/2^{15}$$

where **accel** is the actual measured acceleration in G's, **data** is the digital data sent by the AHRS500CA, and **10** is the G Range for your AHRS500CA. (The data is scaled so that 1 G = 9.80 m s^{-2}.) This maximum G range is a default value.

To convert the angular rate data into degrees per second, use the following conversion:

$$\textbf{rate} = \textbf{data}*(\textbf{800}*1.5)/2^{15}$$

where **rate** is the actual measured angular rate in °/sec, **data** is the digital data sent by the AHRS500CA, and **800** is the Angular rate Range of the AHRS500CA. This maximum angular rate is a default value.

3.4.1 BIT Processing

The BIT message in each packet provides comprehensive information into system health. The following information is supplied in the BIT byte fields of the data packet. The table contains the actual bit definition present in the two-byte output BIT field in the angle mode data packet (see section 3.6 below). The description defines the bit's active (1) position.

Table 5 Bit Message Definition

BIT Data	**Description**	**Bit Location**
Hard Failure	An unrecoverable failure has occurred	Bit 0
Soft Failure	A soft failure has been detected. A soft failure can be generated by any BIT condition designated "soft". If the soft failure persists for more than 2100 data packets the Hard Failure bit is turned on and the Soft Failure bit is permanently on.	Bit 1
Not Ready	The system is not ready to use	Bit 2
Power Fail	A power failure has been detected. The system is on hold-up power and is about to lose power.	Bit 3

Comm	A serial port (user) communications error (ex over-run, parity) has been detected.	Bit 4
Reboot Detect	A processor reset was detected possibly due to a watchdog timeout or low-power setting.	Bit 5
Calibration Table	A bad calibration table in flash memory has been detected.	Bit 6
Turn Indicator	A turn has been detected	Bit 8
Algorithm Status	Not ready, waiting for power-up or post sensor saturation	Bits 10,9: 11
	Valid data but in initialization mode	Bits 10,9: 10
	Valid data but using only gyro integration to provide attitude output	Bits 10,9: 01
	Full accuracy data	Bits 10,9: 00
Magnetometer Cal Status	A Hardiron/Softiron calibration is being performed.	Bit 11
Magnetometer Cal Validity	Bad stored Hardiron/Softiron calibration data has been detected	Bit 12
Magnetometer Cal Performance	The Hardiron/Softiron calibration is unsatisfactory	Bit 13

3.5 Commands

The AHRS500CA has a simple command structure. You send a command consisting of one byte to the AHRS500CA over the RS-232 interface and the AHRS500CA will execute the command.

NOTE

The AHRS500CA commands are case sensitive!

GyroView is a very good tool to use when debugging your own software. GyroView formulates the proper command structures and sends them over the RS-232 interface. You can use GyroView to verify that the AHRS500CA is functioning correctly. GyroView does not use any commands that are not listed here.

NOTE

With the exception of the change to Polled mode command (see below), the commands listed below will only be operational when the unit is in polled mode. When the unit is in continuous mode, only the change to Polled mode command will be operational.

3.5.1 Command List

Command	Ping
Character(s) Sent	R
Response	H
Description	Pings AHRS500CA to verify communications

Command	Voltage Mode
Character(s) Sent	r
Response	R
Description	Factory use only

Command	Scaled Mode
Character(s) Sent	c
Response	C
Description	Factory use only

Command	AHRS Mode
Character(s) Sent	a
Response	A
Description	Changes measurement type to AHRS Mode. AHRS500CA calculates stabilized pitch and roll, and heading. Also outputs sensor measurements in scaled engineering units.

Command	Polled Mode
Character(s) Sent	P
Response	None
Description	Changes data output mode to Polled Mode. AHRS500CA will output a single data packet when it receives a "G" command.

Command	Continuous Mode
Character(s) Sent	C

Response	Data Packets
Description	Changes data output mode to Continuous Mode. AHRS500CA will immediately start to output data packets in continuous mode.

Command	Request Data
Character(s) Sent	G
Response	Data Packet
Description	"G" requests a single data packet. AHRS500CA will respond with a data packet. Sending the AHRS500CA a "G" while it is in Continuous Mode will place the AHRS500CA in Polled Mode.

Command	Query AHRS500CA Version
Character(s) Sent	v
Response	ASCII String Packet
Description	This queries the AHRS500CA firmware and will tell you the AHRS500CA firmware version. The response is an ASCII string packet that describes the AHRS500CA firmware version, preceded with a header byte (hex FF) and followed by a one byte checksum calculated in the manner described below (section 3.7).

Command	Query Serial Number
Character(s) Sent	S
Response	Serial Number Packet
Description	This queries the AHRS500CA for its serial number. The AHRS500CA will respond with a serial number data packet that consists of a header byte (hex FF), the serial number in 4 bytes, and a checksum byte. The serial number bytes should be interpreted as a 32-bit unsigned integer. For example, the serial number 9911750 would be sent as the four bytes 00 97 3D C6.

Command	Query Model
Character(s) Sent	M
Response	Model Configuration Packet
Description	This queries the AHRS500CA model type and will tell you the AHRS500CA model configuration. The response is an ASCII string packet that describes the model type configuration, preceded with a header byte (hex FF) and followed by a one byte checksum calculated in the manner described below (section 3.7).

3.6 Data Packet Format

In general, the digital data representing each measurement is sent as a 16-bit number (two bytes). The data is sent MSB first then LSB.

In voltage mode, the data is sent as unsigned integers to represent the range 0 – 5 V.

In scaled and angle mode, the data generally represents a quantity that can be positive or negative. These numbers are sent as a 16-bit signed integer in 2's complement format. The data is sent as two bytes, MSB first then LSB.

Each data packet will begin with a two-byte header (hex AA 55) and end with a two-byte checksum. The checksum is calculated in the following manner:

1. Sum all packet contents *except* header and checksum.
2. Divide the sum by hex FFFF.
3. The remainder should equal the checksum.

The packet also contains the model type configuration number, and the BIT word output. Please refer to section 3.4.1 for details about the BIT word processing.

The model type configuration number will display the model number of the AHRS500CA model configuration purchased. In general the model type configuration will be described in the model configuration sheet sent with the unit, and is designated by the following string AHRS500CA-[]. The number in the brackets is the model type configuration number output in the angle mode data packet, and should match the model type purchased and described in the configuration sheet.

Table 6 AHRS500CA Series Data Packet Format

Byte	AHRS Mode
0	Header (0xAA)
1	Header (0x55)
2	Roll Angle (MSB)
3	Roll Angle (LSB)
4	Pitch Angle (MSB)
5	Pitch Angle (LSB)
6	Heading Angle (MSB)
7	Heading Angle (LSB)
8	Roll Angular Rate (MSB)
9	Roll Angular Rate (LSB)
10	Pitch Angular Rate (MSB)
11	Pitch Angular Rate (LSB)
12	Yaw Angular Rate (MSB)
13	Yaw Angular Rate (LSB)
14	X-Axis Acceleration (MSB)
15	X-Axis Acceleration (LSB)
16	Y-Axis Acceleration (MSB)
17	Y-Axis Acceleration (LSB)
18	Z-Axis Acceleration (MSB)
19	Z-Axis Acceleration (LSB)
20	Model Number (MSB)
21	Model Number (LSB)
22	BIT (MSB)
23	BIT (LSB)
24	Checksum (MSB)
25	Checksum (LSB)

3.7 Command Packet Format

Command response data packets will begin with a header byte (hex FF) and end with a checksum. The checksum is calculated in the following manner:

1. Sum all packet contents *except* header and checksum.
2. Divide the sum by hex FF.
3. The remainder should equal the checksum.

3.8 Timing

The default AHRS500CA data output rate is 100 samples per second. Depending on the model configuration chosen, the system output sample rate can be set to a different constant value.

In some applications, using the AHRS500CA's digital output requires a precise understanding of the internal timing of the device. The processor internal to the AHRS500CA runs in a loop - collecting data from the sensors, processing the data, and then collecting more data. The data is reported to the user through a parallel process. In continuous mode, the system processor activity is repeatable and accurate timing information can be derived based purely on the overall loop rate.

The unit goes through three processes in one data cycle. First, the sensors are sampled. Second, the unit processes the data for output. After processing the data, the AHRS500CA will make another measurement while presenting the current measurement for output. Third, the unit actually transfers the data out over the RS-232 port. The internal loop rate is set at 1000 Hz, so every 10th sample is available over the RS-232 interface for the default model configuration of the AHRS500CA.

3.9 Magnetic Heading

Magnetic north is the direction toward the magnetic north pole; true north is the direction towards the true North Pole.

The AHRS500CA yaw angle output is referenced to magnetic north. The direction of true north will vary from magnetic north depending on your position on the earth. The difference between true and magnetic north is called declination or magnetic variance. You will need to know your declination to translate the AHRS500CA magnetic heading into a heading referenced to true north.

4 AHRS500CA Operating Tips

4.1 Mounting the AHRS500CA

The AHRS500CA should be mounted as close to the center of gravity (CG) of your system as possible. This will minimize any "lever effect." If it is not mounted at the center of gravity, then rotations around the center of gravity will cause the AHRS500CA accelerometers to measure an acceleration proportional to the product of the angular rate squared and the distance between the AHRS500CA and the CG.

The AHRS500CA will measure rotations around the axes of its sensors. The AHRS500CA sensors are aligned with the AHRS500CA case. The mounting holes of the AHRS500CA case are used as a reference for aligning the AHRS500CA sensor axes with your system. You should align the AHRS500CA case as closely as possible with the axes you define in your system. Errors in alignment will contribute directly to errors in measured acceleration and rotation relative to your system axes.

The AHRS500CA should be isolated from large vibration if possible. AHRS500CA performance is tested to 2G random vibration from 20Hz to 2KHz. Larger vibration will make the accelerometer readings noisy and can, therefore affect the angle calculations. In addition, if the magnitude of the vibration exceeds the range of the accelerometer, the accelerometer output can saturate. This can cause errors in the accelerometer output.

The AHRS500CA should be isolated from magnetic material as much as possible. Magnetic material will distort the magnetic field near the AHRS500CA, which will greatly affect its accuracy as a heading sensor. Because the AHRS500CA is using Earth's weak magnetic field to measure heading, even small amounts of magnetic material near the sensor can have large effects on the heading measurement.

"Bad" materials include anything that will stick to a magnet: iron, carbon steel, some stainless steels, nickel and cobalt. Use a magnet to test materials that will be near the AHRS500CA. If you discover something near the AHRS500CA that is magnetic, attempt to replace it with something made from a non-magnetic material. If you cannot change the material, move it as far as possible from the AHRS500CA. Even small things, such as screws and washers, can have a negative effect on the AHRS500CA performance if they are close. AHRS500CA can correct for the effect of these magnetic fields by using hard and soft iron calibration routine as explained in Appendix C.

"Good" materials include brass, plastic, titanium, wood, aluminum, and some stainless steels. Again, if in doubt, try to stick a magnet on the material. If the magnet doesn't stick, you are using a good material.

DO NOT try to stick a magnet to the AHRS500CA. We have removed as much magnetic material as possible from the unit, but we could not make the unit completely non-magnetic. You can permanently magnetize ("perm up") components in the AHRS500CA if you expose the unit to a large magnetic field. You can use a demagnetizer (tape eraser) to demagnetize the AHRS500CA if it gets "permed." Follow the instructions for your demagnetizer.

The AHRS500CA case is weatherproof, but you should always try and protect it from moisture and dust.

☑ EXAMPLE

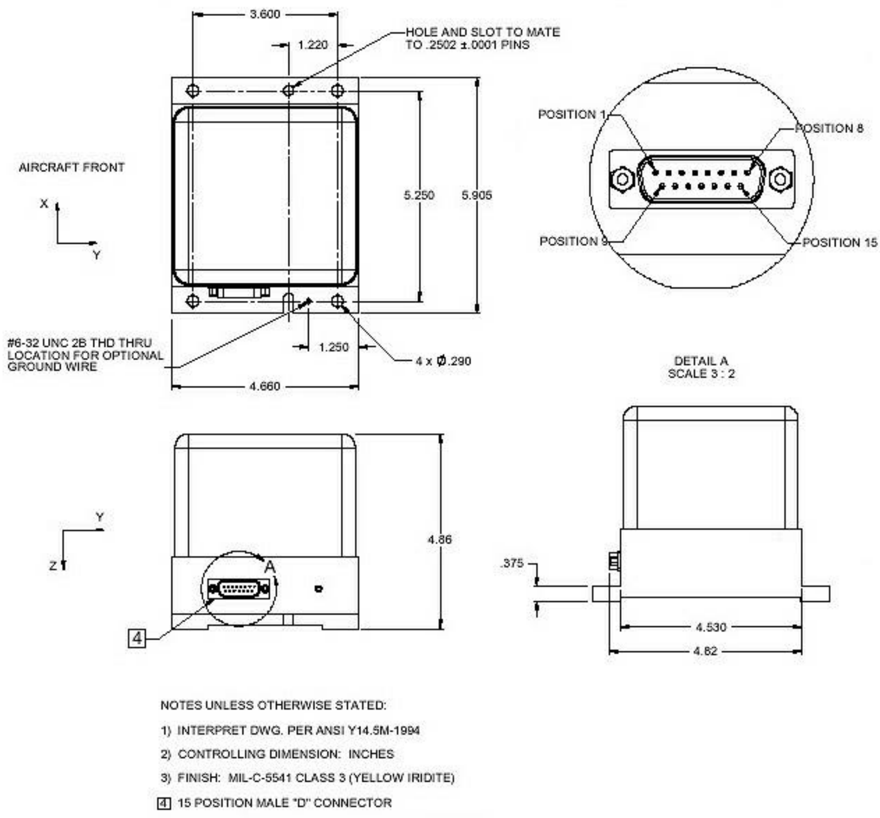
4.2 AHRS500CA Start Up Procedure

As an example, look at how the AHRS500CA might be used on an airplane. Assume AHRS500CA is mounted on a small twin-prop plane and will be used to record the plane's attitude during flight. Flights will be 2 – 6 hours long. The AHRS500CA is mounted near the CG of the plane, and is connected to a laptop serial port during flight.

1. Turn on power to the AHRS500CA and let it warm up 5 – 10 minutes. Power can be on to all electronics, but the engines should be off. Monitor the initialization BITs 10 and 9 of the BIT word, and make sure they are at the 00 position signaling that the unit is in full accuracy mode.
2. Start the engines.
3. Perform hard iron and soft iron calibration routines (Appendix C).
4. Start data collection.
5. Proceed with flight.

5 Appendix A. Mechanical Specifications

5.1 AHRS500CA Outline Drawing



6 Appendix B. AHRS500CA Output Quick Reference

10 is the G-range of the accelerometers. This is the default maximum range of the accelerometers.

800 is the rate range of the rate sensors. This is the default maximum range of the gyros.

Digital Output Conversion

Data is sent as 16-bit signed integer for all but Temperature. Temperature sensor data is sent as unsigned integer.

Acceleration

Accel (G) **= data * 10 * 1.5/2^{15}**

Rate

Rate (°/s) **= data * 800 * 1.5/2^{15}**

Roll, Pitch, Yaw (Angle Mode)

Angle (°) **= data * 180/2^{15}**

Magnetic Field

Mag (Gauss) **= data * 1.25 * 1.5/2^{15}**

7 Appendix C. Hard and Soft Iron Calibration

7.1 Hard/Soft Iron Calibration Introduction

The AHRS500CA will need to be calibrated for hard and soft iron compensation before use with the aircraft. The AHRS500CA series use magnetic sensors to compute heading. Ideally, the magnetic sensors would be measuring only earth's magnetic field to compute the heading angle. In the real world, however, residual magnetism in the AHRS500CA itself and in your system will add to the magnetic field measured by the AHRS500CA.

The extra magnetic field can create errors in the heading measurement if they are not compensated. These extra magnetic fields are called hard iron magnetic fields. In addition, magnetic material can change the direction of the magnetic field as a function of the input magnetic field. This dependence of the local magnetic field on input direction is called the soft iron effect. The AHRS500CA measures any extra constant magnetic field that is associated with the AHRS500CA or your aircraft and corrects for it during the calibration procedure. The AHRS500CA can also make a correction for some soft iron effects. The process of measuring these non-ideal effects and correcting for them is called hard iron and soft iron calibration. Calibration will help correct for magnetic fields that are fixed with respect to the AHRS500CA. It cannot compensate for time varying fields, or fields created by parts that move with respect to the AHRS500CA.

The AHRS500CA accounts for the extra magnetic field by making a series of measurements. The AHRS500CA uses these measurements to model the hard iron and soft iron environment in your aircraft.

7.2 AHRS500CA Hard and Soft Iron Calibration Procedure

The hard and soft iron calibration procedure is performed in place on the aircraft using the calibration/maintenance cable provided, a portable PC running Windows, and Gyroview software provided by Crossbow Technology, Inc. A switch on the cable provides a signal input to the AHRS500CA commanding it to enter the hard iron calibration process. The aircraft will then need to be rotated through a complete circle(s) while monitoring the BIT status using the Gyroview software. The calibration software will determine when an adequate set of calibration data has been acquired and notify the user through the BIT status. The entire procedure may take several rotations of the aircraft to collect sufficient data.

For best accuracy, you should do the calibration process with the AHRS500CA installed in your system. If you do the calibration process with the AHRS500CA by itself, you will only correct for the magnetism internal to the AHRS500CA. If you then install the AHRS500CA in a aircraft and the magnetic environment is different, you will still see errors arising from the magnetism of the aircraft environment.

7.2.1 Equipment Needed

The following equipment and software is needed to perform the hard and soft iron calibration:

- **1 CD with GyroView Software, Rev 2.2 or later**

  GyroView will allow you to immediately view the outputs of the AHRS500CA on a PC running Microsoft® Windows™. You can also download this software from Crossbow's web site at http://www.xbow.com.

- **1 Calibration/Maintenance Cable.**

  This links the AHRS500CA directly to a serial port on a PC running Microsoft Windows for installation and maintenance functions independent of the aircraft wiring harness.

- **1 Portable computer**

  The computer should be a portable "laptop" style if possible with a serial port and Windows 95/98/2000/XP type operating system. The following are minimum capabilities that your computer should have to run GyroView successfully:

  CPU: Pentium-class

  RAM Memory: 32MB minimum, 64MB recommended

  Hard Drive Free Memory: 15MB

  Operating System: Windows 95, 98, NT4, 2000

7.2.2 Installation and Calibration Cable Connections

The AHRS500CA is shipped with an installation and calibration cable to connect the unit to a PC communications port.

1. Connect the 15-pin female end of the calibration cable to the port on the AHRS500CA.
2. Connect the 15-pin male end of the calibration cable to the wiring harness connector.
3. Connect the 9-pin end of the cable to the serial port of your computer.
4. The calibration switch on the cable should be set to OFF. Powering up the unit with the switch in the ON position will erase the magnetometer calibration.

WARNING

Do not reverse the power leads

5. With the AHRS500CA connected to your PC serial port and powered, open the GyroView software.
6. GyroView should automatically detect the AHRS500CA and display the serial number and firmware version if it is connected.
7. If GyroView does not connect, check that you have the correct COM port selected. You find this under the "DMU" menu.
8. If the status indicator says, "Connected", you're ready to go. If the status indicator doesn't say connected, check the connections between the AHRS500CA and the computer; check the power; check the serial COM port assignment on your computer.
9. Let the AHRS500CA warm up for 90 seconds when first turned on. This allows the Kalman filter to estimate the rate sensor biases. Now you're ready to calibrate the AHRS500CA.

7.3 Calibration Process

The BIT status display in GyroView will be used to indicate the progress of the magnetometer compensation calibration. Four bits of the BIT status display are used for evaluating the hard iron calibration:

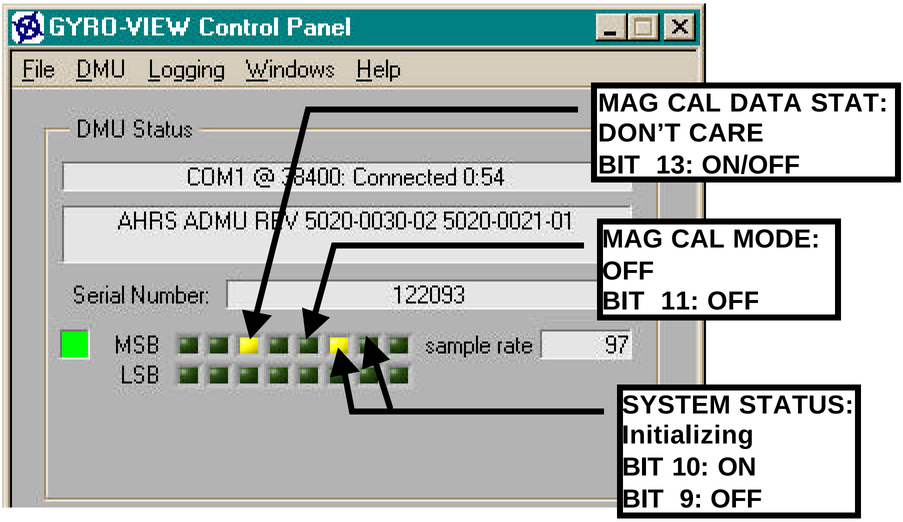
Bits 9 and 10 comprise a two-bit field that shows the state of the attitude algorithm in the AHRS500CA

Bit 11 shows the mag cal mode

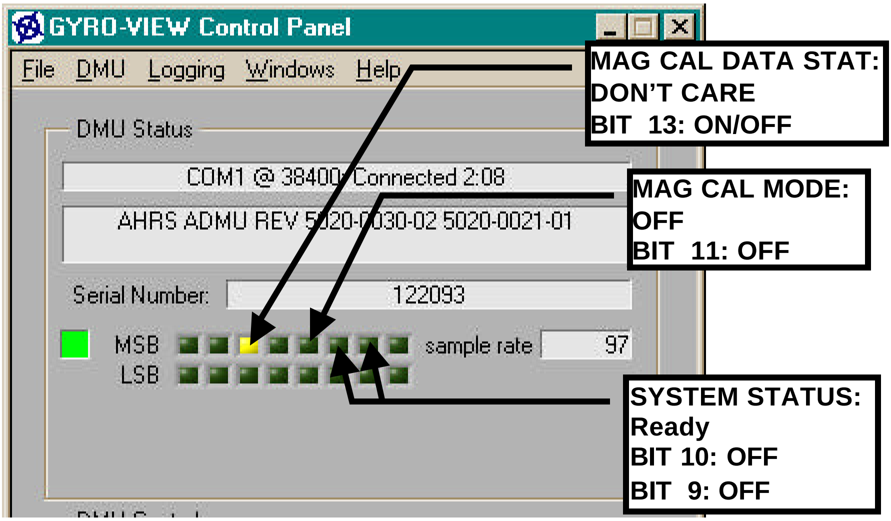
Bit 13 shows the mag calibration data status

7.3.1 Starting the Calibration

If the power has been applied less than approximately 90 seconds, the Gyro View BIT display will indicate that the AHRS500CA is initializing:

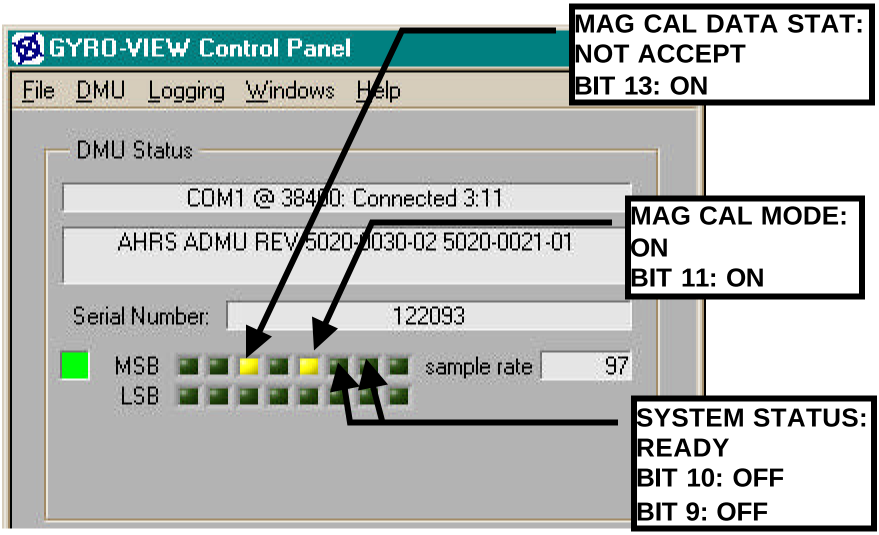


After approximately 90 seconds, the AHRS500CA will complete the initialization mode and change to the ready mode. At this time, the following BIT status should be displayed:



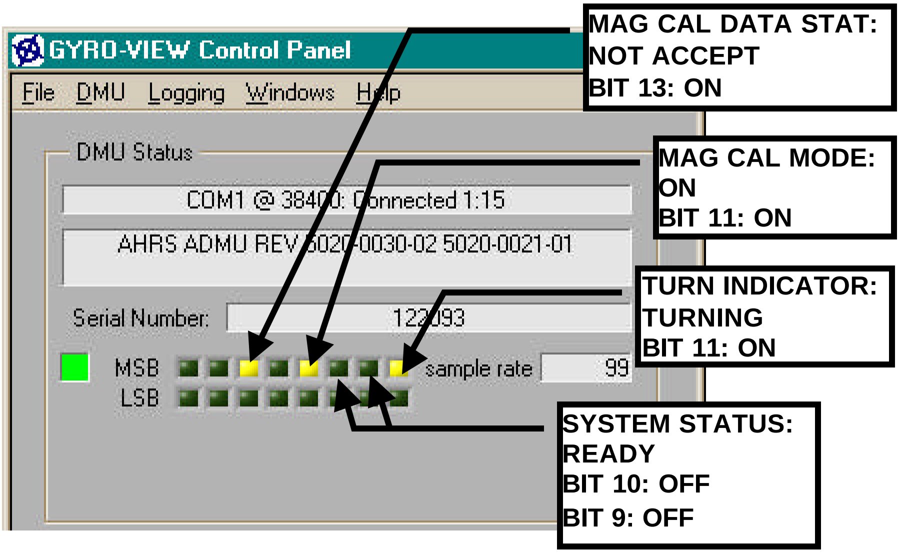
7.3.2 Switch to Mag Cal Mode

Start the magnetic calibration by moving the calibration switch on the calibration/maintenance cable to the ON position. The AHRS500CA will use all the subsequent measurements while the switch is in the ON position to model the magnetic environment. At this time, the following BIT status should be displayed:

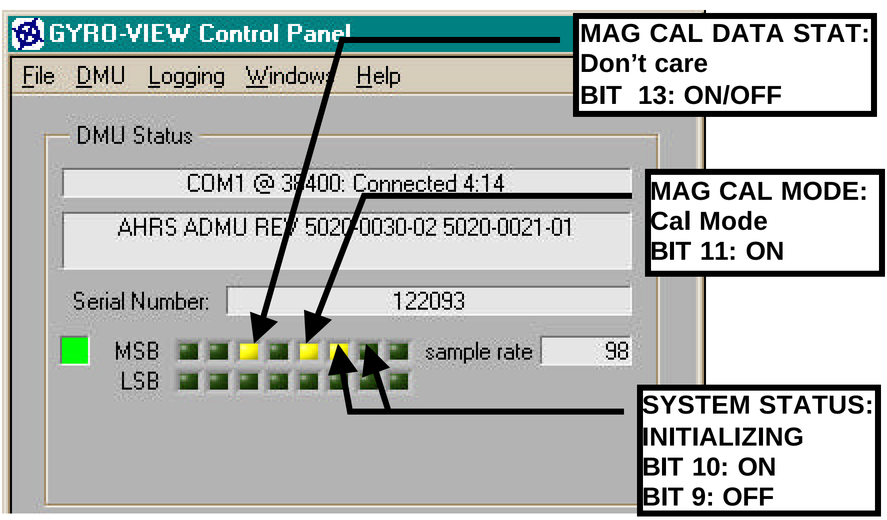


7.3.3 Collecting Calibration Data

Make one complete turn, with the aircraft close to level on the tarmac, compass rose, etc. The aircraft does not have to be perfectly level, as the algorithm will compensate for any angle offsets, but running the test with the aircraft as close to level as possible will ease the process. The AHRS500CA monitors the data and calculates when a full turn is completed. At the completion of the full circle, the AHRS500CA will reset itself into initialization mode and apply the estimated magnetometer calibration parameters. The turn indicator bit will come on while the AHRS500CA is being moved through the turn and the GyroView BIT status panel will have the following appearance during the turn:



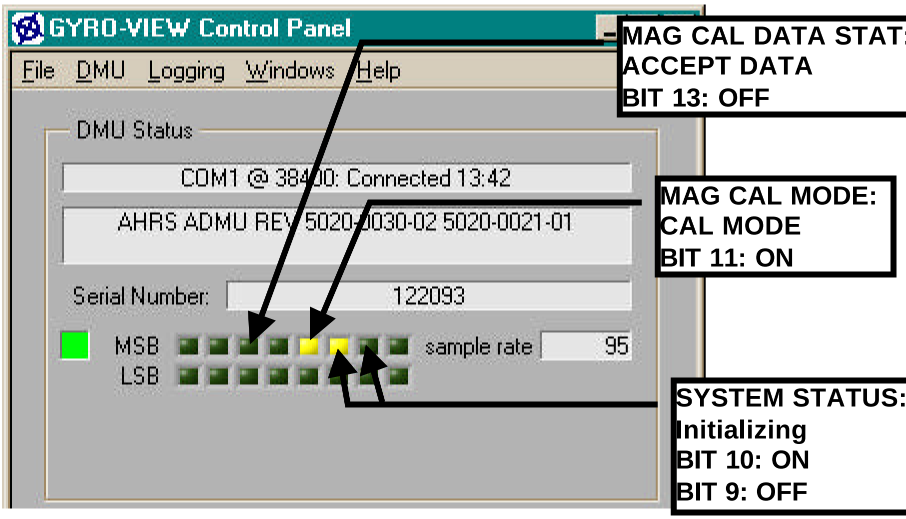
When the circle is completed, the following Gyro View BIT status should be displayed indicating the unit has made a full turn and is applying the estimated calibration. You should stop the rotation motion once the system status bits show the unit has reinitialized.



7.3.4 Evaluating Calibration Data

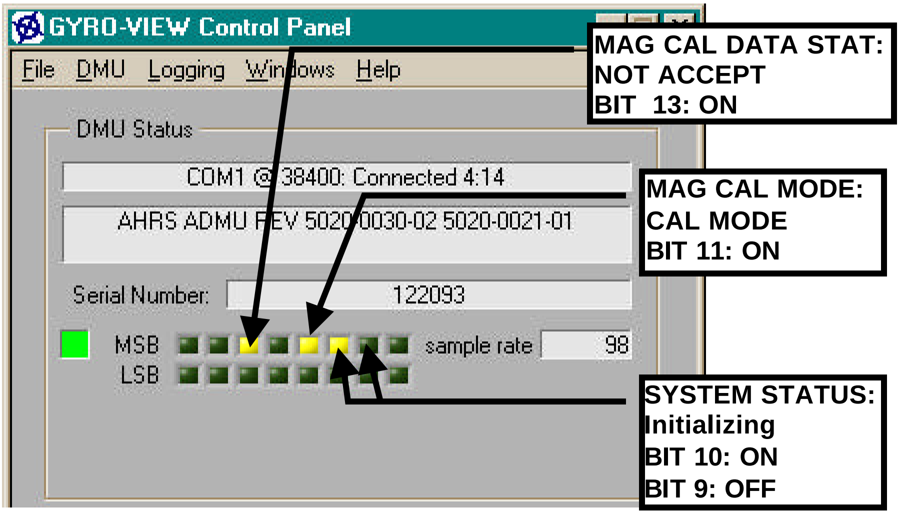
At this point, you should also monitor the Mag Cal Data Status bit 13 of the BIT word.

If the magnetometer compensation is adequate, the following BIT status should be displayed:

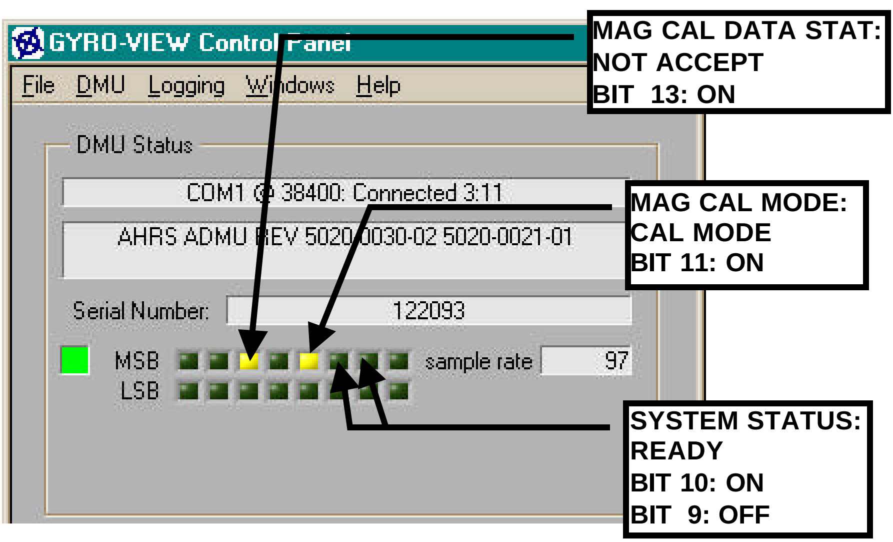


If the Mag Cal Data Status Bit is OFF as shown above, the data collected is adequate for the magnetometer calibration. No further aircraft motion is required. Proceed to the paragraph titled " Completing the Calibration."

If the magnetometer compensation data collection is not adequate, the mag cal data status bit (13) will still be ON and the following BIT status will be displayed:



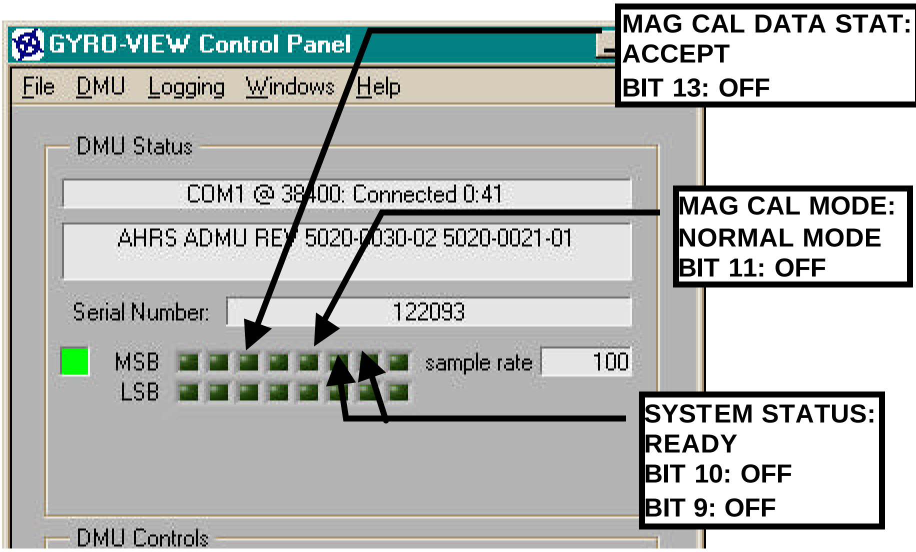
The Mag Cal Data Status Bit ON indicates that the compensation is not yet optimized and more calibration data needs to be collected. It won't usually signal a successful calibration after the first turn, unless the magnetic environment is extremely clean. Wait for the AHRS500CA to complete its initialization. At the end of the initialization, approximately 90 seconds, the following BIT status should be displayed:



Repeat the "collecting calibration data" paragraph above, making another complete turn circle with the aircraft. Always turn the aircraft the same direction as the first turn. After the complete turn, the system will again reinitialize, and apply the latest estimates of the calibration parameters as described in the "Evaluating Calibration Data" paragraph. Continue repeating the cycle of turning the aircraft until initialization mode is indicated, looking at the mag cal data status bit for adequate data, and then waiting for the ready status (~90 seconds) before turning the aircraft again. In this way, the calibration algorithm continues to refine itself until it achieves a successful calibration.

7.3.5 Completing the Calibration

At this point, the AHRS500CA has collected enough data for a good magnetometer compensation calibration. Move the calibration switch on the maintenance/calibration cable to the OFF position. The AHRS500CA will now store these as calibration constants in the EEPROM for use upon subsequent power cycles. The Gyro View BIT status display should look like:



7.3.6 Testing the Calibration

The heading calibration can be tested by comparing the heading output of the AHRS500CA against a known reference (compass or compass markers).

8 Appendix E. Warranty and Support Information

8.1 Customer Service

As a Crossbow Technology customer you have access to product support services, which include:

- Single-point return service
- Web-based support service
- Same day troubleshooting assistance
- Worldwide Crossbow representation
- Onsite and factory training available
- Preventative maintenance and repair programs
- Installation assistance available

8.2 Contact Directory

United States:	Phone:	1-408-965-3300 (7 AM to 7 PM PST)
	Fax:	1-408-324-4840 (24 hours)
	Email:	techsupport@xbow.com
Non-U.S.:	refer to website	www.xbow.com

8.3 Return Procedure

8.3.1 Authorization

Before returning any equipment, please contact Crossbow to obtain a Returned Material Authorization number (RMA).

Be ready to provide the following information when requesting a RMA:

- Name
- Address
- Telephone, Fax, Email
- Equipment Model Number
- Equipment Serial Number
- Installation Date
- Failure Date
- Fault Description
- Will it connect to GyroView?

8.3.2 Identification and Protection

If the equipment is to be shipped to Crossbow for service or repair, please attach a tag TO THE EQUIPMENT, as well as the shipping container(s), identifying the owner. Also indicate the service or repair required, the problems encountered, and other information considered valuable to the service facility such as the list of information provided to request the RMA number.

Place the equipment in the original shipping container(s), making sure there is adequate packing around all sides of the equipment. If the original shipping containers were discarded, use heavy boxes with adequate padding and protection.

8.3.3 Sealing the Container

Seal the shipping container(s) with heavy tape or metal bands strong enough to handle the weight of the equipment and the container.

8.3.4 Marking

Please write the words, "***FRAGILE, DELICATE INSTRUMENT***" in several places on the outside of the shipping container(s). In all correspondence, please refer to the equipment by the model number, the serial number, and the RMA number.

8.3.5 Return Shipping Address

Use the following address for all returned products:

Crossbow Technology, Inc.
41 Daggett Drive
San Jose, CA 95134
Attn: RMA Number (XXXXXX)

8.4 Warranty

The Crossbow product warranty is one year from date of shipment.

Crossbow Technology, Inc.
41 Daggett Drive
San Jose, CA 95134
Phone: 408.965.3300
Fax: 408.324.4840
Email: info@xbow.com
Website: www.xbow.com