CXM544 Orientation Sensor
User's Manual

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Crossbow

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CXM544 ORIENTATION SENSOR

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1. Introduction

The CXM544 Orientation Sensor system contains both a 3-axis fluxgate magnetometer and a 3-axis accelerometer. The combination of these two sensor systems enables the roll, pitch and azimuth angles of the CXM544 reference frame with respect to the local gravity and magnetic field vectors to be determined. Roll and pitch angles are determined from the accelerometer subsystem which measures the orientation of the system with respect to the gravity vector. After roll and pitch are known, the magnetometer subsystem is used to determine the azimuth angle of the system. Knowledge of the roll and pitch angles enable determination of the horizontal components of the earth's local magnetic field; this information defines the azimuth angle.

The CXM544 system also contains a microprocessor and 7 channel 16 bit analog to digital converter. Six channels are assigned to the magnetometer and accelerometer outputs. One channel provides temperature data from an internal thermometer. The functions performed by the system microprocessor and A to D subsystem are: 1) conversion of the sensor analog outputs to digital form; 2) calibration of the sensor scale, offset and alignment factors for a temperature variation and 3) implementation of serial communications between the system and an external computer.

The CXM544 communicates with the outside world over one of two serial bi-directional interfaces which can be selected from either TTL or RS232 voltage levels. An ASCII character command language has been created to facilitate communication with the CXM544. For instance, if the ASCII characters for 0, S and D are sent in sequence, the CXM544 interprets this as a "send data" command and responds by sending over the serial interface an ASCII string representing the value of all magnetometer, accelerometer and temperature outputs. The leading zero in this sequence denotes the system serial number. The CXM544 can also be configured to send angle data (roll, pitch and azimuth) instead of the accelerometer and magnetometer sensor data.

An auto send data mode is included in the CXM544 software. When this mode is active, data is repeatedly sent after power is applied to the system at a rate of two transmissions per second in angular output mode and three times per second in magnetometer/accelerometer output mode.

The CXM544 system accelerometers are calibrated by placing the system in a precision rotation fixture and systematically changing the system orientation in the earth's gravitational field. The CXM544 system magnetometers are calibrated by placing the system in a precision 3 axis Helmholtz coil system which enables the application of known magnetic fields to the system. Both the rotation fixture and Helmholtz coil have alignment pins and reference surfaces which mate to the CXM544 reference surface. System calibration can be performed at a base temperature (usually 25°C) or over a temperature range (for example 15-90°C).

When the system is calibrated over a temperature range, data is read from the system at temperature intervals between the minimum and maximum temperature specification. For instance, for calibration over the interval of 15-90°C, data is usually read at 25°C temperature intervals between 15° and 90°C. The data taken at each temperature includes scale, offset and sensor alignment data. The recorded data is then used to create a look up table for scale offset and alignment corrections. This table is then downloaded into the CXM544 internal EEROM memory where it can be accessed by the system internal microprocessor. Corrections to the read sensor data can then be made by the internal microprocessor system before data is transmitted.

2. System Specifications

Angular Accuracy (0° to 70°C)
 Azimuth: ±1.5°
 Inclination: ±0.5°
 Roll: ±0.5°

Temperature Range
 Operating: 0° to 70°C)

Power

                                 +5V ±0.05V @ 71 ma
                                        or
                                 +7 to +12V @ 71 ma

Size   0.75" x 0.80" x 4.6"

Shock   750 G 1ms half sine wave

Mass   50 grams

Vibration   Random vibrations 10G rms, 5-1000Hz

Digital Outputs
 logic level   TTL or RS232
 baud   user programmable up to 9600 baud
 protocol   user selectable ASCII or binary

 Leads   6" long flying leads

3. Mechanical Features

An outline drawing of the CXM544 system is shown in Figure 1. The system dimensions are 0.75" x 0.80" x 4.60" (1.90 cm x 2.03 cm x 11.68 cm). The system is normally mounted by using 4 2-56 x 0.250 long screws to secure the CXM544 reference surface to a flat mating surface. Two 0.062" dia x 0.125" long pins protruding from the external mating surface can be used to orient the CXM544 on the external mounting surface.   The orientation of the X Y and Z axes is shown in Figure 1. The output polarity sense of the axes is such that a field pointing in the direction of the arrows shown in Fig. 1 will produce a positive output voltage. For example, if the X magnetometer is oriented so the X axis arrow points north, then the X axis output voltage will be positive. If the X axis accelerometer arrow is pointed down, the X axis accelerometer output will be positive.
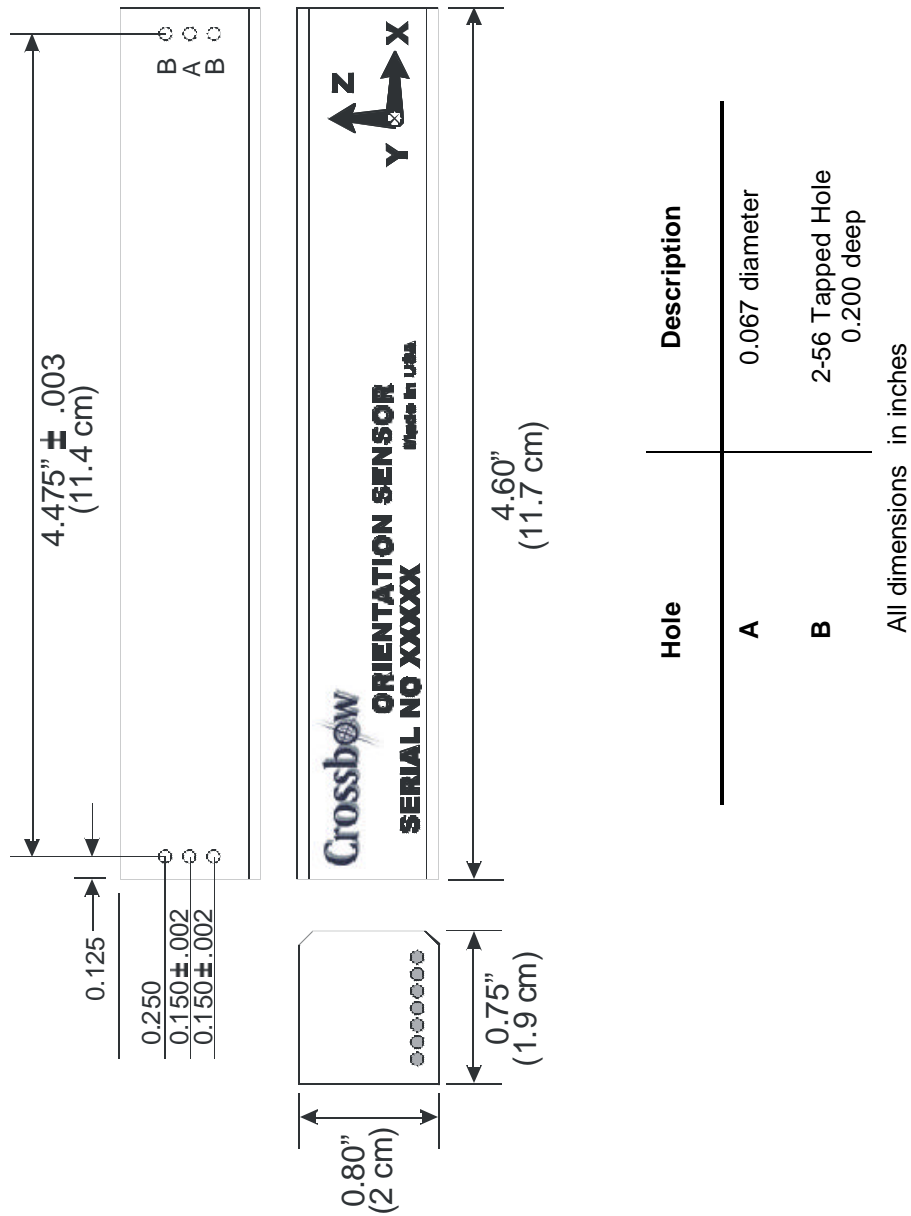
Hole	Description
A	0.067 diameter
B	2-56 Tapped Hole 0.200 deep

All dimensions in inches

Figure 1

4. Electrical Interface

The electrical interface to the CXM544 system is shown in Figure 2. Seven flying leads (#26 gauge Teflon insulated) are used to make connection to the system. The functions of the output wires are shown in Figure 2. The CXM544 system can be powered either through an internal voltage regulator, which converts the input voltage to the +5 volts for internal use, or from +5 VDC. When the input regulator is used, the input voltage can range from +7 to +12V. An ideal input voltage which both provides adequate regulation margin and low power consumption is +7.5V.

The serial communications interface to the CXM544 is provided by the serial in and serial out lines shown in Fig. 2. An external computer talks to the CXM544 on the serial in line and replies from the CXM544 are transmitted out on the serial out line. The serial in and serial out lines operate at TTL or RS232 levels and are normally set to operate at 9600 baud with one stop bit and no parity. The user however can change the baud rate by setting bits in the system EEROM. (See Section 8)

Wire Color	Function
Red	+7 to +12 VDC
Black	Ground
Red/White	+5 VDC
Orange	RS232 serial in
Yellow	RS232 serial out
White/Orange	TTL serial in
White/Yellow	TTL serial out

Figure 2 Electrical Interface for Model 544 Sensor

Two communication protocols are available: 1) ASCII and 2) BINARY.   The ASCII protocol is based upon sending ASCII characters to the CXM544 to obtain data. The CXM544 responds by sending out an ASCII data stream complete with carriage returns and line feeds so that it can be easily displayed on a computer terminal. The binary protocol is used for high speed computer to computer interchange. In this case, one byte is sent to request data (e.g. ASCII 128). The CXM544 then responds with a data packet containing the desired data plus header and checksum.

The currently supported binary commands and their definitions follow:

Command	Command Definition
128	send sensor data in binary format
129	send sensor data in IEEE 32 bit format
131	send angle data in binary format
132	send angle data in IEEE 32 bit format

The CXM544 response to these commands is of the following form:

<number of data bytes> <MX> <AX> <MY> <AY> <MZ> <AZ> <MT> <AT>
<0> <data check sum><end>

Refer to the next section of this manual (Heading Sensor Command Set) for a more detailed discussion of the data format for binary transmissions.

5. Initial Setup of the System

In order to operate the CXM544, power must be applied to it and an interface with an external computer must be set up. Powering will depend upon whether the unit is using a +5V supply or the internal regulators and powers from +7VDC to +12VDC. To ensure system accuracy, the +5V powered system must be within ± 0.05V of +5V.

Connect the correct power lead to the selected supply voltage. (See Figure 2)

After powering, the system should consume about 71 ma of input current.

In order to set up a computer interface with the system, select the output protocol of the CXM544. This can be either TTL or RS232. The TTL protocol is usually used in microprocessor to microprocessor communications. For this mode, the voltage levels for a 0 and 1 are approximately ground and 5V. In the idle or marking state, the output level is +5V.

The RS232 protocol is used by using serial com ports. RS232 voltage levels for a 0 and a 1 are approximately -5V and +5V. In the idle or marking state, the -5V level is output.

About 1 second after power up, the CXM544 will send out a sign on message. This can be observed with an oscilloscope as a series of transitions from +5 to 0V (TTL) or -5V to +5V (RS232).

Since PC's use RS232 protocol, they can be directly connected to a CXM544 employing this protocol. PC's use either a 25 pin or a 9 pin D connector to implement their serial ports. This connector is always a bulkhead male connector on the P.C. chassis. The serial in, serial out and ground connections for these connectors are as follows:

Function	25 pin	9 pin
serial out	2	3
serial in	3	2
ground	7	5

Connect the CXM544 serial output line to the computer in line and the CXM544 serial input line to the computer serial out line.

To communicate with the CXM544, a terminal program will have to be run on the P.C. The Windows HyperTerminal program will suffice for this. Other suitable terminal programs are Procom and ASCII Pro. These programs turn the computer into a dumb terminal. In this mode, whatever you type on the keyboard goes out the selected serial port (e.g. Com 1) and whatever comes in the serial port is displayed on the computer video display.

If you use HyperTerminal, you must select the proper Com port (e.g. COM 1, COM 2, etc.) and set the baud rate to be 9600 with one stop bit and no parity. Set the port up for direct connect and turn off any handshaking.

The easiest method of determining if a working communications link with the CXM544 has been established is to observe the P.C. display when the CXM544 is powered up. The CXM544 transmits a power up sign on message which should appear in readable form on the P.C. display. The appearance of an unreadable message at power up may indicate incorrect protocol (i.e. TTL instead of RS232) or an incorrect baud rate.

6. Operation of the System

After establishing communication with the CXM544, data can be obtained from the system by sending (typing) the command *0SD<CR>* (0 Send Data). The 0 in this sequence is the default serial number of the unit. After sending this command, the CXM544 will respond with an output that appears as follows:

MX: 0.5432   **AX: 0.9456**
MY: 0.1234   **AY: 0.4510**
MZ: 1.0145   **AZ: 0.0112**
t: 45.0

The numbers following the MX, MY and MZ headers represent the sensor magnetometer output in Gauss. The numbers following the AX, AY and AZ headers represent the accelerometer output in gees. The temperature (°C) follows the t header.

The above outputs represent data sent when the CXM544 is in sensor mode. If angular data is required, the system mode will need to be changed. In general, the CXM544 operating characteristics are controlled by the values of internal byte constants. These constants are stored in the system EEROM and can be changed by a two step process. The two step process is used for security reasons to ensure that these constants are not inadvertently changed.

To change the CXM544 to angle mode, byte 02 must be changed from 02 (sensor mode) to 03 (angle mode).

To accomplish this, type: ***01\<CR\>***

The unit will respond with the message: ***enabled!***

Next, type the sequence: ***0WC02b03\<CR\>***   (0 <u>W</u>rite <u>C</u>onstant <u>02</u> <u>b</u>yte 03)

The unit will respond by sending the message: ***done***

Now request data by sending the sequence: ***0SD\<CR\>***

The response will look something like this:

MX: 180.0	**AX: .6451**
MY: 90.3	**AY: .4056**
MZ: 185.6	**AZ: 1.0001**
t: 24.3	

The numbers following MX, MY and MZ represent the system roll, inclination and azimuth. The numbers following the AX, AY and AZ represent the system magnetic roll angle, total magnetic field and total gravitational field.

The total field numbers are of interest because they are the same for all orientations of the sensor since

$$\sqrt{AX^2 + AY^2 + AZ^2} \quad = \quad 1.0 \text{ Gee}$$

$$\sqrt{MX^2 + MY^2 + MZ^2} \quad = \quad .5 \text{ Gauss}$$

The degree to which these field magnitudes are constant for different orientations is a measure of the accuracy of the sensor.   The actual magnetic field amplitude reported will vary somewhat depending on location. This value ranges from 0.4 to 0.6 Gauss over the earth's surface.

It is also possible to configure the system mode to output raw A to D counts. This can be accomplished by setting byte 02=0.

In order to observe the value of any internal system constant send the commands

0SC02b \<CR\>
0SC*b \<CR\>

The first command results in the value of byte constant 02 being transmitted. The second command evokes a response containing the values of all byte constants.

The CXM544 can transmit data in two formats: 1) text and 2) binary. Text transmissions are formatted to display correctly when the CXM544 is connected to a PC running a terminal emulator program (e.g. PC PLUS, HyperTerminal, etc.). Binary transmissions are faster than text transmissions and are more suited to interfacing the CXM544 to a microprocessor system. In command mode, binary transmissions are initialed by sending a single byte to the CXM544, e.g. ASCII 128 or ASCII 129.

The CXM544 has an autosend mode which enables data to automatically be sent repeatedly

upon power up. Byte 01 must be set equal to 5A for autosend mode to be active. The format of the data sent in autosend mode is determined by the value of byte 08. For repetitive text transmissions, set byte 08=10. For repetitive binary transmissions, set byte 08=11.

7. Descriptions of the System Internal Constants

The CXM544 employs two types of internal constants: 1) byte and 2) floating. There are approximately 43 byte constants which are used to configure the operating characteristics of the CXM544. The most important of these constants and their functions follow:

Detailed descriptions of all the internal byte constants can be found in the Appendix of this manual.

Byte	Function
00	enables echoing when non zero
01	enables autosend when = 5A
02	enables sensor A/D count output when =0, sensor output when =02 and angle output when =03
08	Sets power on mode (e.g., =10 enables autosend in ASCII mode on power on)
09	Baud rate lock (=5A if any baud rate other than 9600 is to be used)
10	Sets baud rate

8. Changing the Baud Rate

To change the communication baud rate from 9600 baud to any other rate, you must first change byte constant 09 to 5A. Then, byte 10 can be set according to the following table:

Constant 10 value	Baud rate
35	300
33	1200
32	2400
31	4800

After setting byte 10, turn the power to the CXM544 off and on to set the new baud rate.

Note: When byte 09 is set to any value other than 5A, the system baud rate is 9600.

9. Verifying Proper Operation of the System

Proper operation of the CXM544 can be verified when the system is in either angle mode (byte 02=03) or sensor mode (byte 02=02).

In angle mode, proper operation is verified by placing the CXM544 in known orientations and comparing the CXM544 measured data with the known orientation data.

To check roll and inclination outputs, place the CXM544 on a known flat surface with the Z axis pointed down. A flat surface can be set up and verified by using a bubble level. Request data from the CXM544 and verify that the roll and inclination outputs are as follows:

roll $0° \pm 0.5°$
inclination $90° \pm 0.5°$

Next, roll the CXM544 about the X axis in increments of 90° and verify that for each position the roll angle increments in succession to 90°, 180° and 270° while the inclination angle remains $90° \pm 0.5°$.

To verify inclination at 0° and 90°, position the CXM544 so that the X axis is pointed down (0° inclination) and up (180°). Because the CXM544 leads exit the bottom of the unit when the X axis is up, it may be awkward to verify this orientation without additional support blocks.

To verify azimuth accuracy, a good compass and an area free from magnetic materials must be located. Usually areas inside buildings contain some magnetic material (e.g. metal desks, rebar in concrete floors, etc.). In this case, verifying azimuth accuracy to 1° is difficult.

Use a compass to orient the CXM544 approximately horizontal and East (inclination 90°, azimuth 90°). Carefully align the CXM544 long (X) axis so that it is pointed East and verify that the azimuth reading is $90° \pm 1.0°$. Use the same procedure to verify azimuth accuracy for 180°, 270° and 0° readings.

In sensor mode (byte 02=02) the CXM544 accelerometer sensors should read +1.00 and -1.00 when pointed down and up respectively. Therefore when lying flat on a horizontal surface with the Z axis pointed down, the X and Y accelerometers should read 0±0.01 and the Z accelerometer should read 1.00 ±0.01.

The CXM544 magnetometers are calibrated to read directly in Gauss. Proper operation of these sensors is difficult to verify without elaborate calibration equipment. However, proper "ballpark" verification of operation can be accomplished by pointing each magnetometer sensor into and out of the earth's magnetic field. For these orientations, the magnetometer should read about +0.5G and -0.5G. In the Northern hemisphere, the direction of the earth's magnetic field is North with an inclination of about 60°. For instance, if the system X axis is pointed to magnetic North and inclined about 60° into the earth, (30° from vertical) the X magnetometer output should read +0.5 Gauss.

10. Determining Orientation Angles from CXM544 Accelerometer and Magnetometer Data

This application note describes how to calculate the roll, pitch and azimuth angles for the CXM544 orientation sensor from accelerometer and magnetometer output data.

10.1 Sensor Based Coordinate System

The coordinate system of the CXM544 system is defined in Fig. 5. The accelerometer and magnetometer coordinate systems are both aligned with the physical package coordinate systems shown. For the magnetometer sensors, a positive output voltage will result if the sensor is pointed north. For the accelerometers, a positive voltage will result if the sensors are pointed down.

10.2   Definition of Orientation Angles

The orientation angles are defined in Fig. 5 and 6. Azimuth or yaw is defined as the angle measured from magnetic north (clockwise from above) to the projection of the x axis on the horizontal plane.

Inclination is the angle that the x axis makes with the down direction and is 0 when the x axis is down and 90° when the x axis is horizontal.

Roll or gravity tool face is defined as the angle of counterclockwise rotation about the x axis (looking in the positive x axis direction) required to zero the y axis accelerometer output and position the z axis accelerometer so that its output polarity is positive.

Magnetic roll is defined as the angle of counterclockwise rotation about the x axis (looking in the positive x axis direction) required to zero the y axis magnetometer output and position the z axis magnetometer so that its output polarity is negative.

Magnetic roll is useful in defining the CXM544 orientation when inclination is near vertical. In this situation, g_y and g_z are near zero and roll and azimuth calculations become less accurate.

10.3 Definitions

The following sections describe equations for determining the CXM544 orientation angles.

These equations make use of the following definitions:

g_x accelerometer x axis output
g_y accelerometer y axis output
g_z accelerometer z axis output

H_x magnetometer x axis output
H_y magnetometer y axis output
H_z magnetometer z axis output
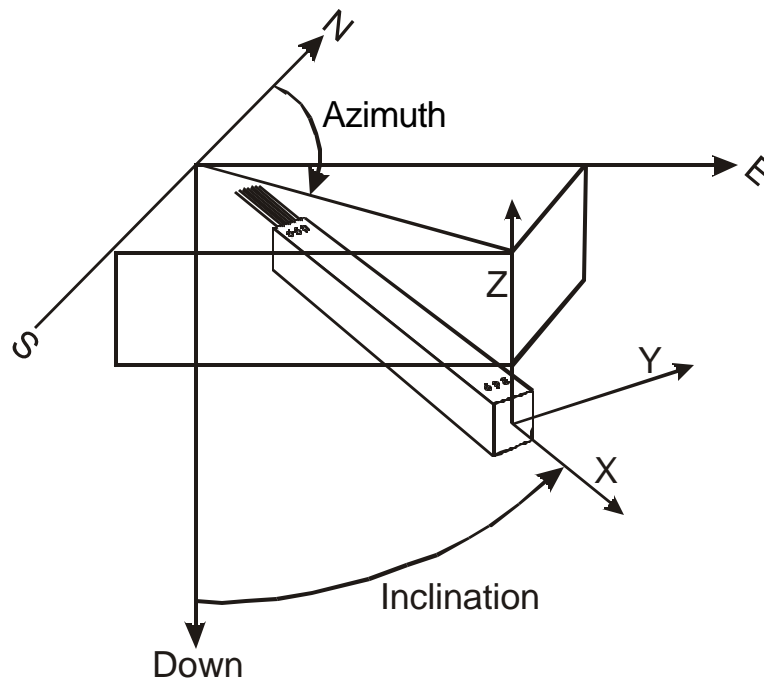
Figure 5 - 544 Coordinate System
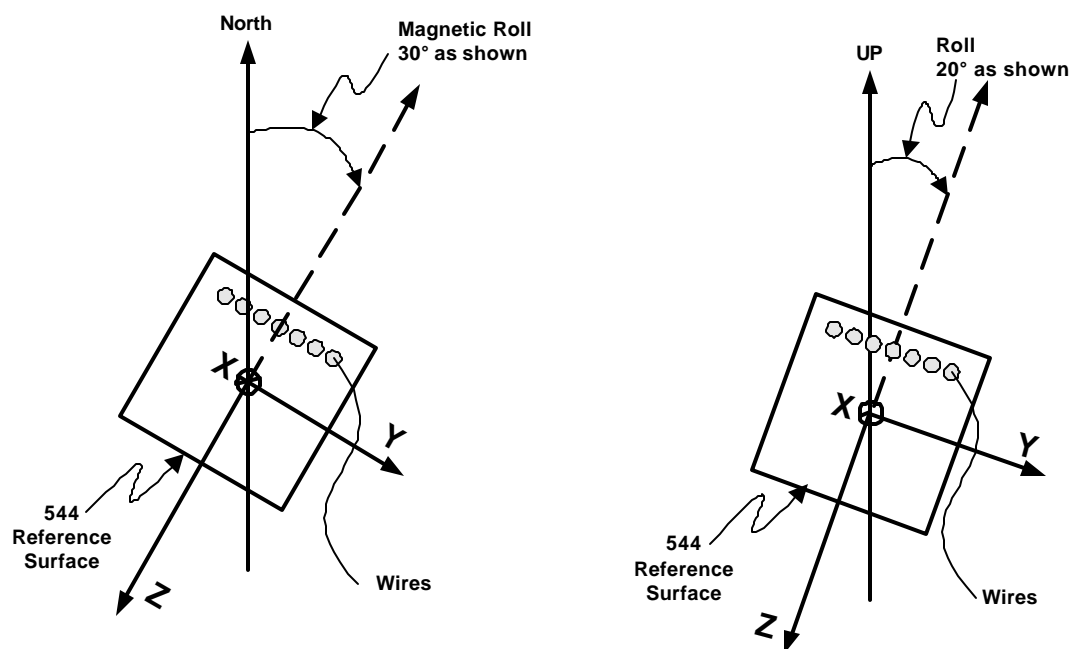
Figure 6 - 544 Orientation Angles

10.4　Calculation of Roll and Magnetic Roll

The roll angle, θ, is determined by using the following equations
$(0 \leq \theta \leq 2\pi)$:

$$Cos\boldsymbol{q} = \frac{g_z}{\sqrt{g_y^2 + g_z^2}}$$

$$Sin\boldsymbol{q} = \frac{g_y}{\sqrt{g_y^2 + g_z^2}}$$

$$Tan\ \boldsymbol{q} = \frac{g_y}{g_z}$$

Roll is 0° when $g_y = 0$ and $g_z > 0$. Roll is 2π radians when $g_y = 0$ and $g_z < 0$. When the X axis is near vertical (pitch < 5°), the quantities g_y and g_z become very small and the above expressions yield a less accurate value of θ. In this situation, magnetic roll is often used to determine the angular orientation of the CXM544 about the longitudinal (X) axis. Magnetic roll, θ_m, is given by the following $(0 \leq \theta_m \leq 2\pi)$:

$$Sin\boldsymbol{q}_m = \frac{-H_y}{\sqrt{H_y^2 + H_z^2}}$$

$$Cos\boldsymbol{q}_m = \frac{-H_z}{\sqrt{H_y^2 + H_z^2}}$$

$$Tan\ \boldsymbol{q}_m = \frac{H_y}{H_z}$$

10.5 Calculation of Inclination

Inclination, ε, is determined from the following equations
$(0 \leq \varepsilon \leq \pi)$:

$$Cos \ \boldsymbol{e} = \frac{g_x}{g}$$

$$Sin \ \boldsymbol{e} = \frac{\sqrt{g_y{}^2 + g_z{}^2}}{g}$$

$$Tan \ \boldsymbol{e} = \frac{\sqrt{g_y{}^2 + g_z{}^2}}{g_x}$$

where $g = \sqrt{g_x{}^2 + g_y{}^2 + g_z{}^2}$

Inclination is 0 when the CXM544 x axis is pointed down and $\pi/2$ radians when horizontal.

10.6   Magnetic Heading (Azimuth, Yaw)

We first give expressions for the magnetic field in a horizontal reference defined by x1, y1, z1 where x1 is aligned with the projection of the CXM544 x axis in the horizontal plane and z1 is down.

$$H_{x1} = \frac{H_x\left(g_y{}^2 + g_z{}^2\right) - H_y g_y g_x - H_z g_x g_z}{g\sqrt{g_y{}^2 + g_z{}^2}}$$

$$H_{y1} = \frac{H_y g_z - H_z g_y}{\sqrt{g_y{}^2 + g_z{}^2}}$$

$$H_{z1} = \frac{H_x g_x + H_y g_y + H_z g_z}{g}$$

Magnetic heading , ø, is then given by $(0 \leq ø \leq 2\pi)$

$$Cos\boldsymbol{f} = \frac{H_{x1}}{\sqrt{H_{x1}{}^2 + H_{y1}{}^2}}$$

$$Sin\boldsymbol{f} = \frac{-H_{y1}}{\sqrt{H_{x1}{}^2 + H_{y1}{}^2}}$$

$$Tan\boldsymbol{f} = \frac{-H_{y1}}{H_{x1}} = \frac{(H_z g_y - H_y g_z)g}{H_x(g_y{}^2 + g_z{}^2) - H_y g_x g_y - H_z g_x g_z}$$

Magnetic heading is 0 when the CXM544 x axis points North and $\pi/2$ radians when it points East.

11.   Using The CXM544TOOL Software

11.1   Basic Description

This DOS program exercises the basic functions of the Model CXM544 Miniature Angular Orientation Sensor and applies some post processing to the data. This program is not shipped with the sensor, but can be provided upon request.

11.2   Using the Software

The compiled program is called CXM544TOOL.EXE. It requires one parameter - the comm port number that the Position Sensor is connected to.   For example, to select COM1, enter a parameter of 1. To start the program from the command line, change the directory to where the program is stored and enter CXM544TOOL followed by a space and then the com port number. If there are no communication problems with the sensor, you will now see a screen resembling the one shown in Fig. 4. If you don't see this but get a series of errors, and are asked to enter a new port number or retry, go to the trouble section later in this description.

The sensor data screen is comprised of a status header, a data display area and a command footer. The first line of the status header has the model number of the unit or APS if this is a prototype. Next to this is the software version number of the software in the sensor. To the right of this is a description of the corrections applied to the data (Raw Data, Scaled & Off-set, Ortho Corrected, Angular Data, or Distance from Table). Next is the number of times the data is averaged. On the far right is the display of the current reading of this average.

On the second line, the accumulated time since the Maximum, Minimum, and Noise data was zeroed is displayed. Next to this is the number of readings taken in this time.

In the data area, there are four data sets. The first is the Current Data. This reflects the last reading from the sensor averaged and corrected as reflected in the status line. The second and third are the Maximum and Minimum Data areas. These areas record the largest and smallest values seen in current data area. The last area is Noise. This reflects the difference between the maximum and the minimum data areas. At the bottom of the screen is a list of available commands.

These are:

Q   -   Quit Program.
<Esc> -   Quit Program.
Z   -   Zero (reset) maximum, minimum, and noise data areas.

Figure 4 – Typical Screen Display

Model: APS 544   Ver: 1.032   Output is Raw Data in Counts   Averaged 1 Times   00
Accumulation Time: 00:00:09 (Counts:14)

Current Data:
   MAG: X:+25838.00000   Y:+25838.00000   Z:+25838.00000   T:+27112.00
   ACC: X:-25318.00000   Y:-25319.00000   Z:-25318.00000   T:+26786.00

Minimum Data:
   MAG: X:+25838.00000   Y:+25838.00000   Z:+25837.00000   T:+27111.00
   ACC: X:-25319.00000   Y:-25320.00000   Z:-25319.00000   T:+26786.00

Maximum Data:
   MAG: X:+25839.00000   Y:+25839.00000   Z:+25839.00000   T:+27112.00
   ACC: X:-25318.00000   Y:-25318.00000   Z:-25318.00000   T:+26788.00

Noise:
   MAG: X: +1.00000   Y: +1.00000   Z: +2.00000   T: +1.00
   ACC: X: +1.00000   Y: +2.00000   Z: +1.00000   T: +2.00

Q or <ESC> - Quit / Z – Zero Max/Mins M – Inc Data Mode / ± Averaging
P – Print / W – Write to File / C – Constant Mode / H – Hold / K – XYZ Cal

M   -   Increment data correction mode from raw to scaled to
              final corrected to angular data.
+   -   Add one to the number of averages done on data.
 -      -   Subtract one from the number of averages done on data.
P   -   Print the Current Data, Maximums, Minimums, and Noise.
W   -   Write the Current Data to a data file.
H   -   Hold the display and the program until a key is pressed.
K   -   Start the process of requesting and reading calibration data.
              (See the Calibration section for more information)
C   -   Change to a mode for displaying, storing, and changing
              constants internal to the sensor. (At the current time, few of these
              constants are used, and those that are preset to their correct values
              so this mode is of little use.)

11.3   Troubleshooting

If after starting the software you get a series of error messages rather than the data screen, wait for about twenty seconds. You will be asked to enter a new serial port. Enter a new com port number and press return to retry or press escape to exit.

If you have a communication error, this can be caused by:

Problem Indication	**Solution**
The sensor's power is off	Turn the sensor on and press return
The serial cable is unplugged	Plug it in and press return
The wrong serial port number was used	Enter the correct poet number and press return
The cable is wired incorrectly (The sensor is configured as a DTC device and so requires a null modem or a cable that reverses 2 & 3 between it and your computer)	Correct the cable or install a null modem and press return
Your P.C. serial port is non-standard or not configured as COM1 or COM2	Configure your port as COM1 or COM2 and your interrupt as INT 3 or INT 4

If the program starts fine but then locks up or displays errors on the screen, you may have a loose connection in your serial cable or at the connector, you may require a shielded cable or your cable may be too long (less than 25' are recommended).

Heading Sensor Command Set
CXM544
V3.18DFX 1/00

544

Addressed Command is : <Address><Command><CR>

An Address is <0-9 | A-Z>
CR is a Carriage Return
Axis is <X - Z | T>
Constant Number is <00 - 99>
Constant Value is <[-]<number>[.<number>]>
Constant String is <A-Z | 0-9><Constant String>
A number is <<0-9>[number]>

A command consists of one of the following:

Send All Data	: SD All Data is sent as requested, raw, vectors or angles as set by byte constant 2	MX: ±#.##### AX:±#.#####<CR><LF> MY: ±#.##### AY:±#.#####<CR><LF> MZ: ±#.##### AZ:±#.#####<CR><LF> MT: ±###.####<CR><LF> AT: ±###.####<CR><LF><EOT>
Send Ana1 Input	: SA ANA: #.#####<CR><LF><EOT>	
Read Float Constant	: SC<Constant Number>F ±########±E##<CR><LF><EOT>	
Read All Float Constants	: SC*F	00: ±########±E##<CR><LF> 01: ±########±E##<CR><LF> ... ##: ±########±E##<CR><LF><EOT>
Read Byte Constant	: SC<Constant Number>B ##<CR><LF><EOT> (In Hex)	
Read All Byte Constants	: SC*B 00: ##<CR><LF> (In Hex) 01: ##<CR><LF><EOT> ... ##: ##<CR><LF><EOT>	
Read int Constant	: SC<Constant Number>I #####<CR><LF><EOT>	
Read all int Constants	: SC*I	00: #####<CR><LF> 01: #####<CR><LF><EOT> ... ##: ##<CR><LF><EOT>

Reset A/D   : RA   Done\<CR>\<LF>\<EOT>

Test ROM Checksum(*)   : TC   if low level writes are
                                   enabled, the output is: STORED HHHH\<CR>\<LF>\<EOT>
                                   If low level writes are
                                   not enabled and the
                                   Checksum of the ROM is
                                   the same as the one
                                   stored: HHHH\<CR>\<LF>\<EOT>
                                   else the Output is: ERR HHHH\<CR>\<LF>\<EOT>

Test EEROM Checksum(*)   : TE   if low level writes are
                                   enabled, the output is: STORED HHHH\<CR>\<LF>\<EOT>
                                   If low level writes are
                                   not enabled and the
                                   Checksum of the ROM is
                                   the same as the one
                                   stored: HHHH\<CR>\<LF>\<EOT>
                                   else the Output is: ERR HHHH\<CR>\<LF>\<EOT>

Test RAM   : TR   Either an OK or an error   OK\<CR>\<LF>\<EOT>
                                   The Error Addr. is in Hex
                                            ERR AT: HHHH\<CR>\<LF>\<EOT>

Test EEROM Read/Write*   : TW   (This takes up to 10 Secs.)
                                   Either an OK or an error   OK\<CR>\<LF>\<EOT>
                                   The Error Addr. is in Hex
                                            ERR AT: HHHH\<CR>\<LF>\<EOT>

Test Serial Port   : TS   Always Echoes   OK\<CR>\<LF>\<EOT>

Return Software Version   : TV   Ver: #.###\<CR>\<LF>\<EOT>

Enable Low Level Writes   : L   Enabled!\<CR>\<LF>\<EOT>

Write Float To Constant*: WC\<Constant Number>F\<Value> Done\<CR>\<LF>\<EOT>

Write Byte To Constant*: WC\<Constant Number>B\<number> Done\<CR>\<LF>\<EOT>

Write Int To Constant*: WC<Constant Number>B<number> Done<CR><LF><EOT>

* All Commands marked with an * require the Enable Low Level Writes command to be executed as the previous command for successful execution.
All Commands Marked with a (*) execute differently when Enable Low Level Writes was executed as the previous command.

----- Binary Commands -----

<128> Send All Data as Vectors in a Binary Format.
<129> Send All Data as Vectors in a IEEE Float Format.
<131> Send All Data as Angles in a Binary Format
<132> Send All Data as Angles in a IEEE Float Format

<128> and <131>   Sends All Data in an encoded Binary Format in the
                       current format as selected by Byte constant #2.
                       If the correction mode is 0, 1 or 2 the data is
                       returned as:

  <<<<Sent First <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<Sent Last<<<<

                       If The Command is 128:

<NUMDATABYTES><MX><AX><MY><AY><MZ><AZ><MT><AT><0><DATACHKSUM><END>
 size   8b   16b   16b 16b 16b 16b 16b 16b 16b 8b   8b   16b
 in bits

                       If The Command is 131:
<NUM DATA
BYTES><Roll><MRoll><Pitch><Mag><Head><Grav><MT><AT><0><DATA CHK SUM><END>
size   8b   16b   16b   16b   16b   16b   16b   16b 8b   8b   16b
in bits

        <END>   = 0x7FFF (is unique in the data stream)
        <NUM DATA BYTES>   = 16
        <0>   = a constant 0 (to allow END to be unique)
        <DATA CHECK SUM>   = The lower 8 bits of the sum of all the bytes
                              in the data area.
        <Roll>   = The Roll data encoded as below.
        <Pitch>   = The Pitch data encoded as below.
        <Head>   = The Heading data encoded as below.

               <MRoll>   = The Magnetic Roll data encoded as below.

    <Mag>   = The Total Magnetic Field data encoded as
                          below.

    <Grav>   = The Total Gravitational Field data encoded as
                          below.

<MX>,<MY>,<MZ> = The Mag. data encoded as below.

<AX>,<AY>,<AZ> = The Acc. data encoded as below.

    <MT>,<AT>   = The Temp data encoded as below.

All data is sent most significant byte first.

If the correction mode is 0, the Mag and Acc data is in a
two byte signed integer format in counts.

If the correction mode is 1 or 2, the Mag and Acc data is in a
two byte signed integer format encoded as the float value
times 10000. (1.2345 = 12345)

If the correction mode is 3 the data is angles and is represented
in a two byte signed integer format encoded as the float value
times 10. (123.45 = 1234)

The Temp data is in a two byte signed integer format encoded
as the float value times 100. (123.45 = 12345)

<129>and <132>   Sends All Data in IEEE Floating point format in the current format as se-
                     lected by Byte constant #2.
                     If the correction mode is 0, 1 or 2 the data is
                     returned as:

<<<<Sent First<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<Sent Last<<<<

                 If The Command is 129:

  <NUM DATA BYTES><MX><AX><MY><AY><MZ><AZ><MT><AT><0><DATA
CHECK SUM>
 size   8b   32b 32b 32b 32b 32b 32b 32b 32b 8b
8b
 in bits
                 If The Command is 132:

  <NUM DATA
BYTES><Roll><MRoll><Pitch><Mag><Head><Grav><MT><AT><0><DATA CHECK
SUM>
 size   8b   32b   32b   32b 32b 32b   32b 32b 32b 8b   8b
 in bits
      <END>   = 0x7FFF (is unique in the data stream)
      <NUM DATA BYTES>   = 16

<0>	= a constant 0 (to allow END to be unique)
<DATA CHECK SUM>	= The lower 8 bits of the sum of all the bytes in the data area.
<Roll>	= The Roll data.
<Pitch>	= The Pitch data.
<Head>	= The Heading data.
<MRoll>	= The Magnetic Roll data.
<Mag>	= The Total Magnetic Field data.
<Grav>	= The Total Gravitational Field data.
<MX>,<MY>,<MZ>	= The Mag. data.
<AX>,<AY>,<AZ>	= The Acc. data.
<MT>,<AT>	= The Temp data.

All data is sent most significant byte first.

Ortho Constants are designated Result Axis first, Component Axis Second.

----- Float Constant Numbers and Their Meanings -----

00 - Ana1 Scale
01 - Temp Scale
02 - Ana1 Offset
03 - Temp Offset
04 - Mag Base Offset X
05 - Mag Base Offset Y
06 - Mag Base Offset Z
07 - Acc Base Offset X
08 - Acc Base Offset Y
09 - Acc Base Offset Z
10 - Mag Base Scale X
11 - Mag Base Scale Y
12 - Mag Base Scale Z
13 - Acc Base Scale X
14 - Acc Base Scale Y
15 - Acc Base Scale Z
16 - Mag Scale2 X
17 - Mag Scale2 Y
18 - Mag Scale2 Z
19 - Acc Scale2 X
20 - Acc Scale2 Y
21 - Acc Scale2 Z
22 - Mag Base Ortho(X,X)
23 - Mag Base Ortho(X,Y)
24 - Mag Base Ortho(X,Z)
25 - Mag Base Ortho(Y,X)

26 - Mag Base Ortho(Y,Y)
27 - Mag Base Ortho(Y,Z)
28 - Mag Base Ortho(Z,X)
29 - Mag Base Ortho(Z,Y)
30 - Mag Base Ortho(Z,Z)
31 - Acc Base Ortho(X,X)
32 - Acc Base Ortho(X,Y)
33 - Acc Base Ortho(X,Z)
34 - Acc Base Ortho(Y,X)
35 - Acc Base Ortho(Y,Y)
36 - Acc Base Ortho(Y,Z)
37 - Acc Base Ortho(Z,X)
38 - Acc Base Ortho(Z,Y)
39 - Acc Base Ortho(Z,Z)
40 - Bow Correction X
41 - Bow Correction Y
42 - Bow Correction Z

----- Byte Constant Numbers and Their Meanings -----

00 - Command Echo Flag. 0 is no command echo; anything else, echo commands
01 - Autostart Flag. If 0x5A executes the selected autostart option on
　　　powerup.
02 - Correction Level 0- Raw / 2- Vectors / 3- Angles
　　　In Angles mode, Roll is labeled MX, Pitch is labeled MY, Heading is
　　　Labeled MZ, Mag. Roll is labeled AX, Total Mag Field is labeled AY,
　　　Total Grav. Field is labeled AZ.
03 - Months since 1/90 when device was calibrated
04 - Version of the Calibration Software used
05 - Power on self test flag. If zero, a self test will be done on power
　　　up.
06 - Enable extended error messages
07 - This Sensor's Address Number 0-36 => 0-9,A-Z
08 - Auto Start Mode, on powerup start accepting commands then:
　　　0x00: Send all data in text mode once.
　　　0x01: Send all data In Binary mode once.
　　　0x02: Send all data In IEEE mode once.
　　　0x10: Send all data in text mode a loop until AutoStart is not 0x5A.
　　　0x11: Send all data In Bin. mode in a loop until AutoStart is not 0x5A.
　　　0x12: Send All Data In IEEE mode in a loop until AutoStart is not 0x5A.
09 - User power on baud rate lock (if not 0x5A sensor will use 9600 Baud).
10 - User power on baud rate. --Use With Caution--

Target Baud	Const #10	Target Baud	Const #10
75	37	1200	33
150	36	2400	32
300	35	4800	31
600	34	9600	30

11 - Not Used

12 - Lowest Calibration Temp. in counts. LSB

13 - Lowest Calibration Temp. in counts. MSB

14 - Distance in counts between Calibration Points LSB

15 - Distance in counts between Calibration Points MSB

16 - Number of Temp. Points in the SEEROM.

17 - The Table Mag Offset Scale Value.
     (Offset = TableOffset / $2^{<Byte\#18>}$)

18 - The Table Acc Offset Scale Value.
     (Offset = TableOffset / $2^{<Byte\#19>}$)

19 - The Table Mag Scale Scale Value. (Scale = TableScale / $2^{<Byte\#20>}$)

20 - The Table Acc Scale Scale Value. (Scale = TableScale / $2^{<Byte\#21>}$)

21 - The Table Mag Ortho Scale Value. (Ortho = TableOrtho / $2^{<Byte\#22>}$)

22 - The Table Acc Ortho Scale Value. (Ortho = TableOrtho / $2^{<Byte\#23>}$)

23 – Not Used

24 - Product I.D. String char #1

25 - Product I.D. String char #2

26 - Product I.D. String char #3

27 - Product I.D. String char #4

28 - Product I.D. String char #5

29 - Product I.D. String char #6

30 - Product I.D. String char #7

31 - Product I.D. String char #8

32 - Product I.D. String char #9

33 - Product I.D. String char #10

34 - Constant 0

35 - RTS Delay is the time in ~2 millisecond units that the RTS line is
     high before data is sent. Any value but 0 will slow the data rate by
     the same amount.

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