AHRS IMU Sensor | WT901C

The Robust Acceleration, Angular velocity, Angle & Magnetic filed Detector

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The WT901C is a IMU sensor device, detecting acceleration, angular velocity, angle as well as magnetic filed. The robust housing and the small outline makes it perfectly suitable for industrial applications such as condition monitoring and predictive maintenance. Configuring the device enables the customer to address a broad variety of application by interpreting the sensor data by smart algorithms and Kalman filtering.

BUILT-IN SENSORS

Accelerometer

Gyroscope

Magnetometer

Tutorial Link

Google Drive

Link to instructions DEMO:
WITMOTION Youtube Channel
WT901C Playlist

If you have technical problems or cannot find the information that you need in the provided documents, please contact our support team. Our engineering team is committed to providing the required support necessary to ensure that you are successful with the operation of our AHRS sensors.

Contact

Technical Support Contact Info

Application

- AGV Truck
- Platform Stability
- Auto Safety System
- 3D Virtual Reality
- Industrial Control
- Robot
- Car Navigation
- UAV
- Truck-mounted Satellite Antenna Equipment

Contents

1 Overview

WT901C's scientific name is AHRS IMU sensor. A sensor measures 3-axis angle, angular velocity, acceleration and magnetic field. Its strength lies in the algorithm which can calculate three-axis angle accurately.

WT901C is employed where the highest measurement accuracy is required. WT901C offers several advantages over competing sensor:

• Heated for best data availability: new WITMOTION patented zero-bias automatic detection calibration algorithm outperforms traditional accelerometer sensor

• High precision Roll Pitch Yaw (X Y Z axis) Acceleration + Angular Velocity + Angle + Magnetic Field output

• Low cost of ownership: remote diagnostics and lifetime technical support by WITMOTION service team

• Developed tutorial: providing manual, datasheet, Demo video, PC software, 51 serial, STM32, Arduino, and Matlab sample code, communication protocol

• WITMOTION sensors have been praised by thousands of engineers as a recommended attitude measurement solution

2 Features

- The default baud rate of this device is 9600 and could be changed.
- The interface of this product only leads to a serial port
- The module consists of a high precision gyroscope, accelerometer, geomagnetic field and barometer sensor. The product can solve the current real-time motion posture of the module quickly by using the high-performance microprocessor, advanced dynamic solutions and Kalman filter algorithm.
- The advanced digital filtering technology of this product can effectively reduce the measurement noise and improve the measurement accuracy.

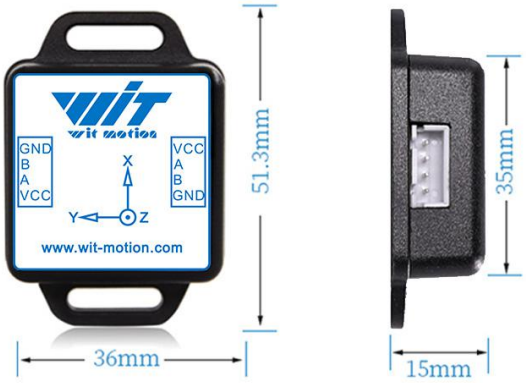
3 Specification

3.1 Parameter

Parameter	Specification
➢ Working Voltage	RS485:3.3V-5V
➢ Current	<40mA
➢ Size	51.3mm x 36mm X 15mm
➢ Data	Angle: X Y Z, 3-axis Acceleration: X Y Z, 3-axis Angular Velocity: X Y Z, 3-axis Magnetic Field : X Y Z, 3-axis Time, Quaternion
➢ Interface	Serial RS485 level
➢ Baud rate	9600(default, could be changed)

Measurement Range & Accuracy		
Sensor	Measurement Range	Accuracy/ Remark
➢ Accelerometer	X, Y, Z, 3-axis ±16g	Accuracy: 0.01g Resolution: 16bit Stability: 0.005g
➢ Gyroscope	X, Y, Z, 3-axis -±2000°/s	Resolution: 16bit Stability: 0.05°/s
➢ Magnetometer	X, Y, Z, 3-axis ±4900μT	0.15μT/LSB typ. (16-bit)
➢ Angle/ Inclinometer	X, Y, Z, 3-axis X, Z-axis: ±180° Y ±90° (Y-axis 90° is singular point)	Accuracy:X, Y-axis: 0.05° Z-axis: 1°(after magnetic calibration)

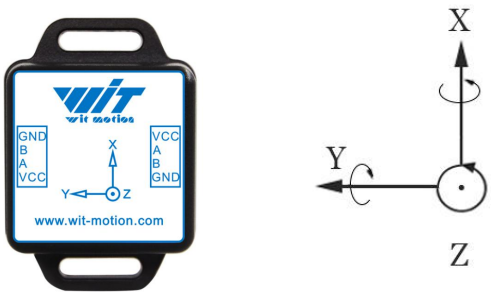
3.2 Size



Parameter	Specification	Tolerance	Comment
Length	51.3	±0.1	Unit: millimeter.
Width	36	±0.1	
Height	15	±0.1	
Weight	13	±1	Unit: gram

3.3 Axial Direction

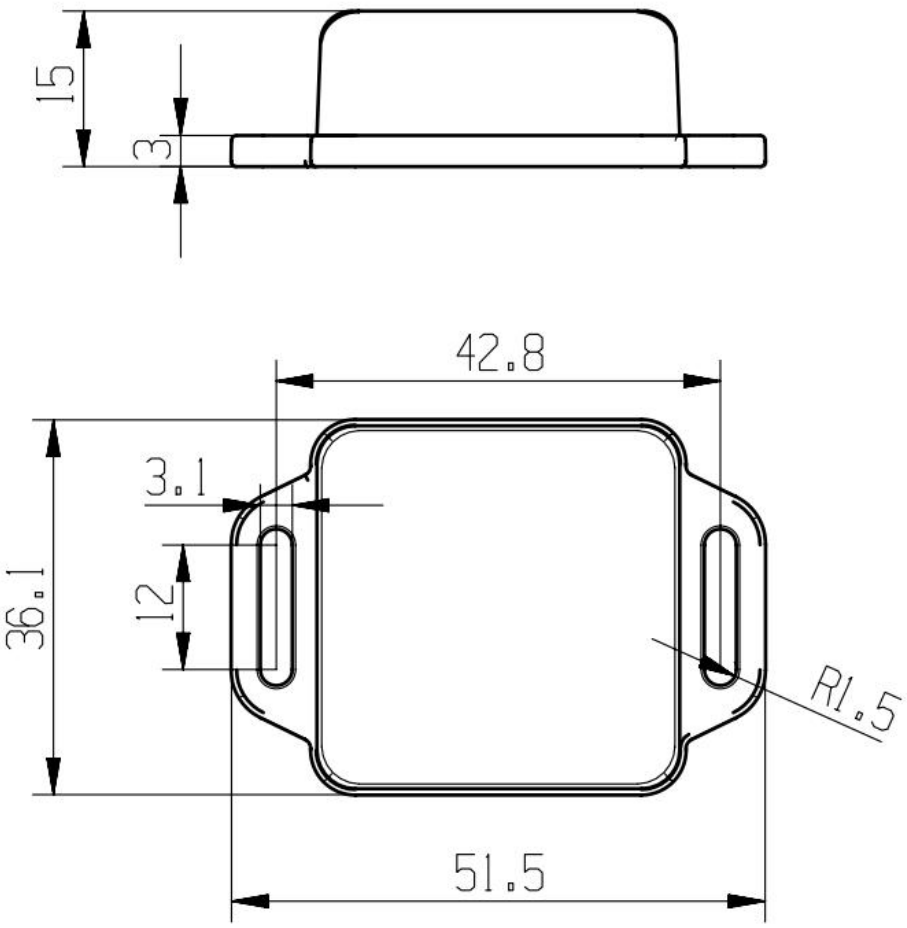
The coordinate system used for attitude angle settlement is the northeast sky coordinate system. Place the module in the positive direction, as shown in the figure below, direction left is the Y-axis, the direction forward is the X-axis, and direction upward is the Z-axis. Euler angle represents the rotation order of the coordinate system when the attitude is defined as Z-Y-X, that is, first turn around the Z-axis, then turn around the Y-axis, and then turn around the X-axis.



4 Pin Definition

PIN	Function
➢ VCC	3.3-5V input supply
➢ A	RS485 interface A - A
➢ B	RS485 interface B - B
➢ GND	Ground

5 Casing Specification



6 MODBUS Communication Protocol

Level: RS485 level
Baud rate: 4800, 9600 (default), 19200 38400, 57600, 115200, 230400, 460800, 921600, stop bit and parity stop bit and parity bit 0
HWT901B RS485 module can be accessed entirely through RS485, the default address is 0x50, can be hanged by serial port instruction or MODBUS write address.

6.1 Register List

The data in each address of the module is 16 bits of data, which is 2 bytes. The address and meaning of the register are as follows:

Address	Symbol	Meaning
0x00	SAVE	Save
0x01	CALSW	Calibration
0x02	RSV	Reserved
0x03	RSV	Reserved
0x04	BAUD	Baud rate
0x05	AXOFFSET	X axis Acceleration bias
0x06	AYOFFSET	Y axis Acceleration bias
0x07	AZOFFSET	Z axis Acceleration bias
0x08	GXOFFSET	X axis angular velocity bias
0x09	GYOFFSET	Y axis angular velocity bias
0x0a	GZOFFSET	Z axis angular velocity bias
0x0b	HXOFFSET	X axis Magnetic bias
0x0c	HYOFFSET	Y axis Magnetic bias
0x0d	HZOFFSET	Z axis Magnetic bias
0x0e~0x19	RSV	Reserved
0x1a	ADDR	Modbus address
0x1b	RSV	Reserved
0x1c	RSV	Reserved
0x30	MMYY	Month , Year
0x31	HHDD	Hour , Day
0x32	SSMM	Second , Minute

0x33	MS	Millisecond
0x34	AX	X axis Acceleration
0x35	AY	Y axis Acceleration
0x36	AZ	Z axis Acceleration
0x37	GX	X axis angular velocity
0x38	GY	Y axis angular velocity
0x39	GZ	Z axis angular velocity
0x3a	HX	X axis Magnetic
0x3b	HY	Y axis Magnetic
0x3c	HZ	Z axis Magnetic
0x3d	Roll	X axis Angle
0x3e	Pitch	Y axis Angle
0x3f	Yaw	Z axis Angle
0x40	TEMP	Temperature
0x41~0x50	RSV	Reserved
0x51	Q0	Quaternion Q0
0x52	Q1	Quaternion Q1
0x53	Q2	Quaternion Q2
0x54	Q3	Quaternion Q3

Details:

Save:

Save	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:00H	Save[15:0]															
Mode	W															
Value	0: Save all register 1: Restore to factory setting															

Calibration:

Calibration	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:01H	CALSW[15:0]															
Mode	W															
Value	0: Finish calibration(quit calibration) 1: Acceleration calibration 3: Reset height to 0 7: Magnetic calibration															

Baud rate:

Baud rate	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:04H	BAUD[15:0]															
Mode	R/W															
Value	1: 4800 2: 9600 3: 19200 4: 38400 5: 57600 6: 115200 7: 230400 8: 460800 9: 921600															

X axis Acceleration bias:

AXOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:05H	AXOFFSET[15:0]															
Mode	R/W															
Value	X axis Acceleration bias															

Y axis Acceleration bias:

AYOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:06H	AYOFFSET[15:0]															
Mode	R/W															
Value	Y axis Acceleration bias															

Z axis Acceleration bias:

AZOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:07H	AZOFFSET[15:0]															
Mode	R/W															
Value	Z axis Acceleration bias															

X axis angular velocity bias:

GXOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:08H	GXOFFSET[15:0]															
Mode	R/W															
Value	X axis angular velocity bias															

Y axis angular velocity bias:

GYOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:09H	GYOFFSET[15:0]															
Mode	R/W															
Value	Y axis angular velocity bias															

Z axis angular velocity bias:

GZOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:0aH	GZOFFSET[15:0]															
Mode	R/W															
Value	Z axis angular velocity bias															

X axis Magnetic:

HXOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:0bH	HXOFFSET[15:0]															
Mode	R/W															
Value	X axis Magnetic bias															

Y axis Magnetic bias:

HYOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:0cH	HYOFFSET[15:0]															
Mode	R/W															
Value	Y axis Magnetic bias															

Z axis Magnetic bias:

HZOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:0dH	HZOFFSET[15:0]															
Mode	R/W															
Value	Z axis Magnetic bias															

Modbus address:

GZOFFSET	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:1aH	ADDR[15:0]															
Mode	R/W															
Value	Modbus address															

Month , Year:

MMYY	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:30H	Month[7:0]								Year[7:0]							
Mode	R/W															
Value	Month , Year															

Hour , Day:

HHDD	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:31H	Hour[7:0]								Day[7:0]							
Mode	R/W															
Value	Hour , Day															

Second , Minute:

SSMM	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:33H	Second[7:0]								Minute[7:0]							
Mode	R/W															
Value	Second , Minute															

Millisecond:

MS	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:33H	MS[15:0]															
Mode	R/W															
Value	Millisecond															

X axis Acceleration:

AX	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:34H	AX[15:0]															
Mode	R															
Value	X axis Acceleration															

Y axis Acceleration:

AY	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:35H	AY[15:0]															
Mode	R															
Value	Y axis Acceleration															

Z axis Acceleration:

AZ	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:36H	AZ[15:0]															
Mode	R															
Value	Z axis Acceleration															

X axis angular velocity:

GX	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:37H	GX[15:0]															
Mode	R															
Value	X axis angular velocity															

Y axis angular velocity:

GY	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:38H	GY[15:0]															
Mode	R															
Value	Y axis angular velocity															

Z axis angular velocity:

GZ	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:39H	GZ[15:0]															
Mode	R															
Value	Z axis angular velocity															

X axis Magnetic:

HX	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:3aH	HX[15:0]															
Mode	R															
Value	X axis Magnetic															

Y axis Magnetic:

HY	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:3bH	HY[15:0]															
Mode	R															
Value	Y axis Magnetic															

Z axis Magnetic:

HZ	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:3cH	HZ[15:0]															
Mode	R															
Value	Z axis Magnetic															

X axis Angle:

Roll	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:3dH	Roll[15:0]															
Mode	R															
Value	X axis Angle															

Y axis Angle:

Pitch	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:3eH	Pitch[15:0]															
Mode	R															
Value	Y axis Angle															

Z axis Angle:

Yaw	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:3fH	Yaw[15:0]															
Mode	R															
Value	Z axis Angle															

Temperature:

TEMP	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:40H	TEMP[15:0]															
Mode	R															
Value	Temperature															

Quaternion:

Quaternion	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:51H	Quaternion Q0[15:0]															
Mode	R															
Value	Quaternion Q0															

Quaternion	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:52H	Quaternion Q1[15:0]															
Mode	R															
Value	Quaternion Q1															

Quaternion	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:53H	Quaternion Q2[15:0]															
Mode	R															
Value	Quaternion Q2															

Quaternion	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Addr:54H	Quaternion Q3[15:0]															
Mode	R															
Value	Quaternion Q3															

6.2 MODBUS Write Format

Device address	0x06	Reg H	Reg L	Data H	Data L	CRCH	CRCL
0x50 (default)	Write	Register high	Register low	Data high	Data low	CRC check high	CRC check low

Note: device address(MODBUS address) can be changed according to 6.1, default is 0x50,it can changed according to their own needs, device address :0x00-0x7F.

According to this date format, the baud rate, return rate and other data can be changed.

6.2.1 Example1:Calibrate Acceleration

Assume the device is 0x50.

Step 1: Send "unlock" commands
0x50 06 00 69 B5 88 22 A1

Place the sensor on a plat interface firstly

Step 2: Set the CSW register to acceleration calibration mode
0x50 06 00 01 00 01 14 4B

After sending the command, please kindly wait for 3-5 seconds.

Step 3: Set the CSW register to normal mode
0x50 06 00 01 00 00 D5 8B

Step 4: Send "Save Configuration" command
0x50 06 00 00 00 00 84 4B

6.2.2 Example2:Calibrate Magnetic

Assume the device is 0x50.

Step 1: Send "unlock" commands
0x50 06 00 69 B5 88 22 A1

Step 2: Set the CSW register to magnetic calibration mode
0x50 06 00 01 00 07 94 49

Please slowly rotate the module 360° around X, Y, Z-axis for three-time separately. After rotation at a uniform speed, proceed Step 3.

Step 3: Set the CSW register to normal mode
0x50 06 00 01 00 00 D5 8B

Step 4: Send "Save Configuration" command
0x50 06 00 00 00 00 84 4B

Purpose:
Magnetic calibration is used to remove the zero bias of the magnetic field sensor. Usually, the magnetic field sensor will have a large zero error when it is manufactured. If it is not calibrated, it will bring a large measurement error, which will affect the accuracy of the measurement of the z-axis Angle of the heading Angle.

Preparation:
Sensors should be 20CM away from magnetic and iron and other materials

6.2.3 Example3:Set Baud Rate

Assume the device address is 0x50.

If you want to change the baud rate from 9600 to 115200.

Step 1.First you should send unlock command to your device use baud rate 9600.
the unlock command is write 0xB588 to register 0x69.
Send: 0x50 06 00 69 B5 88 22 A1

2. Send baud rate set command:
   Send: 0x50 0x06 0x00 0x04 0x00 0x06 0x45 0x88

3. Then change your master device's baud rate to 115200.

4. Send save config command:
   0x50 06 00 00 00 00 84 4B

6.2.4 Example4:Set Modbus address

Assume the device is 0x50. If you want to change address to 0x51, instructions as below.

Step 1: Send “unlock” commands
0x50 06 00 69 B5 88 22 A1

Step 2: Change the device address from 0x50 to 0x51
0x50 06 00 1a 00 51 64 70

Step 3: Send “Save Configuration” command
0x51 06 00 00 00 00 84 4B

Note: Sending frequency shall be 0.5s between each command.

6.3 MODBUS Read Format:

Device address	Read	Reg H	Reg L	regNum H	regNum L	CRC H	CRCL
0x50 (default)	0x03	RegH(First Reg)	RegL(First Reg)	Register number high	Register number low	0x00	0x00

Example:

Read X Y Z angle

0x50 0x03 0x00 0x3d 0x00 0x03 0x99 0x86
(0x3d is the Modbus register address of X-axis angle. 0x99 0x86 needs to be calculated, refer to the CRC calculation part of the communication protocol)

Data Format:

0x50	0x03	0xN	Data H	Data L	...	CRCH	CRCL
Device address	Read function	Register Number =(0-0x7F)	First data high	First data low	...N data	CRC check high	CRC check low

Example:

Read X Y Z angle:180° 90° 30°

0x50 0x03 0x06 0x80 0x00 0x40 0x00 0x15 0x55 0x14 0x49

6.3.1 Read Acceleration:

Send:
50 03 00 34 00 03 49 84

Tips: 50 is device address, 49 84 is the CRC.
For CRC calculation method, please search CRC calculator on Google.

Return:

MODADDR	0X 03	0X 06	AxH	AxL	AyH	Ay L	AzH	AzL	CRC H	CRC L

Calculation:
a x =((AxH<<8)|AxL)/32768*16g(g is Gravity acceleration,9.8m/s 2)
a y =((AyH<<8)|AyL)/32768*16g(g is Gravity acceleration,9.8m/s 2)
a z =((AzH<<8)|AzL)/32768*16g(g is Gravity acceleration,9.8m/s 2)

CRCH:CRC Stop bit High
CRCL:CRC Stop bit Low

Note:
1、The data is transmitted in accordance with the 16 hexadecimal, notASCII code
2、Each data is transmitted in a low byte and a high byte, and the two is combined into a short type of symbol. Such as X axis acceleration data Ax, where AxL is the low byte,AxH is high byte.

The conversion method is as follows:
Assuming Data is the actual data, DataH for its high byte, DataL for its low byte part,then: Data= ((short) DataH<<8) |DataL. Here we must pay attention to that force the DataH to be converted into a symbol of the short type of data and then after shift 8 bit, and the type of Data is also a symbol of the short type, so it can show a negative.

6.3.2 Read Angular Velocity:

MODADDR	0x03	0x06	wxH	wxL	wyH	wyL	wzH	wzL	CRCH	CRCL

Calculated formular:
w x =((wxH<<8)|wxL)/32768*2000(°/s)
w y =((wyH<<8)|wyL)/32768*2000(°/s)
w z =((wzH<<8)|wzL)/32768*2000(°/s)
CRCH:CRC Stop bit High
CRCL:CRC Stop bit Low

6.3.3 Read Angle Output:

MODADDR	0x03	0x06	RollH	RollL	PitchH	PitchL	YawH	YawL	CRCH	CRCL

Calculated formular:
Roll(x axis)Roll=((RollH<<8)|RollL)/32768*180(°)
Pitch(y axis)Pitch=((PitchH<<8)|PitchL)/32768*180(°)
Yaw(z axis)Yaw=((YawH<<8)|YawL)/32768*180(°)
Note:
1. Attitude angle use the coordinate system for the Northeast sky coordinate system, the X axis is East,the Y axis is North, Z axis toward sky. Euler coordinate system rotation sequence defined attitude is z-y-x, first rotates around the Z axis. Then, around the Y axis, and then around the X axis.

2. In fact, the rotation sequence is Z-Y-X, the range of pitch angle (Y axis) is only ±90 degrees, when the pitch angle (Y axis) is bigger than 90 degrees and the pitch angle (Y axis) will become less than 90 degrees. At the same time, the Roll Angle(X axis) will become larger than 180 degree. Please search on Google about more information of Euler angle and attitude information.

3. Since the three axis are coupled, the angle will be independent only when the angle is small. It will be dependent of the three angle when the angle is large when the attitude angle change, such as when the X axis close to 90 degrees, even if the attitude angle around the X axis, Y axis angle will have a big change, which is the inherent characteristics of the Euler angle

6.3.4 Magnetic output:

MODADDR	0x03	0x06	HxH	HxL	HyH	HyL	HzH	HzL	CRCH	CRCL

Calculation:

Magnetic Field(x-axis)Hx=((HxH<<8)| HxL)
Magnetic Field(y-axis)Hy=((HyH <<8)| HyL)
Magnetic Field(z-axis)Hz =((HzH<<8)| HzL)

CRCH:CRC Stop bit high
CRCL:CRC stop bit low

6.3.5 Quaternion output:

MODADDR	0x03	0x08	Q0H	Q0L	Q1H	Q1L	Q2H	Q2L	Q3H	Q3L	CRCH	CRCL

Calculation:

Q0=((Q0H<<8)|Q0L)/32768
Q1=((Q1H<<8)|Q1L)/32768
Q2=((Q2H<<8)|Q2L)/32768
Q3=((Q3H<<8)|Q3L)/32768

CRCH:CRC Stop bit high
CRCL:CRC stop bit low