IMU User's Manual

Models…

IMU300CC-

IMU400CC-

IMU400CD-

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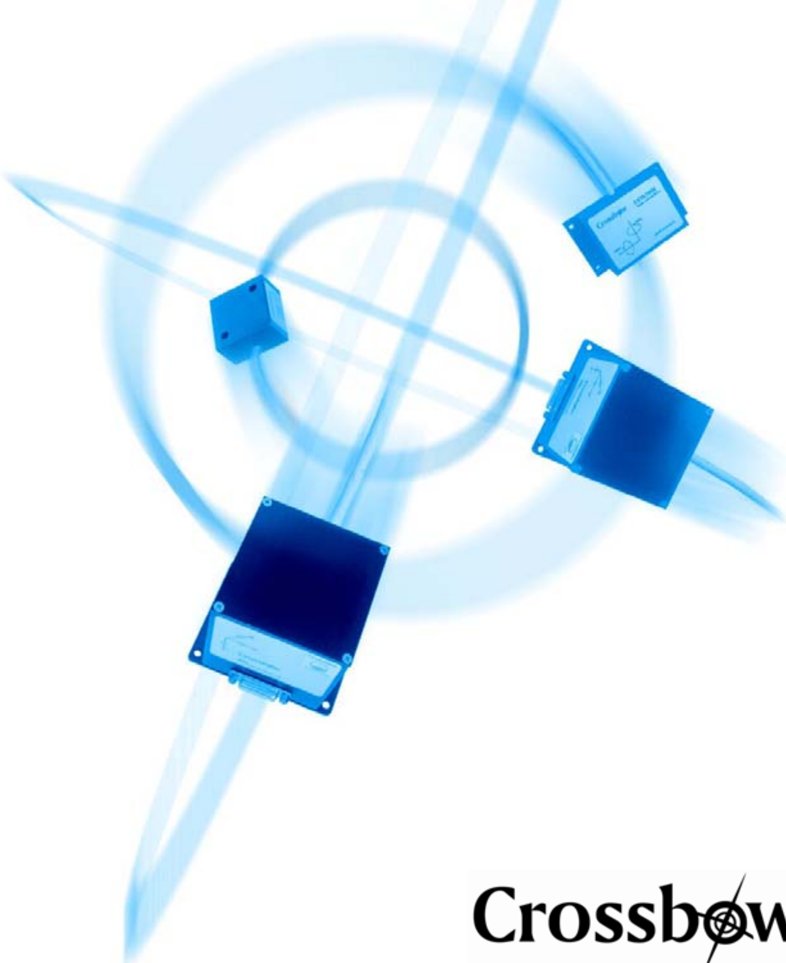

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About this Manual

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 DMU™ Series Motion and Attitude Sensing Units

This manual explains the use of the IMU300 Series, and the IMU400 Series products.

The IMU300 Series and IMU400 Series are six-axis measurement systems designed to measure linear acceleration along three orthogonal axes and rotation rates around three orthogonal axes. They use three accelerometers and three angular rate sensors to make a complete measurement of the dynamics of your system.

The Dynamic Measurement Unit (DMU) series 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 outputs and an RS-232 serial link. Data may be requested via the serial link as a single measurement or streamed continuously. The analog outputs are fully signal conditioned and may be connected directly to a data acquisition device.

The Crossbow DMUs employ on board digital processing to provide application-specific outputs and to compensate for deterministic error sources within the unit. The DMUs accomplish these tasks with an analog to digital converter and a high performance Digital Signal Processor.

All six of the IMU300 Series and IMU400 Series sensor elements 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 IMU300 Series and IMU400 Series products responsive and reliable.

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® Windows™. 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 User's Manual**

This contains helpful hints on programming, installation, 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, Me, NT4, 2000

2.1.2 *Install GyroView*

To install GyroView in your computer:

1. Put in CD "Support Tools".
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 need both.

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 COM 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. 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 9-30 VDC at 200 mA. 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 is not responsible for resulting damage to the unit.

NOTE

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

IMPORTANT

The Crossbow Inertial Systems have an EMI filtered connector. The issue with grounding EMI shield is very important because the EMI filter capacitively couples the signals together if it is left floating. The solution is to provide a good ground for the DMU connector shell. This can be accomplished by soldering a wire between ground pin (Pin 4) and the cable metal part that contacts the DMU connector (eg. backshell).

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. Under "DMU" or "DMU Controls", you can set the erection rate and rate sensor zeroing time. Enter a value, and click the button. **The value is not sent until the button is clicked.**
6. 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.

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 DMU Details

3.1 DMU Coordinate System

The DMU will have a label 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 rate, and the z-axis sensor would measure a positive angular rate.

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).

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, then yaw.

3.2 Connections

IMU300CC, IMU400CC and IMU400CD have a male DB-15 connector. The signals are as shown in Table 1. All analog outputs are fully buffered and are designed to interface directly to data acquisition equipment. See "Analog Output" for details.

15 Pin "D" Connector Male Pinout

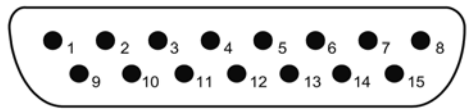


Table 1. DMU Connector Pin Out

Pin	Signal
1	RS-232 Transmit Data
2	RS-232 Receive Data
3	Positive Power Input (+)
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	NC – factory use only
12	X-axis accel scaled analog voltage[3]
13	Y-axis accel scaled analog voltage[3]
14	Z-axis accel scaled analog voltage[3]
15	NC – factory use only

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. The accelerometer analog outputs are scaled to represent G's. These outputs are created by a D/A converter.

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 9-30 VDC unregulated at 200 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 we supply. The analog outputs are fully buffered and conditioned and can be connected directly to an A/D. The analog outputs can require a data acquisition device with an input impedance of 10kΩ or greater for DAC outputs and relatively higher impedance for raw analog outputs.

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 C++ and LabVIEW. Source code for the DMU serial interface can be obtained via the web at http://www.xbow.com/Support/downloads.htm

3.4 Measurement Modes

The IMU300CC, IMU400CC and IMU400CD are designed to operate as six-axis systems and can be set to operate in one of two modes: voltage mode, or scaled sensor mode. The IMU Series of products do not support angle mode. The measurement mode selects the information that is sent in the data packet over the RS-232 interface. See "Data Packet Format" 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 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:

$$\mathbf{voltage} = \mathbf{data}*(5\ \mathrm{V})/2^{12},$$

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 and angle analog outputs are **not** enabled in this mode. Only the linear accelerometer analog output on pins 5 – 7 will be 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, 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 DMU operates as a six-axis measurement system.

The scaled sensor analog outputs are enabled in this 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:

accel = **data***(**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 that1 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:

rate = **data***(**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 your DMU. The angular rate range of your DMU is the range of angular rates your DMU will measure. For example, if your DMU uses a ±100 °/s rate sensors, then **AR** range is 100.

3.5 Commands

The DMUs have a simple command structure. You send a command consisting of one or two bytes to the DMU over the RS-232 interface and the DMU will execute the command. Note that the DMU commands are case sensitive!

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.

3.5.1 Command List

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

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	Polled Mode
Character(s) Sent	P
Response	none
Description	Changes data output mode 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	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. The exact string will vary according to the DMU type and 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. 3. Change the baud rate of your communications program. 4. Send "R" to the DMU. The DMU will respond with "H" at the new baud rate when a successful detection of the new baud rate is completed.

Remember when sending the z<x> command that 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 DMU.

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.

Table 4 shows the data packet format for each mode.

Table 4. IMU Data Packet Format

Byte	Scaled Sensor Mode	Voltage Mode
0	Header (255)	Header (255)
1	Roll Rate (MSB)	Gyro Voltage X (MSB)
2	Roll Rate (LSB)	Gyro Voltage X (LSB)
3	Pitch Rate (MSB)	Gyro Voltage Y (MSB)
4	Pitch Rate (LSB)	Gyro Voltage Y (LSB)
5	Yaw Rate (MSB)	Gyro Voltage Z (MSB)
6	Yaw Rate (LSB)	Gyro Voltage Z (LSB)
7	Acceleration X (MSB)	Accel Voltage X (MSB)
8	Acceleration X (LSB)	Accel Voltage X (LSB)
9	Acceleration Y (MSB)	Accel Voltage Y (MSB)
10	Acceleration Y (LSB)	Accel Voltage Y (LSB)
11	Acceleration Z (MSB)	Accel Voltage Z (MSB)
12	Acceleration Z (LSB)	Accel Voltage Z (LSB)
13	Temp Voltage (MSB)	Temp Voltage (MSB)
14	Temp Voltage (LSB)	Temp Voltage (LSB)
15	Time (MSB)	Time (MSB)
16	Time (LSB)	Time (LSB)
17	Checksum	Checksum

NOTE

The header byte 0xFF will likely not be the only 0xFF 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.

3.7 Timing

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, 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.

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 65,535 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 DMU 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 sensor is specified to be within ±2% accurate over the DMU temperature operating range. The DMU reads and outputs the temperature sensor voltage in the digital data packet with 12-bit precision.

The temperature sensor voltage is sent in the data packet scaled as:

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

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:

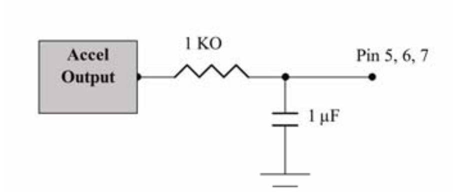
$$T\ (^\circ\mathrm{C}) = 44.4\ (^\circ\mathrm{C/V}) * (\mathbf{V_{temp}}\ (\mathrm{V}) - 1.375\ \mathrm{V}),$$

where $\mathbf{V_{temp}}$ is the temperature sensor voltage sent in the DMU data packet.

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 DMU provides six fully conditioned analog outputs in scaled mode – three accelerometer voltages and three rate sensor voltages. In angle mode, the scaled accelerometer voltages are replaced with the pitch and roll analog voltages. In all modes, the raw accelerometer sensor output is also available. The analog signals can be connected directly to an A/D or other data acquisition device without further buffering. The input impedance of your data acquisition device should be greater than 10 kΩ for the DAC outputs and relatively higher impedance for raw analog outputs. The circuit diagram for the raw accelerometer outputs (Pin 5, 6 and 7) is shown below:



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

3.9.1 "Raw" Accelerometer Voltage

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:

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

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.

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 "raw" accelerometer voltages will always be available on pins 5- 7.

3.9.2 Scaled Accelerometer Voltage

In scaled mode, the DMU will create scaled analog accelerometer voltages on pins 12 – 14. These analog voltages reflect any calibration or correction the DMU applies to the accelerometer data. The analog voltage is created by an internal D/A converter using the digital data available to the DSP. The data is scaled to the range ±4.096 V with 12-bit resolution. You do not need to use the calibration data that came with the DMU to use these outputs – the DMU is already applying the calibration stored in its EEPROM to the data.

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

$$\textbf{accel}\ (G) = \textbf{GR} * 1.5 * \mathbf{V_{out}}(V) / 4.096\ V,$$

where **accel** is the actual acceleration measured, $\mathbf{V_{out}}$ is the voltage at the analog output and **GR** is the G range of your sensors. The G range is listed on the calibration sheet. For example, if your DMU has ±2 G accelerometers, **GR** is 2.

3.9.3 Scaled Rate Sensor Voltage

The DMU will output analog voltages representing the rate sensor measurement on pins 8 – 10 in both scaled sensor mode and angle mode.

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:

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

where **rate** is the actual measured rate in units °/s, **AR** is the angular rate range of your 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.

4 DMU Operating Tips

4.1 The “Zero” Command

The “z<x>” command is used to zero the rate sensor outputs. This should be an essential part of your strategy in using the DMU effectively. 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 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 DMU 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 to 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 Mounting the DMU

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

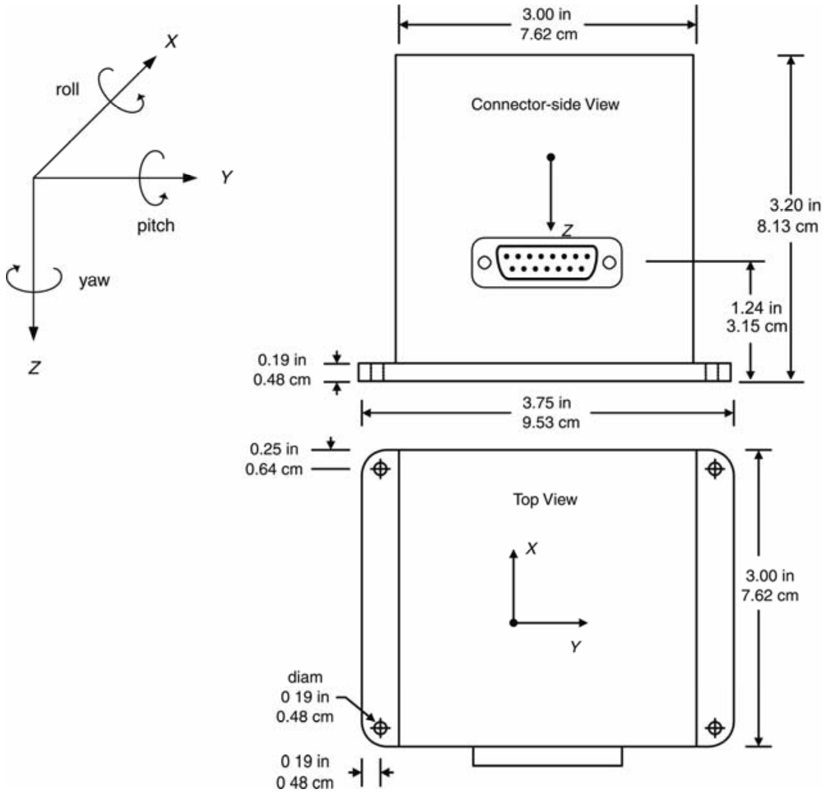
The DMU will measure rotations around the axes of its sensors. The DMU sensors are aligned with the DMU case. You should align the DMU case as closely as possible with the axes you define in your system. Errors in alignment will contribute directly into errors in measured acceleration and rotation relative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

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 DMU case is not weather proof. You should protect the DMU from moisture and dust.

5 Appendix A. Mechanical Specifications

5.1 IMU300CC, IMU400CC and IMU400CD Outline Drawing



6 Appendix B. DMU 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

Accelerometer (Scaled Mode only)

Accel (G) =
V_{out} (V) *** GR * 1.5/4.096**

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

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

Rate

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

Temperature

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

7 Appendix C. DMU Command Quick Reference

Command (ASCII)	Response	Description
R	H	Ping: Pings DMU to verify communications.
r	R	Change to Voltage Mode.
c	C	Change to Scaled Sensor 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.
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.
b	Change baud rate	Autobaud detection. Send "b"; change baud rate; send "a" or "A"; DMU will send "D" when new baud rate is detected.
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.

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

8 Appendix D. Troubleshooting Tips

Is the supply voltage and connections okay?

The DMU needs at least 9V power supply for proper operation. Verify that your power supply is regulated and not current limited. Ensure that the supply does not fall below 9V or go above 30V. Make sure that all the connections are intact.

Are you exceeding the range of sensors?

Whenever the maximum range of the rate sensors is exceeded, the outputs saturate. When recovered from this over-ranged condition, the data will not be valid.

Do you have extended maneuvers close to the maximum range of rate sensors?

Although the IMU is rated to operate at 100 or 200 deg/sec, extended maneuvers close to the range should be avoided. Prolonged rates close to the maximum range may result in larger errors due to scale factor errors on the rate sensors.

Do you have heavy EMI interference in the environment?

Heavy EMI interference can cause a bias shift of the rate sensors. Before you install the IMU in the system, by closely watching the rate sensor outputs, you can test the effect of different potential EMI contributors (strobe lights, microwave transmitters, alternators, radio modems, controllers etc), by actually operating them. Move the IMU to a location where effects of such interferences are within the acceptable accuracy.

Is the vibration isolation adequate?

Large amounts of vibration will make the accelerometer readings noisy. 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 IMU must be installed in a location that is rigid enough to alleviate potential vibration errors induced from normal airframe vibration sources. You can use vibration isolators if needed to dampen out the unwanted vibrations.

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 (8 AM to 5 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.
4145 N. First Street
San Jose, CA 95134
Attn: RMA Number (XXXXXX)

9.4 Warranty

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

Crossbow Technology, Inc.
4145 N. First Street
San Jose, CA 95134
Phone: 408.965.3300
Fax: 408.324.4840
Email: info@xbow.com
Website: www.xbow.com