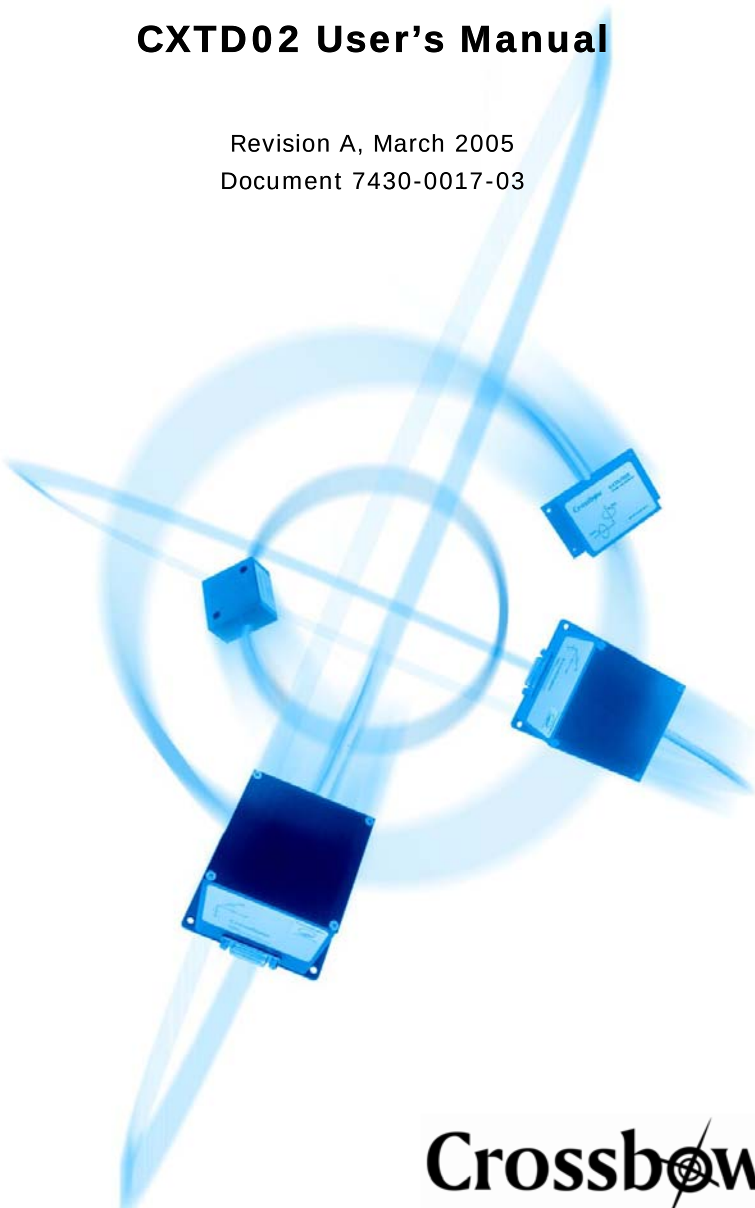
CXTD02 User's Manual

Revision A, March 2005

Document 7430-0017-03



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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 CXTD02 Digital Tilt and Acceleration Sensor

This manual explains the use of the CXTD02. The CXTD02 is a 3-axis digital accelerometer that also provides the means to measure Roll and Pitch angles for static and quasi-static applications. The CXTD02 measures tilt using a tri-axial MEMS accelerometer that is responsive to gravity.

Thus it is a 3-axis measurement system designed to measure linear acceleration along three orthogonal axis. This tri-axial accelerometer allows sensing over the entire 360^0 roll angle and 180^0 pitch angle.

CXTD02 provides an RS-232 serial link. Data may be requested via the serial link as a single polled measurement or may be streamed continuously. The digital RS-232 output makes it easy to collect data in real-time without external data acquisition or Analog-Digital converter cards.

The CXTD02 employs onboard digital processing to compensate for deterministic error sources within the unit. Each CXTD02 is tested and temperature compensated over the full temperature range. In addition, alignment, scale factor and non-linearity compensation are computed internal to the sensor with the on board high performance Digital Signal Processor.

The three MEMS accelerometers are surface micro-machined silicon devices that use differential capacitance to sense acceleration. Solid-state MEMS sensors make the CXTD02 responsive and reliable.

The CXTD02 provides superior performance in more demanding measurement applications, where high accuracy must be maintained over the wide industrial temperature range. CXTD02 can also be used as a precision digital accelerometer. The low-noise floor and true DC response make it an excellent choice for long-term structural and seismic monitoring applications.

1.2 Package Contents

In addition to your CXTD02 sensor product you should have:

- **1 CD with GyroView Software**

GyroView will allow you to immediately view the outputs of the CXTD02 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 CXTD02 directly to a serial port. Only the transmit, receive, power, and ground channels are used.

- **1 CXTD Calibration Sheet**

The Digital Calibration Sheets contains the custom offset and sensitivity information for your unit. The calibration sheet is not needed for normal operation as the unit 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 CXTD02 User's Manual**

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 CXTD02 right out of the box and the evaluation is straightforward. Install the GyroView software, connect the CXTD02 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. Insert the CD "Support Tools" in the CD-ROM drive.
2. Find the GyroView folder. Double click on the setup file.
3. Follow the setup wizard instructions. You will install GyroView and a LabVIEW Runtime Engine. You will need both these applications.

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

2.2 Connections

The CXTD02 is shipped with a cable to connect the CXTD02 to a PC COM port.

1. Connect the 15-pin end of the digital signal cable to the port on the CXTD02.
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 CXTD02. 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 CXTD02 can damage the unit; Crossbow is not responsible for resulting damage to the unit.

2.3 Setup GyroView

With the CXTD02 connected to your PC serial port and powered, open the GyroView software.

1. GyroView should automatically detect the CXTD02 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 CXTD02 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 CXTD02 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 unit, 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.

3 CXTD02 Details

3.1 CXTD02 Coordinate System

The CXTD02 will have a label on one face illustrating the 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 CXTD02

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 CXTD02 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 CXTD02 z-axis.

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, and then yaw.

3.2 Connections

The CXTD02 has a female DB-15HD connector. The signals are as shown in Table 1.

DB-15HD Male

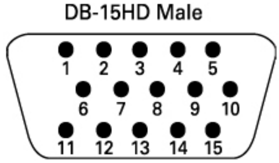


Table 1. CXTD02 Series Connector Pin Out

Pin	Signal
4	RS-232 Transmit Data
3	RS-232 Receive Data
11	Positive Power Input (+Vcc)
1	Ground

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			CXTD02 Connector	
Pin #	Signal		Pin #	Signal
2	TxD		3	RxD
3	RxD		4	TxD
7	GND*		1	GND*

*Note: Pin 1 on the CXTD02 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			CXTD02 Connector	
Pin #	Signal		Pin #	Signal
2	RxD		4	TxD
3	TxD		3	RxD
5	GND*		1	GND*

*Note: Pin 1 on the CXTD02 is data ground as well as power ground.

Power is applied to the CXTD02 on pins 1 and 11; Pin 1 is ground; Pin 11 should have 9 - 30 VDC unregulated at 100 mA. If you are using the cable supplied with the CXTD02, 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.

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.

3.4 Measurement Modes

The CXTD02 can be set to operate in one of three modes: voltage mode, scaled sensor mode, or 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 CXTD02 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.

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 CXTD02 non-volatile memory. A single data packet can be requested using a serial poll command or the CXTD02 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 CXTD02 operates as a three-axis digital accelerometer.

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

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

where **accel** is the actual measured acceleration in G's, **data** is the digital data sent by the CXTD02, and **GR** is the G Range for your CXTD02. (The data is scaled so that1 G = 9.80 m s^{-2}.) The CXTD02 uses a ±2 G accelerometer and hence the G range is 2.

Since there are no gyros in CXTD02 in Scaled mode, the gyro output is set to 0.0 to maintain consistency with GyroView packet structure.

3.4.3 Angle Mode

In angle mode, the CXTD02 will output the static pitch and roll angles only. 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 single data packet can be requested using a serial poll command or the CXTD02 can be set to continuously output data packets to the host. The data is sent as signed 16-bit 2's complement integers.

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 (either pitch or roll), and **data** is the signed integer data output in the data packet, and **SCALE** is a constant. **SCALE** = 180^0 for roll and pitch.

3.5 Commands

The CXTD02 has a simple command structure. You send a command consisting of one or two bytes to the CXTD02 over the RS-232 interface and the unit will execute the command.

NOTE

The CXTD02 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 CXTD02 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	Ping
Character(s) Sent	R
Response	H
Description	Pings CXTD02 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	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	Query CXTD02 Version
Character(s) Sent	v
Response	ASCII string
Description	This queries the CXTD02 firmware and will tell you the CXTD02 type and firmware version. The response is an ASCII string that describes the CXTD02 type and firmware version.

Command	Query Serial Number
Character(s) Sent	S
Response	Serial Number Packet
Description	This queries the CXTD02 for its serial number. The CXTD02 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 CXTD02 baud rate from its default. This change will not affect the default settings. 1. Start with communications program and CXTD02 at same baud rate. 2. Send "b" to the CXTD02. The CXTD02 will respond with "B." 3. Change the baud rate of your communications program. 4. Send "R" to the CXTD02. The CXTD02 will respond with "H" at the new baud rate when a successful detection of the new baud rate is completed.
Command	Filter Settings Command
Character(s) Sent	N<x>
Response	-
	Command applies single pole low pass filter to the sensor outputs. This sets the sensor response and the resolution. The argument of the command <x> is a single binary byte that tells CXTD02 measurement bandwidth to apply to sensor outputs. The available <x> values and corresponding filter frequencies are listed in Table 5.

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.

The order of data sent will depend on the selected operating mode of the CXTD02.

In angle mode, each data packet will begin with a two-byte header (hex 0xFFFF) and end with a two-byte checksum. The checksum is calculated in the following manner:

1. Sum all packet contents *except* header and checksum.
2. Divide the sum by 0xFFFF.
3. The remainder should equal the checksum.

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

In Scaled mode and Voltage mode, 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 255.
3. The remainder should equal the checksum.

NOTE

The header byte 0xFFFF (or 0xFF) will likely not be the only 0xFFFF (or 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 CXTD02. This is especially critical when using the continuous data packet output mode.

Table 4 shows the data packet format for each mode.

Table 4. CXTD02 Series Data Packet Format

Byte	Angle Mode	Scaled Sensor Mode	Voltage Mode
0	Header (255)	Header (255)	Header (255)
1	Header (255)	Roll Rate (MSB)	Undefined
2	Pitch Angle (MSB)	Roll Rate (LSB)	Undefined
3	Pitch Angle (LSB)	Pitch Rate (MSB)	Undefined
4	Roll Angle (MSB)	Pitch Rate (LSB)	Undefined
5	Roll Angle (LSB)	Yaw Rate (MSB)	Undefined
6	Checksum (MSB)	Yaw Rate (LSB)	Undefined
7	Checksum (LSB)	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

3.7 Timing

The maximum CXTD02 data update rate is 100 packets per second at 38,400 baud when operating in Continuous mode.

In some applications, using the CXTD02's digital output requires a precise understanding of the internal timing of the device. The processor internal to the CXTD02 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.

The unit goes through three processes in one data cycle. First, the sensors are sampled. Second, the unit processes the data for output. Third, the unit actually transfers the data out over the RS-232 port.

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 CXTD02 has an onboard temperature sensor. The temperature sensor is used to monitor the internal temperature of the CXTD02 to allow for temperature calibration of the sensors. The temperature sensor is specified to be within ± 2% accurate over the CXTD02 operating temperature range. The CXTD02 reads and outputs the temperature sensor voltage with 12-bit precision.

The CXTD02 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 CXTD02 uses two full bytes to express the data, but it is really scaled to 12 bits.)

Calculate the temperature with the following calibration:

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

where $\mathbf{V_{temp}}$ is the temperature sensor voltage sent in the CXTD02 data packet.

The CXTD02 temperature sensor is internal to the CXTD02, and is not intended to measure the ambient temperature. The internal temperature of the CXTD02 may be as much as 15°C higher than the ambient temperature.

3.9 The "Filter Settings" command

The angular noise limits the resolution or granularity in which small angular changes can be detected. The angular noise is dependent on the measurement bandwidth. The measurement bandwidth is the set of frequencies to which the tilt sensor responds. Decreasing the measurement bandwidth increases the resolution. At the same time, however, decreases in measurement bandwidth also increase the settling time of the sensor. If the measurement bandwidth is set too low, the tilt sensor may take long time to settle to its final value.

The CXTD02 is unique in its ability to provide high resolution and short settling time. The CXTD02 is also unique in its ability to be user configured for different measurement bandwidths (and hence higher resolution and settling time). The sensor is configured via the RS-232 command interface.

The N<x> command is used to set the CXTD02 Filter Settings. The command applies single pole low pass filter to the sensor outputs. This sets the sensor response and the resolution. The argument of the command <x> is a single binary byte that tells CXTD02 measurement bandwidth to apply to sensor outputs.

Table 5 shows the various filter settings and available filter values for CXTD02. Note that the CXTD02 returns to the default filter level (5) upon power-up and must be re-configured as required.

Table 5. CXTD02 Programmable Filter Settings

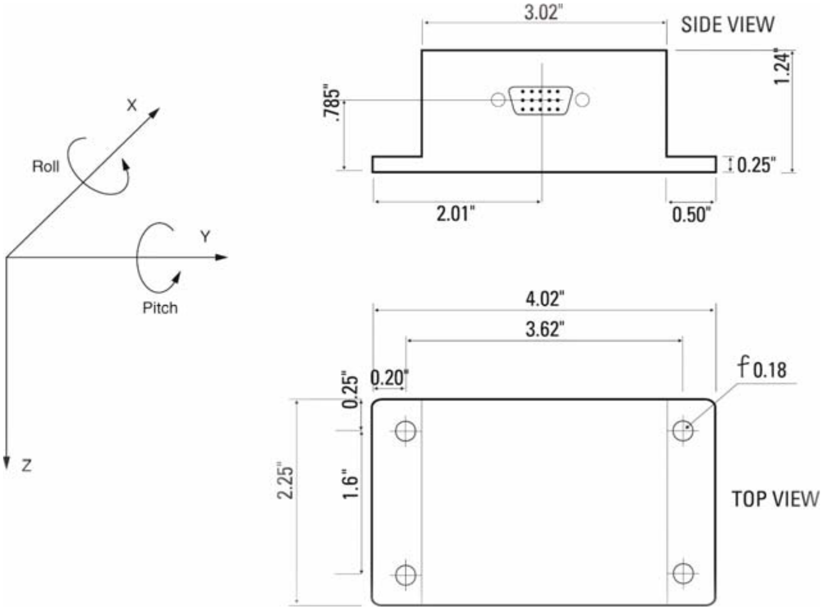
<x>	**F_c(Hz)**	**Resolution (deg)**
0	None	0.090
1	None	0.090
2	12.5	0.025
3	6.7	0.011
4	3.1	0.0089
5*	1.5	0.0079
6	0.7	0.0041
7	0.35	0.0026
8	0.17	0.0016
9	0.0875	0.0010

<x> 0 and 1 implies no digital filter, but there is a 75 Hz single pole response from the MEMS sensor.

* Default Setting.

4 Appendix A. Mechanical Specifications

4.1 CXTD02 Outline Drawing



5 Appendix B. CXTD02 Output Quick Reference

GR is the G-range of the accelerometers. In case of CXTD02, since it has ± 2 G accelerometers, GR = 2.

5.1 Digital Output Conversion

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

Acceleration (Scaled Mode)

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

Roll, Pitch (Angle Mode)

Angle (°) **= data * 180/2^{15}**

Temperature (Scaled Mode)

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

6 Appendix C. CXTD02 Command Quick Reference

Command (ASCII)	Response	Description
R	H	Ping: Pings the CXTD02 to verify communications.
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 CXTD02.
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 CXTD02. Data format depends on operating mode.
S	ASCII String	Query CXTD02 serial number. Returns serial number as 32-bit binary number.
v	ASCII String	Query CXTD02 version ID string. Returns ASCII string.
b	Change baud rate	Autobaud detection. Send "b"; CXTD02 responds “B”; change baud rate; send "R"; CXTD02 will send "H" when new baud rate is detected.
N<x>	None	Command applies single pole low pass filter to the sensor outputs. This sets the sensor response and the resolution. The argument of the command <x> is a single binary byte that tells CXTD02 measurement bandwidth to apply to sensor outputs.

7 Appendix D. Warranty and Support Information

7.1 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

7.2 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

7.3 Return Procedure

7.3.1 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?

7.3.2 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.

7.3.3 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.

7.3.4 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.

7.3.5 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)

7.4 Warranty

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

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