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**Crista Inertial Measurement Unit (IMU)  
Interface Control Document (ICD)**

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**2621 Wasco Street  
PO Box 1500  
Hood River, OR 97031**

(541) 387-2120 phone  
(541) 387-2030 fax

[www.cloudcaptech.com](http://www.cloudcaptech.com)  
[sales@cloudcaptech.com](mailto:sales@cloudcaptech.com)  
[support@cloudcaptech.com](mailto:support@cloudcaptech.com)

**Author(s):  
Jon Becker, Jeff Fisher**

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# 1 Introduction

The Crista Inertial Measurement Unit (IMU) is a very small three-axis inertial sensor that provides high-resolution angular rate and acceleration measurements. It uses MEMS gyroscopic rate sensors and accelerometers mounted on orthogonal axes to nominally provide 300°/s rate and 10g acceleration data. The digital interfaces provide fully calibrated and corrected rate and acceleration readings over fully-configurable serial interfaces.

## 1.1 Key Features

- RS232 and CAN serial data outputs
- Very small size (2.05 x 1.55 x 1.00 inches)
- Axis Rate and Acceleration Sensing
- Calibrated over full temperature range
- Compensated for cross-axis and acceleration sensitivities
- GPS PPS input for data synchronization
- Internal sample rates »1 KHz, with user-defined output and oversample rates
- Standard DB9 interface connector

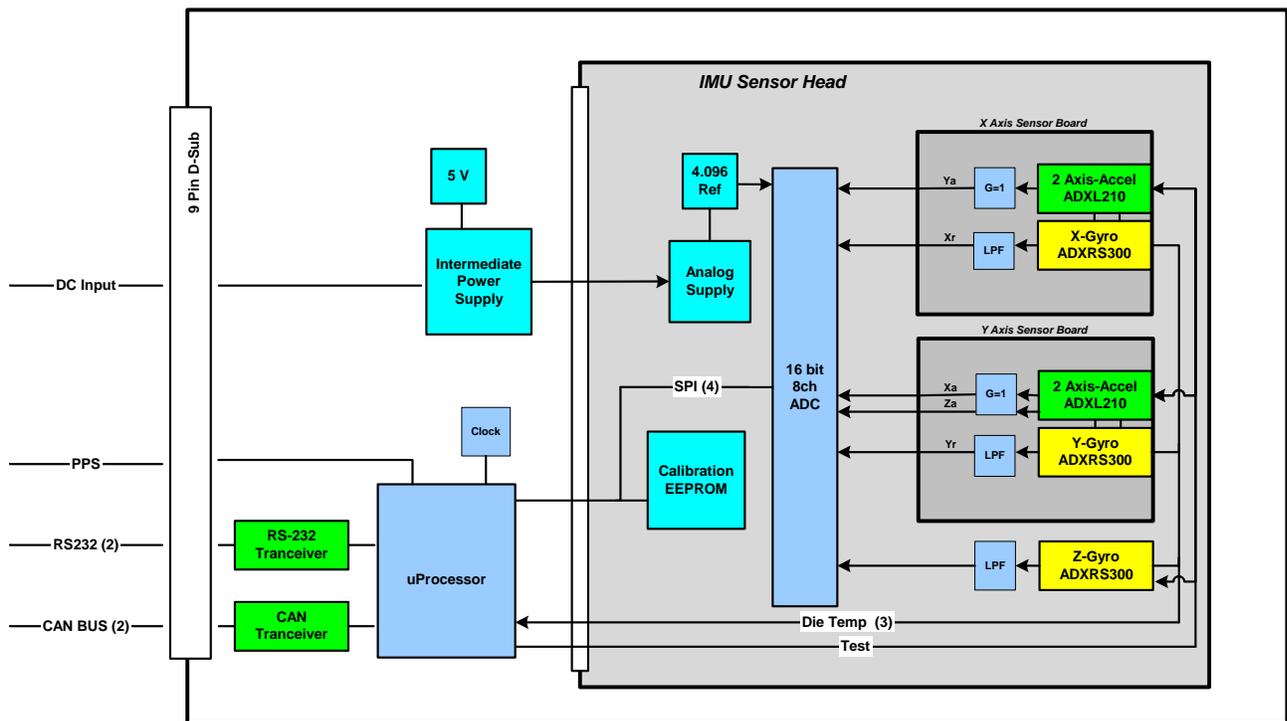


Figure 1 - Crista IMU Block Diagram

## 1.2 Crista Serial Developers Kit and Accessories

All of the equipment necessary to interface with the Crista IMU are available for purchase either separately or as a part of the Crista Serial Developers Kit (part number 900-90006-00). The kit includes the following:

- **Crista IMU Unit**
- **PC Interface Software:** Provides test and evaluation tools and sample drivers for IMU interface support, plus all applicable Crista documentation.
- **Developers Cable:** Custom wiring harness providing interfaces for power, RS-232 communications, CAN communications, and GPS PPS input.
- **Serial Cable:** Basic cable for connecting the Developers Cable to a PC.

If a CAN interface is desired, the following two additional items are necessary to communicate with the Crista:

- **USB-CAN module (500-00250-00):** To send and receive CAN frames using a standard USB port; and
- **USB-CAN interface cable (500-00259-00):** To connect the CAN module to the appropriate connector on the Developers Cable.

The Sensor Head used in the Crista IMU is also available in a very small - 1.10 x 1.15 x .59 inches - stand-alone package targeted for direct integration into end-user application circuits. It provides high bandwidth raw measurements from three MEMS accelerometers and three MEMS angular rate sensors by providing direct SPI access to a 16-bit multiplexing A/D converter. SPI access is also provided to a serial EEPROM chip used to store calibration data. Three analog temperature outputs (gyro die temperatures) are provided to implement precision temperature calibrations. Physical access is via four 0.050 inch single row headers.

## 1.3 Applicable Export Controls

The Crista IMU is a controlled export device under Department of Commerce Export Administration Regulations (EAR), as a CCL Category 7A994 device. As such, export licenses may be required for export of these products, dependent on the export country. Source software falls under CCL Category 7D002 and has different export rules. Prior to selling to foreign customers, Cloud Cap Technology requires an end-use letter from the customer stating that the that license requirements are followed for the country of export. Customers are also responsible for following Department of Commerce rules for re-export of these devices.

## 2 Specifications

### 2.1 Angular Rates

Parameter	A Spec	B Spec	Units	Notes
Range	±300		°/sec	
Scale Factor Error	< 1		% FS	
Bias Error (Fixed Temperature)	< 0.05		% FS	
Bias Error (Over Temperature)	< 0.2	< 0.5	% FS	
Turn-on to Turn-on Bias	< 0.25		% FS	
Alignment Error	< 2.5	< 5.0	% FS	Before on-board corrections
Linear Acceleration Bias	0.2 (typ.)		°/sec/g	Before on-board corrections
Resolution	0.009		°/sec	
Bandwidth	100		Hz	2 <sup>nd</sup> Order Filter

### 2.2 Accelerations

Parameter	A Spec	B Spec	Units	Notes
Range	±2, ±6, ±10		g	±2g and ±6g by special order
Scale Factor Error	< 1.0		% FS	
Bias Error (Fixed Temperature)	< 0.025		% FS	
Bias Error (Over Temperature)	< 0.4	< 0.7	% FS	
Turn-on to Turn-on Bias	< 0.3		% FS	
Alignment Error	< 2.5	< 5.0	% FS	Before on-board corrections
Resolution	0.3		mg	
Bandwidth	40		Hz	Simple RC low-pass filter

### 2.3 Sampling Architecture

Parameter	Min	Typ	Max	Units	Notes
Internal Sample Rate	200	--	> 2000	Hz	User-configurable
Data Output Rate	--	--	> 200	Hz	

### 2.4 Electrical

Parameter	Min	Typ	Max	Units	Notes
Input Voltage	4.4	5.0	8.0	V	
Current	90	100	150	mA	V <sub>IN</sub> = 5.0V

### 2.5 Physical

Parameter	Min	Typ	Max	Units	Notes
Weight (w/o Enclosure)	--	18.8	--	grams	
Weight (w/ Enclosure)	--	36.8	--	grams	
Operating Temperature	-40	--	80	°C	
Storage Temperature	-60	--	100	°C	
Max Acceleration	--	500	--	g	

*Note: See section 5.2 for complete IMU dimensions.*

### 3 Signal Descriptions

The IMU has a single 9-pin D-Sub connector interface which provides the electrical interface to the host application. The signal pin-out is shown in **Table 1**.

**Table 1 - IMU Pin-Out**

Pin	Signal Name	Dir	Signal Description
1	PPS	In	The PPS input allows data synchronization with an external GPS unit. The IMU data includes a counter value that is incremented on the leading edge of the PPS input and the 10MHz clock time since the last PPS rising edge. The PPS input accepts logic levels from either 5V or 3V logic (Vhigh > 2.5V). The PPS line is connected to a 10K pull-up resistor to 5V. If PPS functionality is not required, leave this pin disconnected.
2	GND	Both	Ground
3	Reserved	NC	Reserved
4	GND	Both	Ground
5	Vin	In	DC power input to the IMU
6	RS232 - TX	Out	Standard RS232 TX and RX lines for serial communication with the IMU
7	RS232 - RX	In	
8	CAN - L	Both	CANbus H and L interface lines
9	CAN - H	Both	

## 4 Theory of Operation

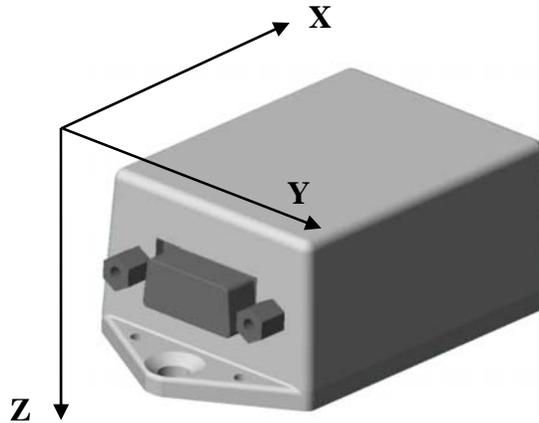
The Crista IMU is a three-axis inertial sensor that provides high accuracy, high-resolution digital rate and acceleration data in the form of compact serial packets over one or both of a pair of on-board serial buses. The basic principles of operation are as follows.

- Angular rate and acceleration data for all three axes are measured as analog outputs from MEMS sensors (three gyroscopes and two two-axis accelerometers), which are individually passed through a low-pass filter and a buffer before being sampled by a 16-bit multiplexing analog-to-digital converter.
- Die temperatures are also measured on each gyro and compared to a 10-point temperature calibration table to internally correct the measured sensor outputs to remove any temperature-induced errors and non-linearities.
- The IMU also stores correction matrices to account for alignment errors and linear acceleration sensitivities. As of firmware version 1.3.0, these matrices are applied internally to the converted output data, maximizing the off-the-shelf accuracy of the IMU.
- Telemetry and configuration data are passed using either the CANOpen 2.0b protocol (a multi-drop 2-wire differential serial bus running at 1 Mbps) or the RS-232 standard protocol running at 115,200 baud. The output rate and internal sensor sampling rate are both fully user-configurable, offering sensor measurements at rates greater than 200 Hz. For more information, please see the *IMU Communications Specification* document, as well as section 6 - *Software Interface* in this document.
- In order to facilitate tight synchronization of navigation sensor measurements, the Crista IMU accepts a GPS PPS signal and outputs an offset time with every telemetry output cycle that indicates the amount of time elapsed between the last GPS position update and the current inertial sensor measurements. This timer has a resolution of 100 nanoseconds.
- Internally, the IMU features an switching regulator and follow-on linear regulators to allow a wide range of input voltages while still providing clean, constant power to the analog circuitry. The input range of 4.4 to 8.0 volts easily accommodates the range of voltages expected from a standard 4-cell battery pack.

## 5 Mechanical Interface

### 5.1 Axis Orientation

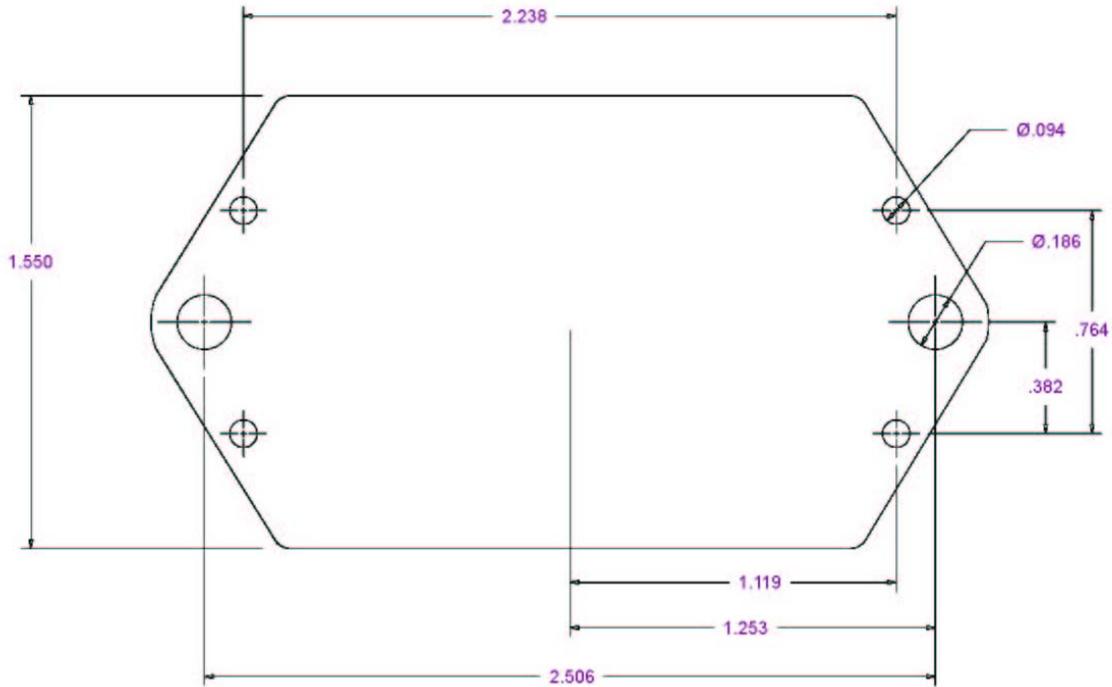
The orientation of the measurement axes for the Crista IMU are shown in **Figure 2**. Rate data polarity is right-hand-rule of the axes presented (Gyro X is positive with a clockwise roll around the x axis line, etc.)



**Figure 2 - Orientation of XYZ Axis**

## 5.2 Mounting Provisions

**Figure 3** provides locations of the mounting holes. Two sets of mounting holes are provided on the Crista mounting flanges. There are 4 small holes sized for #2 hardware. Two large holes are sized for #8 flathead hardware.



**Figure 3 - Hole Mounting Patterns**

*Note: In high-vibration environments, such as in applications with large amounts of engine noise, soft mounting of the IMU may be required to meet performance specifications.*

## 6 Software Interface

The Crista IMU reports raw sensor readings and/or converted engineering data at a fixed interval using one or both of its on-board serial ports (RS-232 and CANbus). The serial ports are also used for setting and querying many settings relevant to the operation of the unit.

### 6.1 Communications Specification

The associated *IMU Communications Specification* document provides comprehensive instructions for communicating with the Crista IMU over both the RS-232 and CAN data links. Also included is a short example application demonstrating a very basic RS-232 packet processing scheme.

### 6.2 Output Rate Limits

The software interface allows control of IMU update rate and oversample ratios to meet user requirements. Output rate is defined as the number of output measurement sets transmitted from the IMU every second. The oversample ratio is defined as the number of A/D measurements acquired and averaged for each signal between each IMU output cycle. Increasing the number of oversamples decreases the measurement noise of the output data.

The following tables outline the maximum supported output rate for selected oversample ratio settings. Note that each table represents a different IMU configuration as specified by the firmware version and the processor type.



**Do not operate outside the limits of the following tables. If an Output Rate and oversample setting combination is beyond the values in these tables, the IMU may cease to output data.**

**If the base sampling rate (Output Rate x Oversamples) is less than 200 Hz, unexpected behavior will occur.**

*Note: Output timing may be briefly corrupted when setting IMU settings, or reading configuration data (access to EEPROM will disrupt output timing temporarily).*

**Table 2 - Max output rate (Hz) by Oversample Ratio  
(Firmware v1.3.0, Enhanced Processor)**

Oversamples	RS-232			CAN		
	Converted Data	Conv + Raw Data	Fast Raw Mode	Converted Data	Raw Data	Conv + Raw Data
1	280	190	640	425	880	350
2	250	180	340	370	675	310
5	200	150	245	260	390	230
6	185	140	230	240	340	215
10	145	115	170	175	225	160
12	130	105	145	155	195	145
14	120	100	125	140	170	130
20	88	82	96	108	125	103
30	62	59	72	78	86	75
32	55	55	69	73	81	71
50	35	35	45	49	52	48
70	25	25	32	36	38	35
100	24	24	24	26	26	26
200	12	12	12	13	13	13
360	7	7	7	7.5	7.5	7.5
500	5	5	5	5	5	5
700	3.5	3.5	3.5	3.5	3.5	3.5
1000	2.5	2.5	2.5	2.5	2.5	2.5
2000	1.3	1.3	1.3	1.3	1.3	1.3
3000	0.9	0.9	0.9	0.9	0.9	0.9
3300	0.8	0.8	0.8	0.8	0.8	0.8
3600	0.75	0.75	0.75	0.75	0.75	0.75

*Note: Firmware changes in version 1.3.0 have slightly decreased the output rates in many cases in favor of greater system stability, better timing accuracy, and more deterministic behavior.*

**Table 3 - Max output rate (Hz) by Oversample Ratio  
(Firmware v1.2.0, Enhanced Processor)**

Oversamples	RS-232			CAN		
	Converted Data	Conv + Raw Data	Fast Raw Mode	Converted Data	Raw Data	Conv + Raw Data
1	450	365	600	754	1428	635
2	446	250	495	630	592	385
5	326	205	355	416	402	295
6	300	190	325	374	362	275
10	226	160	244	264	260	210
12	200	145	214	232	228/	185
14	180	136	192	206	202	170
20	140	110	145	154	152	130
30	100	84	102	108	106	95
32	96	80	100	102	101	92
50	64	58	66	68	67	62
70	48	44	48	48	48	47
100	36	32	35	35	35	34
200	17	17	18	17	17	17
360	10	9	10	10	10	9
500	7	7	7	7	7	7
700	5	5	5	5	5	5
1000	3.5	3.5	3.5	3.5	3.5	3.5
2000	1.8	1.8	1.8	1.8	1.8	1.8
3000	1.2	1.2	1.2	1.2	1.2	1.2
3300	1	1	1	1	1.1	1.1
3600					1	1

**Table 4 - Max Output Rate (Hz) by Oversample Ratio  
(Firmware v1.2.0, Classic Processor)**

Oversamples	RS-232			CAN		
	Converted Data	Conv + Raw Data	Fast Raw Mode	Converted Data	Raw Data	Conv + Raw Data
1	450	360	600	720	1340	605
2	420	240	470	590	560	375
5	300	196	310	380	365	275
6	280	184	290	340	330	255
10	206	150	220	235	233	190
12	182	136	190	206	204	170
14	162	126	170	180	180	155
20	124	100	130	136	134	120
30	88	76	90	94	94	86
32	84	72	85	88	88	82
50	56	52	55	58	58	56
70	42	38	40	42	42	40
100	30	28	30	30	30	28
200	14	14	15	15	15	15
360	8	8	8	8	8	8
500	6	6	6	6	6	6
700	4	4	4	4	4	4
1000	3	3	3	3	3	3
2000	1.6	1.5	1.5	1.5	1.5	1.5
3000	1	1	1	1	1	1

**Table 5 - Max Output Rate (Hz) by Oversample Ratio  
(Firmware v1.1.5, Classic Processor)**

Oversamples	RS232		CAN	
	Converted Data	Conv + Raw Data	Converted Data	Conv + Raw Data
1	285	138	368	241
2	262	132	332	226
5	210	116	252	188
7	186	109	218	168
10	159	98	182	146
20	107	76	115	100
40	64	51	67	62
50	53	44	56	52
70	39	35	41	38
100	29	26	29	28
200	15	14	15	15
300	10	9	10	10
500	5	5	5	5
700	3	3	3	3
1000	2	2	2	2

## 7 Software Tools and Operation

Some software tools are provided to support evaluation of the Crista IMU, as well as to provide demonstration of the full capabilities of the unit.

### 7.1 IMU Serial

IMU Serial provides a graphical interface to the Crista IMU using its RS-232 connection. The application, shown in **Figure 4**, displays IMU telemetry data in real-time, providing the following functionalities:

**IMU Settings:** Controls the Sample Rate (output rate), oversample ratio, communications mode (RS232 and/or CAN), and Sample Mode (Raw and/or Converted). The IMU settings are updated by clicking the **Send Settings** button.

*Note: Selecting CAN communications only will cause IMU Serial to stop updating.*

**Data Display Windows:** The first tab displays converted (engineering units) data received from the IMU and the second displays raw (A/D counts) data. The IMU settings determine which data set(s) are currently being updated.

**Logfile:** The **Select File** button requests a filename and location to record an IMU log text file. When the **Log Data** button is clicked, the incoming IMU telemetry is written to the requested file. If the **Log Data** button is clicked a second time without selecting a new output file, all the data that the log file contains is overwritten.

**IMU Configuration:** The **Get Configuration** button requests all the relevant configuration data from the IMU.

**Set IMU Neutrals:** Initiates a function in the IMU that sets bias nominals assuming that the IMU is mounted flat, with the z axis pointed down. For best performance, set IMU for 1 Hz, 250 over-samples before using.

*Note: As of firmware version 1.3.0, this functionality is no longer supported.*

**Bootloader Mode:** The **Enable Bootloader Mode** button changes the operating mode of the IMU to allow it to accept firmware updates over its RS-232 connection.



**Clicking the Bootloader Mode will set the IMU to a non-operational program mode. See section 8.3 Firmware Update - Bootloader Procedure.**

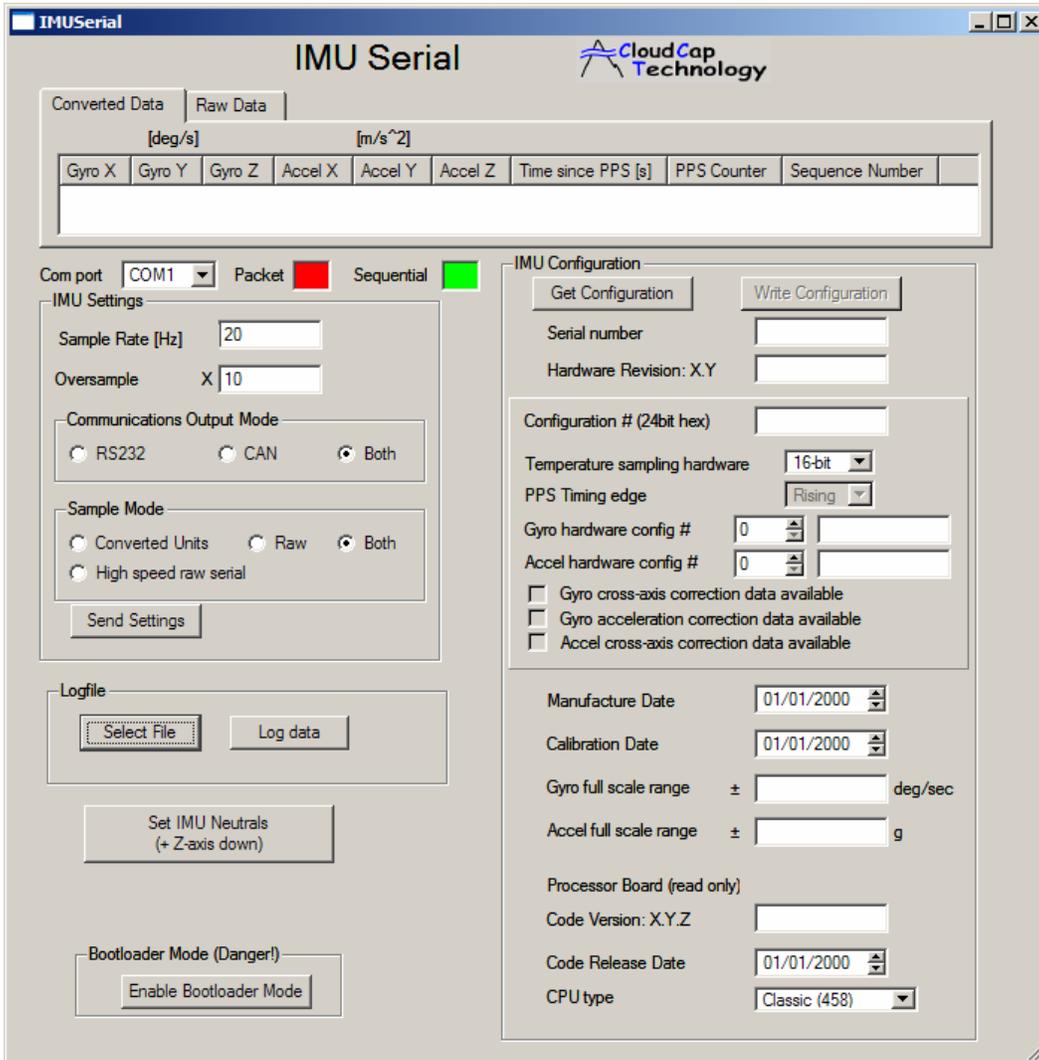


Figure 4 - IMU Serial User Interface

## 7.2 IMU /Nav Filter Demo

The IMU/Nav Filter Demo demonstrates the abilities of the Crista IMU when connected to an attitude solution and display based on the data from the IMU. See **Figure 5**.

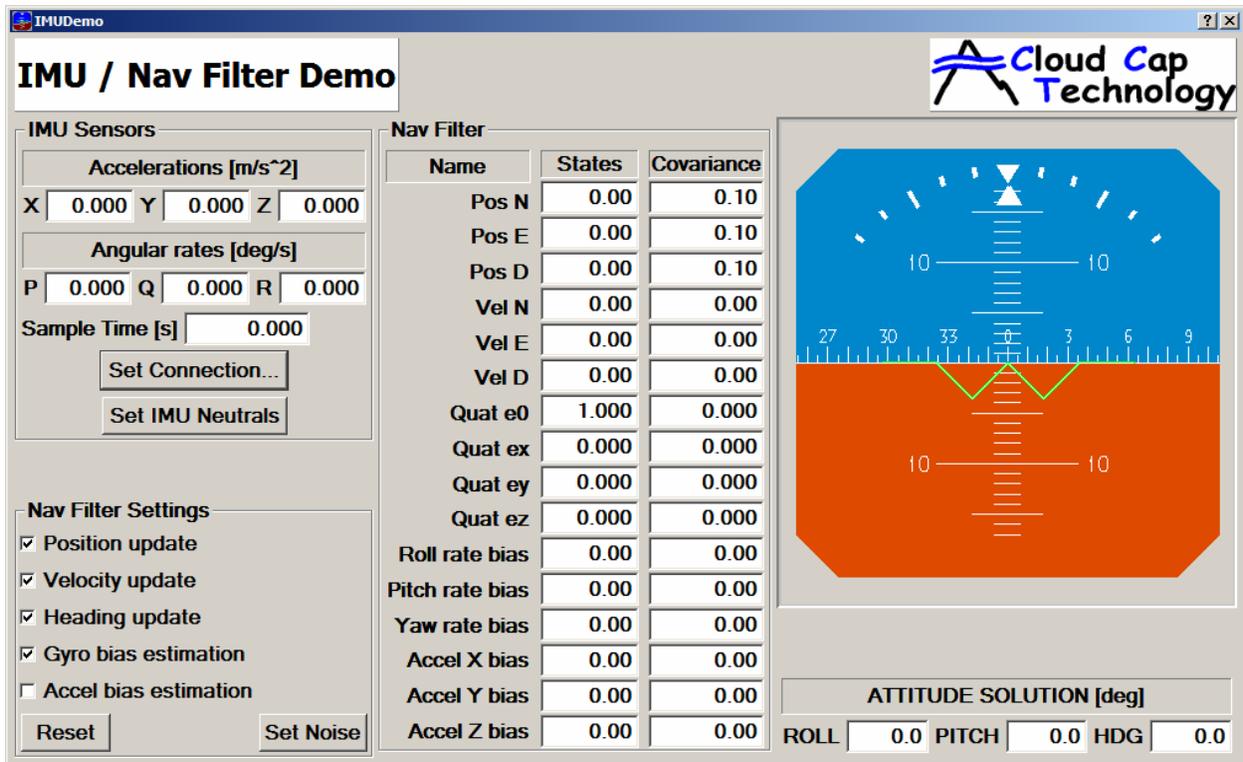


**IMUDemo will configure the IMU to output telemetry at a rate of 50 Hz with 10 oversamples. If other output settings are important for your application, re-set settings using the IMUSerial application after using IMUDemo.**

A **Set IMU Neutrals** button is provided that initiates a function in the IMU that zeros bias nominals assuming that the IMU is mounted flat, with the z axis pointed down.

*Note: To allow running the IMUDemo.exe application, run the Setup.bat batch file that enables required registration files. See section 8.3 Installing Software Tools.*

*The PPS signal input must NOT be connected to the IMU for proper operation of the IMUDemo.exe application.*



Name	States	Covariance
Pos N	0.00	0.10
Pos E	0.00	0.10
Pos D	0.00	0.10
Vel N	0.00	0.00
Vel E	0.00	0.00
Vel D	0.00	0.00
Quat e0	1.000	0.000
Quat ex	0.000	0.000
Quat ey	0.000	0.000
Quat ez	0.000	0.000
Roll rate bias	0.00	0.00
Pitch rate bias	0.00	0.00
Yaw rate bias	0.00	0.00
Accel X bias	0.00	0.00
Accel Y bias	0.00	0.00
Accel Z bias	0.00	0.00

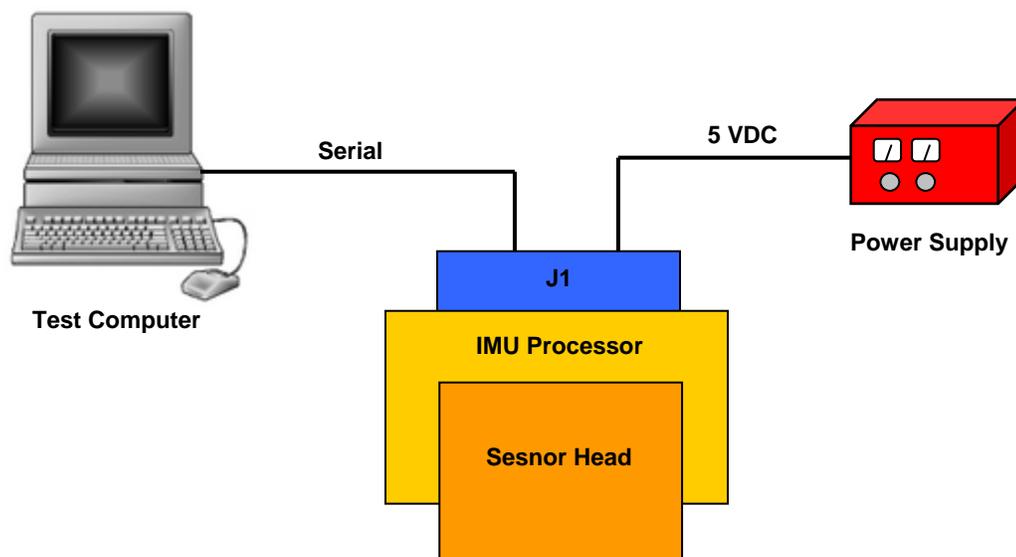
ATTITUDE SOLUTION [deg]  
 ROLL  PITCH  HDG

**Figure 5 - IMUDemo Interface**

## 8 Operation / Procedures

### 8.1 Installing Software Tools

1. Create a IMU folder on the local machine that will be used for a IMU test/evaluation computer.
2. Copy the contents of the Crista IMU support software CD (p/n 900-00494-00) into the local IMU folder. You can get Crista documents and updates to the latest Crista IMU software by downloading them from [www.cloudcaptech.com](http://www.cloudcaptech.com). Download all updated files to the IMU folder on the test/evaluation computer.
3. To allow the Microchip applications used in bootloader updates of the IMU firmware to run, run the **Setup.exe** application in the provided Firmware Update Support folder. This install process provides access to the P1618QP programming application via the test computer **START » Programs » P1618QP** menu. This is a one-time only installation.
4. To allow the IMU/Nav Filter Demo (**IMUDemo.exe**) to run, run the **Setup.bat** batch file that enables the required registration files.
5. If you are going to use the CAN interface to the IMU, install the USB-CAN adaptor drivers provided on the CD that is included with the adaptor. Re-boot the test computer after installation of the USB-CAN drivers.



**Figure 6 - IMU RS-232 Test Setup**

6. Start the IMU Serial interface (**IMUSerial.exe**) from the IMU folder on the test computer.
7. In the IMU Serial interface, change the **Sample Rate** to “10 Hz” , **Over-Sample** to “200”, **Communications Output Mode** to RS232, and **Sample Mode** to **Converted Units**. Click the **Send Settings** button. Verify that the **Converted Data** for all of the gyro and accelerometer data columns except the Z acceleration are  $0 \pm 0.5$  and that Z acceleration is approximately  $-9.8 \text{ m/sec}^2$ .

## 8.2 Data Logging

1. In the IMU Serial interface, click the **select File** button. Browse to and select the name of desired .txt log file to be collected.
2. When you want to record data, click the **Log Data** button. To stop logging click the **Log Data** button again. Every time you start to **Log Data** it will overwrite the data in the selected file. For subsequent data logging tests be sure to define a new .txt log file.

*Note: Data files are comma delimited text files, with a column for each data type. Be aware that with both raw and converted data being collected, this datafile can get quite large.*

## 8.3 Firmware Update (Bootloader Procedure)



**Please contact us before conducting firmware upgrades. If the following procedure is followed incorrectly it will result in a non-functional sensor.**

1. Verify that software from the Crista IMU support software CD (p/n 900-00494-00) has been copied into the local IMU folder and that the QuickProgram application has been installed is section 8.1.
2. Download the latest firmware update from [www.cloudcaptech.com](http://www.cloudcaptech.com). Copy files to the IMU folder on the test computer. Copy all provided software updates.
3. Connect the IMU test setup as follows
  - a) Connect the power supply black GND lead. DO NOT connect the red lead to the power supply at this time.
  - b) Connect the IMU developers cable to the DB-9 connector of the IMU.
  - c) Connect the test computer COM 1 port to the IMU developers cable serial connector.
4. Set bench DC power supply with digital current monitor readout to  $+5 \text{ VDC} \pm 0.2 \text{ VDC}$ .
5. Turn the power to the IMU ON by connecting the positive (red) power lead to the power supply.
6. Start IMU Serial interface (**IMUSerial.exe**) from the IMU folder on the test computer. Verify that the data displayed is non-zero and changing.
7. Click the **Enable Bootloader Mode** button and answer “Yes” to the confirmation.

8. Cycle power on the IMU. The IMU is now in bootloader mode and not running normal IMU code. If the IMU Serial Demo data display shows that it is still updating data, repeat step 7.
9. Close the IMU Serial application.
10. Start the Microchip QuickProgram application **P1618QP.exe** from the **START » Programs » P1618QP** menu. This is Microchip’s debugger / programming interface.
11. On the QuickProgram application, perform the following steps:

*Note: If you are updating firmware in an enhanced IMU containing the new 4680 processor, you MUST use the updated QuickProgram 0.1.0.4 application. This application can program either the classic or enhanced IMU's.*



**It is VERY IMPORTANT that the steps shown below are followed exactly!**

<b>Action (Icon)</b>	<b>Sub-Action / Notes±</b>
a) PullDown Menu	Select CCT IMU and click the <b>select</b> button.
b) Connect to Device	
c) Read Device	Verify that device is communicating properly. Once you see the reading counter being incremented, you can click the <b>Abort Operation</b> button.
d) Erase Device	Will count up erasing of memory space through 32K.
e) Open Hex File	Browse to local machine IMU Test latest version folder and open the latest version of <b>IMU.X.Y.Z.bootloader.hex file</b> .
f) Write Device	It will program starting at decimal address 512. Watch carefully and verify that a full 32Kbytes are transferred. This will take over a minute.
g) Right Arrow Button	Affirm the confirmation request. Wait until Run mode is indicated.
h) Exit	

12. Cycle power on the IMU. It is now in normal operation mode with updated firmware.
13. Start the IMU Serial interface (**IMUSerial.exe**) from the IMU folder on the test computer. Verify that the data displayed is non-zero and changing.
14. The firmware update is now complete.