AHRS300 Series User's Manual

AHRS300CA-

(DMU-AHRS)

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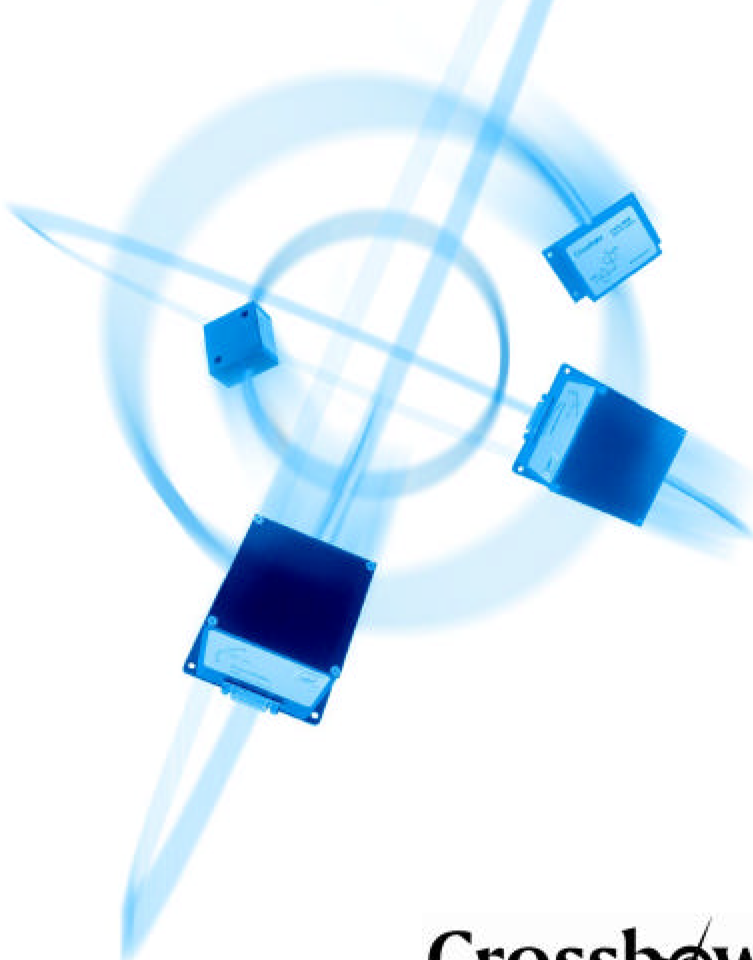

Crossbow

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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 AHRS Series Motion and Attitude Sensing Units

This manual explains the use of the AHRS300CA, a nine-axis measurement system designed to measure stabilized pitch, roll and yaw angles in a dynamic environment.

The AHRS300CA is a nine-axis measurement system that combines linear accelerometers, rotational rate sensors, and magnetometers. The AHRS 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 AHRS to make a true measurement of magnetic heading.

The AHRS300CA is the solid-state equivalent of a vertical gyro/artificial horizon display combined with a directional gyro.

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

All DMU products have both an analog output and an RS-232 serial link. Data may be requested via the serial link as a single polled measurement or may be streamed continuously. The analog outputs are fully conditioned and may be connected directly to an analog data acquisition device.

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

The AHRS300CA 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 AHRS both responsive and reliable. The magnetic sensors are state-of-the-art miniature fluxgate sensors. Fluxgate sensors make the AHRS sensitive and responsive, with better temperature performance than other technologies such as magneto-resistive sensors.

The AHRS300CA should not be exposed to large magnetic fields. This could permanently magnetize internal components of the AHRS and degrade its magnetic heading accuracy.

1.2 Package Contents

In addition to your DMU sensor product you should have:

- **1 CD with GyroView Software**

  GyroView will allow you to immediately view the outputs of the DMU on a PC running Microsoft® Windows95™ or WindowsNT™. You can also download this software from Crossbow's web site at http://www.xbow.com.

- **1 Digital Signal Cable.**

  This links the DMU directly to a serial port. Only the transmit, receive, power, and ground channels are used. The analog outputs are not connected.

- **1 DMU Calibration Sheet**

  The Digital Calibration Sheets contains the custom offset and sensitivity information for your DMU. The calibration sheet is not needed for normal operation as the DMU has an internal EEPROM to store its calibration data. However, this information is useful when developing your own software to correctly scale the output data. Save this page!

- **1 DMU Data Sheet**

  This contains valuable digital interface information including data packet formats and conversion factors.

2 Quick Start

2.1 GyroView Software

Crossbow includes GyroView software to allow you to use the DMU right out of the box and the evaluation is straightforward. Install the GyroView software, connect the DMU 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 6 Runtime Engine. You will need both these applications.

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

2.2 Connections

The DMU is shipped with a cable to connect the DMU to a PC communications port.

1. Connect the 15-pin end of the digital signal cable to the port on the DMU.
2. Connect the 9-pin end of the cable to the serial port of your computer.
3. Connect the additional black and red wires on the cable supply power to the DMU. Match red to (+) power and black to (-) ground. The input voltage can range from 8 - 30 VDC at 275 mA for the AHRS300CA. For further information, see the specifications for your unit.

WARNING

Do not reverse the power leads! Applying the wrong power to the DMU can damage the unit; Crossbow Technology is not responsible for resulting damage to the unit.

NOTE

The analog outputs from the DMU are unconnected in this cable.

2.3 Setup GyroView

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

1. GyroView should automatically detect the DMU 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 DMU 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 DMU 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 DMU, 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 DMU.

Let the DMU warm up for 30 seconds when you first turn it on. You should zero the rate sensors when you first use the DMU. Set the DMU down in a stable place. On the main control panel, enter a value into the "zero ave time" box. "50" will work well. Click the "Z" button. This measures the rate sensor bias and sets the rate sensor outputs to zero. The average time determines the number of samples for averaging. 1 unit equals 10 samples at the ADC sampling rate. For normal applications, your average time should be at least 20. The "zero" command is discussed more in "The 'Zero' Command" section. Now you're ready to use the DMU!

3 AHRS300CA Details

3.1 AHRS300CA Coordinate System

The AHRS300CA will have a sticker on one face illustrating the DMU 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 DMU

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

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

The axes form an orthogonal right-handed coordinate system. An acceleration is positive when it is oriented towards the positive side of the coordinate axis. For example, with the DMU 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 this is defined as positive for the DMU 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 DMU 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 DMU has a female DB-15 connector. The signals are as shown in Table 1.

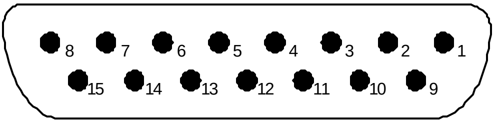


Table 1. AHRS300CA Connector Pin Out

Pin	Signal
1	RS-232 Transmit Data
2	RS-232 Receive Data
3	Positive Power Input (+Vcc)
4	Ground
5	X-axis accelerometer Analog voltage[1]
6	Y-axis accelerometer Analog voltage[1]
7	Z-axis accelerometer Analog voltage[1]
8	Roll rate analog voltage[2]
9	Pitch rate analog voltage[2]
10	Yaw rate analog voltage[2]
11	Timing Pulse
12	Roll angle/X-axis magnetometer scaled analog voltage[3]
13	Pitch angle/Y-axis magnetometer scaled analog voltage[3]
14	Yaw angle/Z-axis magnetometer scaled analog voltage[3]
15	Unused

Notes:

1. The accelerometer analog voltage outputs are the raw sensor output. These outputs are taken from the output of the accelerometers.
2. The rate sensor analog voltage outputs are scaled to represent °/s. These outputs are created by a D/A converter.
3. Actual output depends on DMU measurement mode. These outputs are created by a D/A converter.

All analog outputs are fully buffered and are designed to interface directly to data acquisition equipment.

The serial interface connection is standard RS-232. On a standard DB-25 COM port connector, make the connections per Table 2.

Table 2. DB-25 COM Port Connections

COM Port Connector			DMU Connector	
Pin #	Signal		Pin #	Signal
2	TxD		2	RxD
3	RxD		1	TxD
7	GND*		4	GND*

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

On a standard DB-9 COM port connector, make the connections per Table 3.

Table 3. DB-9 COM Port Connections

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

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

Power is applied to the DMU on pins 3 and 4. Pin 4 is ground; Pin 3 should have 8-30 VDC unregulated at 275 mA. If you are using the cable supplied with the DMU, the power supply wires are broken out of the cable at the DB-9 connector. The red wire is connected to VCC; the black wire is connected to the power supply ground. DO NOT REVERSE THE POWER LEADS.

The analog outputs are unconnected in the cable Crossbow supplies. The analog outputs are fully buffered and conditioned and can be connected directly into an A/D. The analog outputs require a data acquisition device with an input impedance of 10kΩ or greater.

3.3 Interface

The serial interface is standard RS-232, 38400 baud, 8 data bits, 1 start bit, 1 stop bit, no parity, and no flow control.

Crossbow will supply DMU communication software examples written in LabView. Source code for the DMU serial interface can be obtained via the web at http://www.xbow.com. The source code has a .vi file format and requires a National Instruments LabView 5.0 or newer license to use.

The DMU baud rate can be changed per the following procedure:

1. Start with the DMU connected to the serial interface, with your software set to the default baud rate of 38400.
2. Send the ASCII character "b" (0x62 hex) to the DMU. In a terminal program like Windows HyperTerminal or ProComm, this means simply type the letter "b". The DMU is case sensitive. The DMU will respond "B" (0x42 hex).
3. Now change the baud rate of your terminal software.
4. Send the ASCII character "a" (61 hex). The DMU will detect the character and automatically match the baud rate your software is using. Upon successful operation, the DMU will return the character "A" (0x41 hex) at the new baud rate.
5. You can now use the DMU at the new baud rate.

The new baud rate setting is not permanent; therefore, this process must be repeated after any power reset.

3.4 Measurement Modes

The AHRS300CA is designed to operate as a complete attitude and heading reference system. You can also use the DMU as a nine-axis sensor module. The AHRS can be set to operate in one of three modes: voltage mode, scaled sensor mode, or angle (VG) mode. The measurement mode selects the information that is sent in the data packet over the RS-232 interface. See the "Data Packet Format" section for the actual structure of the data packet in each mode.

3.4.1 Voltage Mode

In voltage mode, the analog sensors are sampled and converted to digital data with 1 mV resolution. The digital data represents the direct voltage output of the sensors. The data is 12-bit, unsigned. The value for each sensor is sent as 2 bytes in the data packet over the serial interface. A single data packet can be requested using a serial poll command or the DMU can be set to continuously output data packets to the host.

The voltage data is scaled as:

$$\textbf{voltage} = \textbf{data}*(5\text{ V})/2^{12}$$

where **voltage** is the voltage measured at the sensor, and **data** is the value of the unsigned 16-bit integer in the data packet. Note that although the data is sent as 16-bit integers, the data has a resolution of only 12 bits.

The DMU rate sensor, magnetometer, and angle analog outputs are **not** enabled in this mode. Only the linear accelerometer analog outputs on pins 5 - 7 are enabled because these signals are taken directly from the accelerometers. See the "Analog Output" section for a complete description of the analog outputs.

3.4.2 Scaled Sensor Mode

In scaled sensor mode, the analog sensors are sampled, converted to digital data, temperature compensated, corrected for misalignment, and scaled to engineering units. The digital data represents the actual value of the quantities measured. A calibration table for each sensor is stored in the DMU non-volatile memory. A single data packet can be requested using a serial poll command or the DMU can be set to continuously output data packets to the host. The data is sent as signed 16-bit 2's complement integers. In this mode, the AHRS300CA operates as a nine-axis measurement system.

The scaled sensor analog outputs are enabled in this mode. Note that stabilized pitch, roll, and yaw angles are not available in scaled sensor mode. See the "Analog Output" section for a complete description of the analog outputs.

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

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

where **accel** is the actual measured acceleration in G's, **data** is the digital data sent by the DMU, and **GR** is the G Range for your DMU. (The data is scaled so that 1 G = 9.80 m s^{-2}.) The G range of your DMU is the range of accelerations your DMU will measure. For example, if your DMU uses a ± 2 G accelerometer, then the G range is 2.

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

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

where **rate** is the actual measured angular rate in °/sec, **data** is the digital data sent by the DMU, and **AR** is the Angular rate Range of the DMU. The angular rate range of your DMU is the range of angular rates your DMU will measure. For example, if your DMU uses ± 150 °/s rate sensors, then the **AR** range is 150.

To convert the acceleration data into Gauss, use the following conversion:

$$\textbf{mag} = \textbf{data}*(\textbf{MR}*1.5)/2^{15}$$

where **mag** is the actual measured magnetic field in Gauss, **data** is the digital data sent by the DMU, and **MR** is the Magnetic field Range of the DMU. **MR** is 1.25 for the AHRS300CA.

3.4.3 Angle Mode

In angle mode, the AHRS300CA acts as a complete attitude and heading reference system and outputs the stabilized pitch, roll, and yaw angles along with the angular rate, acceleration, and magnetic field information. The angular rate, acceleration, and magnetic field values are calculated as described in the scaled sensor mode.

The DMU analog outputs are enabled in this mode, including stabilized pitch, roll, and yaw angles.

In angle mode, the AHRS300CA uses the angular rate sensors to integrate over your rotational motion and find the actual pitch, roll, and yaw angles. The DMU uses the accelerometers to correct for rate sensor drift in the vertical angles (pitch and roll); the DMU 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 DMU 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 DMU orientation relative to gravity; the DMU then uses the accelerometers to provide long term stability to keep the rate gyro drift in check.

The AHRS300CA gives you control over the weighting between the accelerometers and rate gyros through a parameter called the "erection rate." This term is derived from analog vertical gyros, and refers to the rate at which the system can pull the gyro spin axis back to vertical as measured by gravity. With a small erection rate, you are depending more on the rate gyros than the accelerometers; with a large erection rate, you are forcing the rate gyros to follow the accelerometer measurement of vertical more closely. In general, for dynamic measurements, you will want a low erection rate. But the erection rate should always be greater than the drift rate of the rate gyros. The erection rate is discussed in section 4.2 in more detail.

The AHRS300CA outputs the stabilized pitch, roll and yaw angles in the digital data packet in angle mode. 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 and yaw; **SCALE** = 90° for pitch.

3.5 Commands

The AHRS300CA has a simple command structure. You send a command consisting of one byte to the DMU over the RS-232 interface and the DMU will execute the command.

NOTE

The DMU 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 DMU is functioning correctly. GyroView does not use any commands that are not listed here.

NOTE

Certain combinations of characters not listed here can cause the unit to enter a factory diagnostic mode. While this mode is designed to be very difficult to enter accidentally, it is recommended that the following command set be adhered to for proper operation.

3.5.1 Command List

Command	Reset
Character(s) Sent	R
Response	H
Description	Resets DMU to default state

Command	Voltage Mode
Character(s) Sent	r
Response	R
Description	Changes measurement type to Voltage Mode. DMU outputs raw sensor voltage in the data packet.

Command	Scaled Mode
Character(s) Sent	c
Response	C

Description	Changes measurement type to Scaled Mode. DMU outputs measurements in scaled engineering units.
Command	Angle Mode
Character(s) Sent	a
Response	A
Description	Changes measurement type to Angle (VG) Mode. DMU calculates stabilized pitch and roll. Also outputs sensor measurements in scaled engineering units.
Command	Polled Mode
Character(s) Sent	P
Response	none
Description	Changes data output mo de to Polled Mode. DMU 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. DMU will immediately start to output data packets in continuous mode. Data rate will depend on the measurement type the DMU is implementing (Raw, Scaled or Angle). Sending a "G" will return DMU to Polled Mode.
Command	Request Data
Character(s) Sent	G
Response	Data Packet
Description	"G" requests a single data packet. DMU will respond with a data packet. The format of the data packet will change with the measurement mode (Raw, Scaled or Angle). Sending the

	DMU a "G" while it is in Continuous Mode will place the DMU in Polled Mode.

Command	Set Erection Rate
Character(s) Sent	T<x>
Response	None
Description	The T command sets the vertical gyro erection rate. The argument of the command <x> is a single binary byte that represents the value you want to set as the erection rate. The units are in degrees per minute. For example, if you wanted to set the erection rate to 50 deg/min, you would send the command T<50>, which in hex would be 54 32.

Command	Calibrate Rate Sensor Bias
Character(s) Sent	z<x>
Response	Z
Description	Measure the bias on each rate sensor and set as the new zero. **The DMU should be still (motionless) during the zeroing process.** The argument of the command <x> is a single binary byte that tells the DMU how many measurements to average over. The units are 10 measurements per increment of <x>. For example, to average over 300 measurements, you would send the command z<30>, which in hex is 7A 1E.

Command	Query DMU Version
Character(s) Sent	v
Response	ASCII string
Description	This queries the DMU firmware and will tell you the DMU type and firmware version. The response is an ASCII string that describes the DMU type and firmware version.

Command	Query Serial Number
Character(s) Sent	S
Response	Serial Number Packet
Description	This queries the DMU for its serial number. The DMU will respond with a serial number data packet that consists of a header byte (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	Request Auto Baud Rate
Character(s) Sent	b
Response	-
Description	This starts the auto baud rate detection process. This will allow you to change the DMU baud rate from its default. This change will not affect the default settings. 1. Start with communications program and DMU at same baud rate. 2. Send "b" to the DMU. The DMU will respond with "B". 3. Change the baud rate of your communications program. 4. Send "a" to the DMU. The DMU will respond with "A" at the new baud rate when a successful detection of the new baud rate is completed.

Remember when sending the T<x> or z<x> command that each command is only two bytes long. For example, to tell the DMU to zero the rate sensors and average over 50 units, you would send two bytes 7A,32 (hex). 7A is the hex value of the ASCII "z" character, and 32 is the number 50 in hex. (The DMU averages over 10 samples for each unit in the z command.)

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.

In scaled and angle mode, the timer information and temperature sensor voltage are sent as unsigned integers.

The order of data sent will depend on the selected operating mode of the AHRS300CA.

Each data packet will begin with a header byte (255) 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 256.
3. The remainder should equal the checksum.

NOTE

The header byte FF will likely not be the only FF byte in the data packet. You must count the bytes received at your serial port and use the checksum to ensure you are in sync with the data sent by the DMU. This is especially critical when using the continuous data packet output mode.

Table 4 shows the data packet format for each mode.

Table 4. AHRS300CA Data Packet Format

Byte	VG Mode	Scaled Sensor Mode	Voltage Mode
0	Header (255)	Header (255)	Header (255)
1	Roll Angle (MSB)	Roll Angular Rate (MSB)	Roll Gyro Voltage (MSB)
2	Roll Angle (LSB)	Roll Angular Rate (LSB)	Roll Gyro Voltage (LSB)
3	Pitch Angle (MSB)	Pitch Angular Rate (MSB)	Pitch Gyro Voltage (MSB)
4	Pitch Angle (LSB)	Pitch Angular Rate (LSB)	Pitch Gyro Voltage (LSB)
5	Heading Angle (MSB)	Yaw Angular Rate (MSB)	Yaw Gyro Voltage (MSB)
6	Heading Angle (LSB)	Yaw Angular Rate (LSB)	Yaw Gyro Voltage (LSB)
7	Roll Angular Rate (MSB)	X-Axis Acceleration (MSB)	X-Axis Accel Voltage (MSB)
8	Roll Angular Rate (LSB)	X-Axis Acceleration (LSB)	X-Axis Accel Voltage (LSB)
9	Pitch Angular Rate (MSB)	Y-Axis Acceleration (MSB)	Y-Axis Accel Voltage (MSB)
10	Pitch Angular Rate (LSB)	Y-Axis Acceleration (LSB)	Y-Axis Accel Voltage (LSB)
11	Yaw Angular Rate (MSB)	Z-Axis Acceleration (MSB)	Z-Axis Accel Voltage (MSB)
12	Yaw Angular Rate (LSB)	Z-Axis Acceleration (LSB)	Z-Axis Accel Voltage (LSB)
13	X-Axis Acceleration (MSB)	X-Axis Magnetic Field (MSB)	X-Axis Mag Voltage (MSB)
14	X-Axis Acceleration (LSB)	X-Axis Magnetic Field (LSB)	X-Axis Mag Voltage (LSB)
15	Y-Axis Acceleration (MSB)	Y-Axis Magnetic Field (MSB)	Y-Axis Mag Voltage (MSB)
16	Y-Axis Acceleration (LSB)	Y-Axis Magnetic Field (LSB)	Y-Axis Mag Voltage (LSB)
17	Z-Axis Acceleration (MSB)	Z-Axis Magnetic Field (MSB)	Z-Axis Mag Voltage (MSB)
18	Z-Axis Acceleration (LSB)	Z-Axis Magnetic Field (LSB)	Z-Axis Mag Voltage (LSB)
19	X-Axis Magnetic Field (MSB)	Temp Sensor Voltage (MSB)	Temp Sensor Voltage (MSB)
20	X-Axis Magnetic Field (LSB)	Temp Sensor Voltage (LSB)	Temp Sensor Voltage (LSB)
21	Y-Axis Magnetic Field (MSB)	Time (MSB)	Time (MSB)
22	Y-Axis Magnetic Field (LSB)	Time (LSB)	Time (LSB)
23	Z-Axis Magnetic Field (MSB)	Checksum	Checksum
24	Z-Axis Magnetic Field (LSB)		
25	Temp Sensor Voltage (MSB)		
26	Temp Sensor Voltage (LSB)		
27	Time (MSB)		
28	Time (LSB)		
29	Checksum		

3.7 Timing

The maximum AHRS data update rate is 75 samples per second.

In some applications, using the DMU's digital output requires a precise understanding of the internal timing of the device. The processor internal to the DMU 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 DMU will make another measurement while presenting the current measurement for output. Third, the unit actually transfers the data out; either over the RS-232 port, or onto the analog outputs.

In the case of the analog output, the data is presented immediately on the analog output pins after the data processing step is over. In the case of the digital data, the data is transferred only if the previous data packet is cleared. The DMU continues to take data, so that in practice, roughly every third measurement will be available over the RS-232 interface.

A time tag is attached to each data packet. The time tag is simply the value of a free running counter at the time the A/D channels are sampled. The clock counts down from 65535 to 0, and a single tick corresponds to 0.79 microseconds. The timer rolls over approximately every 50 milliseconds. You can use this value to track relative sampling time between data packets, and correlate this with external timing.

3.8 Temperature Sensor

The AHRS300CA has an onboard temperature sensor. The temperature sensor is used to monitor the internal temperature of the DMU to allow for temperature calibration of the sensors. The temperature sensor is specified to be within ± 2% accurate over the DMU operating temperature range. The DMU reads and outputs the temperature sensor voltage with 12-bit precision.

The DMU will output the temperature sensor voltage in the digital data packet scaled as follows:

$$\mathbf{V_{temp}}\,(V) = \mathbf{data} * 5/4096$$

where **data** is the 16-bit unsigned integer sent as the temperature information in the data packet. (The DMU uses two full bytes to express the data, but it is really scaled to 12 bits.)

Calculate the temperature with the following calibration:

$$\mathbf{T}\ (°C) = 44.4\ (°C/V) * (\mathbf{V_{temp}}\ (V) - 1.375\ V)$$

The DMU temperature sensor is internal to the DMU, and is not intended to measure the ambient temperature. The internal temperature of the DMU may be as much as 15°C higher than the ambient temperature.

3.9 Analog Output

The AHRS300CA provides nine fully conditioned analog outputs; of these, six are output voltages created by a DAC in the DMU. The analog signals can be connected directly to an ADC or other data acquisition device without further buffering. The input impedance of any data acquisition device should be greater than 10 kΩ.

The DMU must be set to scaled sensor measurement mode or angle measurement mode to enable the analog signals.

The analog outputs from the accelerometers are taken directly from the sensor through a buffer. They are "raw" in the sense that they do not represent a calculated or calibrated value. You will need the zero bias point and scale factor given on the DMU calibration sheet to turn the analog voltage into an acceleration measurement.

To find the acceleration in G's, use the following conversion:

$$\mathbf{accel}\ (G) = (\mathbf{V_{out}}\ (V) - \mathbf{bias}\ (V)) * \mathbf{sensitivity}\ (G/V)$$

where **accel** is the actual acceleration measured, $\mathbf{V_{out}}$ is the voltage at the analog output, **bias** is the zero-G bias voltage, and **sensitivity** is the scale factor in units G/volts. This applies only to the signals on pins 5, 6, and 7.

For example, if the x-axis of your accelerometer has a zero-G bias of 2.512 V, a sensitivity of 1.01 G/V, and you measure 2.632 V at the analog output, the actual acceleration is (2.632 V – 2.512 V)*1.01 G/V = 0.121 G.

The analog outputs for the angular rate signals are not taken directly from the rate sensors; they are created by a D/A converter internal to the DMU. The output range is +/- 4.096V with 12-bit resolution. The analog data will represent the actual measured quantities, in engineering units, not the actual voltage at the sensor output. To convert the analog output to a sensor value use the following relation:

$$\mathbf{rate} = \mathbf{AR} * 1.5 * \mathbf{V_{out}}\ (V) / 4.096\ V$$

where **rate** is the actual measured rate in units °/s, **AR** is the angular rate range of the sensor and $\mathbf{V_{out}}$ is the measured voltage at the analog output.

For example, if your DMU has a ±100 °/s rate sensor, and the analog output for that sensor is –1.50 V, the value of the measurement is 100 (°/s)*1.5*(-1.50)/4.096 = -54.9 °/s.

In scaled measurement mode, pins 12 – 14 represent the magnetic vector measured by the DMU. To convert the voltage to magnetic field in Gauss, use the following relation:

$$\mathbf{mag} = \mathbf{MR} * 1.5 * \mathbf{V_{out}} (V) / 4.096\ V$$

where **mag** is the magnetic field measured along that axis, **MR** is the magnetometer range, and $\mathbf{V_{out}}$ is the voltage measured at the analog output. **MR** is 1.25 for the AHRS300CA.

In angle mode, the AHRS300CA outputs the pitch, roll, and yaw angles on pins 12 - 14. The analog outputs are created by the D/A. The voltage output will be in the range ± 4.096 V. The output is scaled so that full scale is 180° for both roll and yaw. Pitch is scaled so that full scale is 90°. To convert the voltage to an actual angle, use the following conversion:

$$\mathbf{angle} = \mathbf{FA} * \mathbf{V_{out}} (V) / 4.096\ V$$

where **angle** is the actual pitch, roll or yaw angle in degrees, **FA** is the full-scale angle, and $\mathbf{V_{out}}$ is the analog voltage measured. **FA** is 180° for roll and yaw; **FA** is 90^0 for pitch.

3.10 Magnetic Heading

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

The AHRS300CA 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 AHRS magnetic heading into a heading referenced to true north.

4 AHRS300CA Operating Tips

4.1 The "Zero" Command

The "z<x>" command is used to zero the angular rate sensor biases. This command does not "zero" the angle output! This should be an essential part of your strategy in using the DMU effectively. Stabilized pitch and roll angles are calculated by integrating the output of the angular rate sensors. Rate sensors are subject to small offsets in the angular rate measurement. A constant offset error in angular rate will integrate into an error in angle that increases linearly with time -- angular drift. The AHRS300CA uses accelerometers to correct the calculated angle, but in a dynamic situation, the accelerometers will be an inaccurate indication of the angle due to motional accelerations. The DMU rate sensors should therefore be zeroed to maintain the best accuracy.

Zeroing the rate sensors allows you to use a smaller value for the erection rate (T-Setting), which gives you better performance in dynamic environments.

The rate sensors need to be zeroed more often when subject to large shocks or extremes of temperature.

The AHRS300CA unit should be still during the zeroing process, but need not be level. You should let the DMU warm-up for 5 minutes before issuing the zero command. Zeroing the DMU measures the bias in the output of the rate sensors when the DMU is in a condition of zero angular rate, and uses these values of the biases as the new offset calibrations for the rate sensors. The zeroing command does not level the stabilized angle output.

The DMU will average over a number of samples equal to ten times the value of the parameter passed with the "z<x>" command. For example, if you send the DMU the command "z<100>", the DMU will average over 1000 samples. As a rule of thumb, each sample will take 3 – 4 ms. A good value to start with for the averaging command is 200. You would send the two bytes 7A,C8 (hex).

Remember that the DMU does not store the rate sensor zero calibration in non-volatile memory. If you cycle power to the DMU, it loses the zero calibration. Ideally, you would issue the zero command every time you power on the DMU. Also ideally, you would let the DMU warm up for 5 minutes before zeroing the rate sensors.

If you find that the DMU zeroing algorithm does not work well in your particular application, please contact Crossbow to discuss possible options.

4.2 The Erection Rate

The erection rate parameter controls the weighting between the rate gyro sensors and the accelerometers. This is the rate at which the direction of vertical as measured by integrating the rate gyros is forced to agree with the direction of vertical as measured by the accelerometers. The erection rate is specified in degrees per minute. The erection rate must be higher than the drift rate of the rate gyros, or the calculated angles will drift off with increasing error. If the erection rate is too high, however, the calculated angles will be forced to follow the accelerometers too closely. This will lead to inaccuracies when the unit is under dynamic conditions.

One way to start is to set the erection rate about twice as fast as the worst rate gyro drift rate. This is appropriate for a dynamic environment, when the unit will be under significant acceleration. Estimate the drift rate by looking at the offset on the rate gyro output. Use the zero command first to zero the rate gyros. The rate gyro output is in degrees per second; the erection rate is set in degrees per minute. So take the rate gyro offset; multiply by 60 to turn it into degrees per minute; multiply by two and use this as a starting value for the erection rate. As an example, if the rate sensor offset is 0.1 degrees per second, we would set the erection rate to 0.1 x 60 x 2 = 12. The stabilized pitch and roll output will be responsive to actual rotations, and relatively insensitive to linear accelerations.

You can set the T-Setting in a qualitative way using GyroView. Graph the pitch and roll. Zero the rate sensors. Start with the T-Setting at about 100. Lower the T-Setting in increments of 10 – 20 until the roll and/or pitch starts to drift. When the angle outputs start to drift, the T-Setting is just a bit lower than the rate sensor offset. Increase the T-Setting by about 5 each time. This should keep the angle outputs stable.

If you expect the DMU to be subject to changing temperatures, or to have to operate for long periods without re-zeroing, you should increase the T-Setting further. You may have to experiment to find the best erection rate for your situation.

If the DMU is used in a less dynamic environment, the erection rate can be set much higher. The DMU angles will stabilize quicker to the gravity vector. So if the motion is slow, or if you sit in one position for a long time, then you should probably use a high erection rate.

A more advanced approach to the erection rate would take advantage of both regimes of operation. Use a low erection rate when the unit is subject to dynamic motion; use a high erection rate when the unit is relatively stable. You can use the DMU itself to distinguish between the two cases by looking for changes in the accelerometer outputs. For example, in an airplane, you could use a low erection rate when the airplane executes a banked turn; and a high erection rate (100+) when the plane is flying straight and level.

Unfortunately, there is no single ideal erection rate for all applications. We can suggest a starting point based on past experience with similar applications, but you should be prepared to experiment some in the beginning to find the best setup for your DMU in your application.

4.3 Mounting the AHRS300CA

The AHRS300CA 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 DMU accelerometers to measure an acceleration proportional to the product of the angular rate squared and the distance between the DMU and the CG.

The DMU will measure rotations around the axes of its sensors. The DMU sensors are aligned with the DMU case. The sides of the DMU case are used as reference surfaces for aligning the DMU sensor axes with your system. You should align the DMU 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 DMU should be isolated from vibration if possible. 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 AHRS300CA should be isolated from magnetic material as much as possible. Magnetic material will distort the magnetic field near the AHRS, which will greatly affect its accuracy as a heading sensor. Because the DMU 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 AHRS300CA. If you discover something near the DMU 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 DMU. Even small things, such as screws and washers, can have a negative effect on the AHRS performance if they are close. AHRS300CA 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, 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 AHRS300CA. 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 AHRS300CA if you expose the unit to a large magnetic field. You can use a demagnetizer (tape eraser) to demagnetize the DMU if it gets "permed." Follow the instructions for your demagnetizer.

The DMU case is not weatherproof. You should protect the DMU from moisture and dust.

☑ EXAMPLE

4.4 AHRS300CA Start Up Procedure

As an example, look at how the DMU might be used on an airplane. Assume AHRS 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 AHRS is mounted near the CG of the plane, and is connected to a laptop serial port during flight.

1. Turn on power to the DMU and let it warm up 5 – 10 minutes. Power can be on to all electronics, but the engines should be off.
2. Zero the rate sensors. Engines are off, so there is no vibration.
3. Change the T-Setting. After zeroing, you should be able to set the T-Setting in the range 5 – 10 for AHRS300CA.
4. Start the engines.
5. Perform hard iron and soft iron calibration routines (Appendix C).
6. Start data collection.
7. Proceed with flight.

4.5 Advanced Strategies for Adjusting the Erection Rate

The DMU attitude estimation algorithm is divided into two separate entities. Gyro angular rate information is integrated in time to propagate the DMU body attitude with respect to the tangent plane. If the initial attitude of the vehicle was known exactly and if the gyros provided perfect readings then this integration process would suffice. However, the initial state is seldom known to great precision, especially a vehicle's attitude, and the gyros usually provide corrupted data. Rate gyro bias, bias drift, misalignment, acceleration (g-sensitive), nonlinear (square term), and scale factor errors will be present in the angular rate measurements. The largest error is typically associated with the bias and bias drift terms. Without a correction algorithm and separate independent sensors, the attitude estimation algorithm would diverge off the true trajectory. Accelerometers provide the separate measurements, which help keep the attitude estimates on track.

The correction algorithm involves deriving an estimate of the roll and pitch angle from the accelerometer's gravity reference, comparing this estimate to the gyro propagated quaternion Euler angles, and providing a linear feedback gain to the quaternion propagation to take out the errors observed from the gyro angular rate measurements. The correction feedback is also referred to as the "erection rate" implying that the attitude errors are erected out by moving the estimated orientation more towards the absolute attitude measurements derived from the accelerometer measurements. It is also given the name T-Setting to describe the user interface which allows the user to command the DMU to use a desired erection rate. Sensed dynamic accelerations can introduce error into the accelerometer absolute attitude reference. The angle calculation algorithm has no way of knowing whether the sensed acceleration change is being caused by an attitude tilt change in the gravity vector, or from external translational accelerations.

For this reason a user selectable erection rate is available which allows for the possibility of a rapidly maneuvering mission. There is a tradeoff between how much error in the gyros, the algorithm can overcome with a low erection setting, compared to the errors induced from having a high erection rate while experiencing large maneuvering accelerations. The gyro zeroing command is useful in maintaining the gyro bias errors down to a minimum, which allows a lower T-Setting to be used during the mission. It must be noted that for the zeroing command to work properly, there must no external disturbance to the unit (engine noise, wind disturbance, etc.) and it would be advised to perform a gyro zeroing in the initial phase of the mission when only electrical power is available. If the user has knowledge of the intensity of upcoming maneuvers or complete control of the flight profile, and can maintain constant serial communications with the DMU unit, then an adapted erection setting profile can be developed. An example follows.

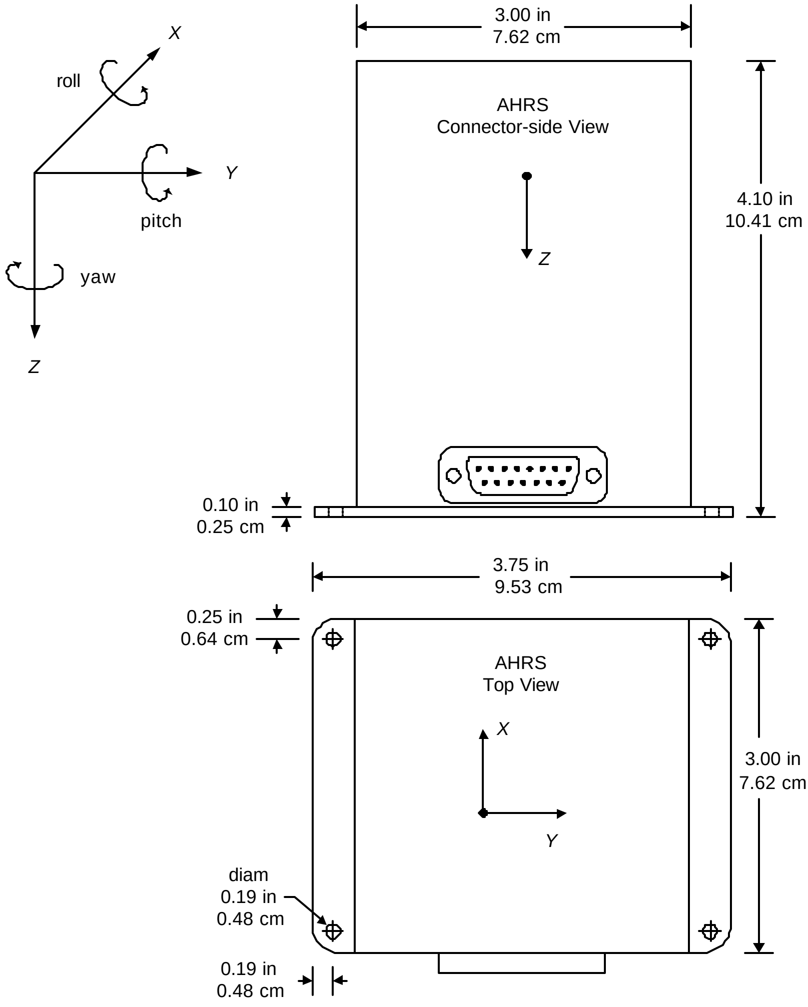
☑ EXAMPLE

4.6 Adapted Flight Profile T-Setting

1. Vehicle electric power is applied to the DMU while the vehicle is out of external disturbances (within the hanger for instance).
2. Following a warm-up period, (10 minutes should suffice) a gyro-zeroing command is sent to the unit to average out the gyro biases.
3. Send a T-setting command to set the erection rate at a high setting (T-setting = 100), which should remove any initial attitude errors or drifts.
4. Engine turn-on and rollout onto the runway.
5. Maneuver 1 (Takeoff and climb to desired altitude) – set the erection rate to a low setting (T-setting = 7).
6. Maneuver 2 (1st Coast Phase) – set the erection rate to a high setting (T-setting=100).
7. Maneuver 3 (45 degree heading change) – set the erection rate to a low setting (T-setting = 7).
8. Maneuver 4 (2nd Coast Phase) – set the erection rate to a high setting (T-setting=100).
9. Maneuver 5 (180 degree turn and altitude change – very fast 20 second maneuver) – set the erection rate to an even lower setting since the maneuver is short and the dynamics are large (T-setting = 4).
10. Maneuver 6 (3rd Coast Phase) – set the erection rate to a very high setting to remove any gyro saturation or acceleration saturation from the previous high dynamic maneuver (T-setting=150), and then set the erection rate back to a high setting (T-setting=100).
11. Maneuver 7 (Altitude descent and landing) – set the erection rate to a low setting (T-setting = 7).
12. Maneuver 8 (Runway taxi and stop) – set the erection rate to a high setting (T-setting = 100).

The profile above can be used as an example to produce an adapted erection rate profile to achieve the best possible performance from the DMU. A constant erection rate would not allow the DMU to perform as well because of the highly dynamic environment. A high erection rate would result in very large errors during the high acceleration maneuvers; a low erection rate might not recover from a large gyro bias drift or saturation of the rate sensors because of very large dynamics. Since every flight profile is different, this approach necessitates careful erection rate profile planning. If enough care is taken, active control of the erection rate will provide the best performance.

5 Appendix A. Mechanical Specifications



6 Appendix B. AHRS300CA Output Quick Reference

GR is the G-range of the accelerometers. For example, if your DMU has ± 2 G accelerometers, GR = 2.

RR is the rate range of the rate sensors. For example, if your DMU has ± 100°/s rate sensors, RR = 100.

6.1 Analog Output Conversion

Accelerometer

Use sensitivity, offset from calibration sheet. Output is raw sensor voltage.

Pin 5	X axis accelerometer, raw
Pin 6	Y axis accelerometer, raw
Pin 7	Z axis accelerometer, raw

Rate Sensor

Rate (°/s) = V_{out} (V) *** RR * 1.5/4.096**

Pin 8	Roll rate sensor
Pin 9	Pitch rate sensor
Pin 10	Yaw rate sensor

Magnetometer (Scaled Mode)

Mag (Gauss) = V_{out} (V) *** 1.25 * 1.5/4.096**

Pin 12	X axis magnetometer
Pin 13	Y axis magnetometer
Pin 14	Z axis magnetometer

Roll, Pitch, Yaw (Angle Mode)

Angle (°) = V_{out} (V) *** FA/4.096**

Pin 12	Roll Angle	FA = 180
Pin 13	Pitch Angle	FA = 90
Pin 14	Yaw angle	FA = 180

6.2 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 * GR * 1.5/**2^{15}

Rate

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

Magnetic Field

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

Roll, Yaw (Angle Mode)

Angle (°) = **data * 180/**2^{15}

Pitch (Angle Mode)

Angle (°) = **data * 90/**2^{15}

Temperature

Temperature (°C) = **[(data * 5/4096) – 1.375]*44.44**

7 Appendix C. Hard and Soft Iron Calibration

7.1 Description

The AHRS300CA uses 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 AHRS itself and in your system will add to the magnetic field measured by the AHRS. This extra magnetic field will create errors in the heading measurement if they are not accounted for. 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 AHRS can actually measure any extra constant magnetic field that is associated with the AHRS or your system and correct for it. The AHRS 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 AHRS. It cannot help for time varying fields, or fields created by parts that move with respect to the AHRS300CA.

The AHRS300CA accounts for the extra magnetic field by making a series of measurements. The AHRS uses these measurements to model the hard iron and soft iron environment in your system. The correction algorithm is two-dimensional. You start the magnetic calibration by sending the "s" command. The AHRS will use all subsequent measurements to model the magnetic environment. You should make at least one complete turn, with your system basically level. For example, in an airplane, do a circle on the taxiway. Multiple turns will slightly improve the estimates, but more than 3 turns is usually not helpful. At the end of this time, send the "u" command to end the magnetic calibration process. The AHRS will calculate the hard iron magnetic fields and soft iron corrections and store these as calibration constants in the EEPROM.

To clear the hard iron calibration constants, send the “h” command. The AHRS300CA will set the hard iron offset corrections to zero. To clear the soft iron calibration constants, send the "t" command. The AHRS will set the soft iron correction parameters to zero. This is useful to see the performance of the bare AHRS in your system.

For best accuracy, you should do the calibration process with the AHRS installed in your system. If you do the calibration process with the AHRS by itself, you will only correct for the magnetism in the AHRS itself. If you then install the AHRS in a vehicle (for instance), and the vehicle is magnetic, you will still see errors arising from the magnetism of the vehicle.

7.2 Command List

Command	Start Soft Iron Calibration
Character(s) Sent	s
Response	S
Description	This command starts the soft iron calibration. The AHRS will remain in calibration mode until it receives the "u" command. While in calibration mode, the AHRS should be rotated through at least one complete turn (360° of rotation) with the system basically level.

Command	End Soft Iron Calibration
Character(s) Sent	u
Response	U
Description	This command ends the soft iron calibration process. The AHRS will store the soft iron calibration constants in its EEPROM. The calibration constants will be applied to all subsequent magnetic measurements.

Command	Clear Hard Iron Calibration
Character(s) Sent	h
Response	H
Description	This command clears the hard iron calibration constants stored in the AHRS EEPROM. The calibration constants will be set to zero.

Command	Clear Soft Iron Calibration
Character(s) Sent	t
Response	T
Description	This command clears the soft iron calibration constants stored in the AHRS EEPROM. The calibration constants will be set to zero.

8 Appendix D. AHRS300CA Command Quick Reference

Command (ASCII)	Response	Description
R	H	Reset: Resets the DMU firmware to default operating mode of Voltage Mode and Polled operation.
r	R	Change to Voltage Mode.
c	C	Change to Scaled Sensor Mode.
a	A	Change to Angle Mode (VG Mode).
P	None	Change to polled mode. Data packets sent when a G is received by the DMU.
C	None	Change to continuous data transmit mode. Data packets streamed continuously. Packet rate is dependent on operating mode. Sending "G" stops data transmission.
G	Data Packet	Get Data. Requests a packet of data from the DMU. Data format depends on operating mode.
T <0-255>*	None	2-byte command sequence that changes the vertical gyro erection rate.
z <0-255>*	Z	Calibrate and set zero bias for rate sensors by averaging over time. 1st byte initiates zeroing process. 2nd byte sets duration for averaging. Unit should be still during zeroing.
S	ASCII String	Query DMU serial number. Returns serial number as 32-bit binary number.
v	ASCII String	Query DMU version ID string. Returns ASCII string.
b	Change baud rate	Autobaud detection. Send "b"; DMU will respond "B"; change baud rate; send "a"; DMU will send "A" when new baud rate is detected.
s	S	Start Soft iron calibration. DMU should be rotated through at least one complete turn (360° of rotation) with the system basically level.
u	U	End Soft iron calibration. Calibration is saved in EEPROM.
h	H	Clear hard iron calibration.
t	T	Clear Soft Iron Calibration

*Argument of command is sent as a single hex byte, not an ASCII character.

9 Appendix E. Warranty and Support Information

9.1 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

9.2 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

9.3 Return Procedure

9.3.1 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?

9.3.2 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.

9.3.3 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.

9.3.4 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.

9.3.5 Return Shipping Address

Use the following address for all returned products:

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

9.4 Warranty

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

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