



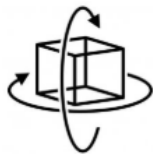
## Bluetooth AHRS IMU sensor | WT9011DCL-BT5.0

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

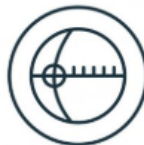
---

*The WT9011DCL-BTL5.0 is a Bluetooth 5.0 multi-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.*

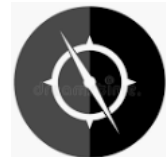
### BUILT-IN SENSORS



Accelerometer



Gyroscope



Magnetometer

## Tutorial Link

[Google Drive](#)

**Link to instructions DEMO:**

[WITMOTION Youtube Channel](#)

[WT9011DCL-BT5.0 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

- Unmanned/Assisted Driving
- Large-scale farming automated farming
- Safety monitoring for working at heights
- Unmanned aerial vehicle
- Industrial attitude monitoring
- Human motion tracking/capture
- Robot, Automated Guided Transporter
- Pedestrian Navigation
- Truck-mounted Satellite Antenna Equipment

## Contents

|                                               |        |
|-----------------------------------------------|--------|
| Tutorial Link.....                            | - 2 -  |
| Contact .....                                 | - 2 -  |
| Application .....                             | - 2 -  |
| Contents .....                                | - 3 -  |
| 1 Overview .....                              | - 4 -  |
| 2 Features .....                              | - 5 -  |
| 3 Specification .....                         | - 6 -  |
| 3.1 Parameter .....                           | - 6 -  |
| 3.2 Size.....                                 | - 8 -  |
| 3.3 Axial Direction .....                     | - 9 -  |
| 4 Port Definition .....                       | - 10 - |
| 5 Casing Specification .....                  | - 11 - |
| 6 Communication Protocol .....                | - 12 - |
| 6.1 Data Format.....                          | - 12 - |
| 6.1.1 Data Packet(Default) .....              | - 12 - |
| 6.1.2 Single Return Register Data Packet..... | - 15 - |
| 6.2 Commands.....                             | - 19 - |
| 6.2.1 Read Register Value.....                | - 19 - |
| 6.2.2 Calibration.....                        | - 19 - |
| 6.2.3 Save Settings .....                     | - 20 - |
| 6.2.4 Return Rate .....                       | - 20 - |
| 6.3 Register Address.....                     | - 21 - |

# 1 Overview

WT9011DCL-BT5.0's scientific name is AHRS IMU sensor. A sensor measures 3-axis angle, angular velocity, acceleration, magnetic field. Its strength lies in the algorithm which can calculate three-axis angle accurately.

WT9011DCL-BT5.0 is an CE certified accelerometer. It is employed where the highest measurement accuracy is required. WT9011DCL-BT5.0 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, free software for Windows computer, APP for Android smartphones, iOS APP for iPhone, communication protocol for project development
- WITMOTION sensors have been praised by thousands of engineers as a recommended attitude measurement solution

## 2 Features

- The sensor integrates high-precision gyroscope, accelerometer and geomagnetic field sensor, and adopts high-performance microprocessor and advanced dynamic calculation and Kalman dynamic filtering algorithm, which can quickly solve the current real-time motion attitude of the sensor.
- The advanced digital filtering technology can effectively reduce the measurement noise and improve the measurement accuracy.
- The sensor is integrated with the attitude solver and the dynamic Kalman filter algorithm, which can accurately output the current attitude of the sensor in the dynamic environment. The attitude measurement accuracy is 0.2 degree, the stability is extremely high, and the performance is even better than some professional inclination meter.
- The Z-axis heading angle is added to the filter fusion of the geomagnetic sensor, which solves the cumulative error caused by the drift of the gyroscope integral in the 6-axis algorithm, and can output the heading angle data stably for a long time. Note: Due to the magnetic field detection, it needs to be calibrated before use, and it needs to be at least 20cm away from magnetic interference areas, electronic equipment, magnets, speakers and other hard magnetic objects.
- Working current:  $\approx 14\text{mA}$ , standby current  $14\mu\text{A}$ - $30\mu\text{A}$ .
- Data interface: baud rate 115200.
- The output content can be selected arbitrarily, data output frequency:  $0.2\text{Hz}\sim 200\text{Hz}$ , default  $10\text{Hz}$ .
- Bluetooth 5.0 wireless transmission, transmission stability, the longest distance up to 90 meters.
- Bluetooth 5.0: Support Android /IOS operating system (the actual use depends on the final device)
- battery: working time: 8 hours, charging time: 2 hours, capacity: 130mAh

## 3 Specification

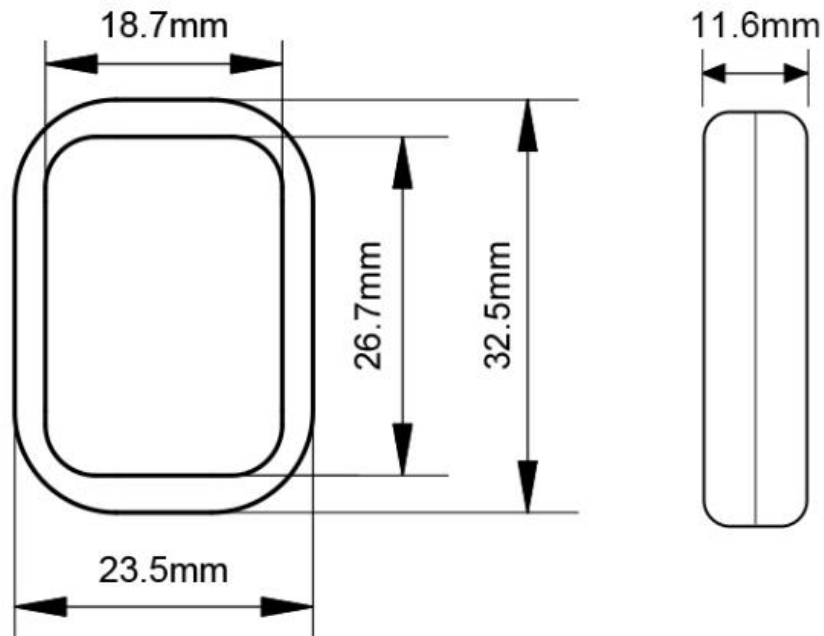
### 3.1 Parameter

| Parameter          | Specification                                                                                                                                    |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| ➤ Voltage          | 3.3-5V                                                                                                                                           |
| ➤ Current          | Working current:14mA<br>Broadcast current:21mA<br>Stand-by current:14uA-30uA                                                                     |
| ➤ Range            | Acceleration: $\pm 16g$<br>Angular Velocity: $\pm 2000^\circ/s$<br>Magnetic field: $\pm 2Gauss$<br>Angle: X/Z $\pm 180^\circ$ , Y $\pm 90^\circ$ |
| ➤ Resolution       | Acceleration:0.5mg/LSB(2048LSB/g)<br>Angular Velocity:0.061( $^\circ/s$ )/LSB<br>Magnetic field:0.0667mG/LSB<br>Angle:0.0055 $^\circ$ /LSB       |
| ➤ Accuracy         | acceleration: 0.01g, angular speed 0.2 $^\circ/s$                                                                                                |
| ➤ Output content   | Acceleration, Angular Velocity, Angle<br>(Magnetic is not output by default)                                                                     |
| ➤ Distance         | up to 90 meters (open area)                                                                                                                      |
| ➤ Battery          | working time: 8 hours, charging time: 2 hours,<br>capacity: 130mAh                                                                               |
| ➤ Duration         | 8 hours                                                                                                                                          |
| ➤ Size             | 23.5mm x 32.5mm x 11.4mm                                                                                                                         |
| ➤ Weight           | 9g                                                                                                                                               |
| ➤ Data             | Angle: X Y Z, 3-axis<br>Acceleration: X Y Z, 3-axis<br>Angular Velocity: X Y Z, 3-axis<br>Magnetic Field : X Y Z, 3-axis<br>Time, Quaternion     |
| ➤ Output frequency | 0.2Hz--200Hz, default 10HZ                                                                                                                       |
| ➤ Interface        | Bluetooth5.0/Type-C                                                                                                                              |
| ➤ Bluetooth        | Bluetooth Coverage range: $\leq 90m$<br>Built-in Chip: nRF52832                                                                                  |

## Measurement Range & Accuracy

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

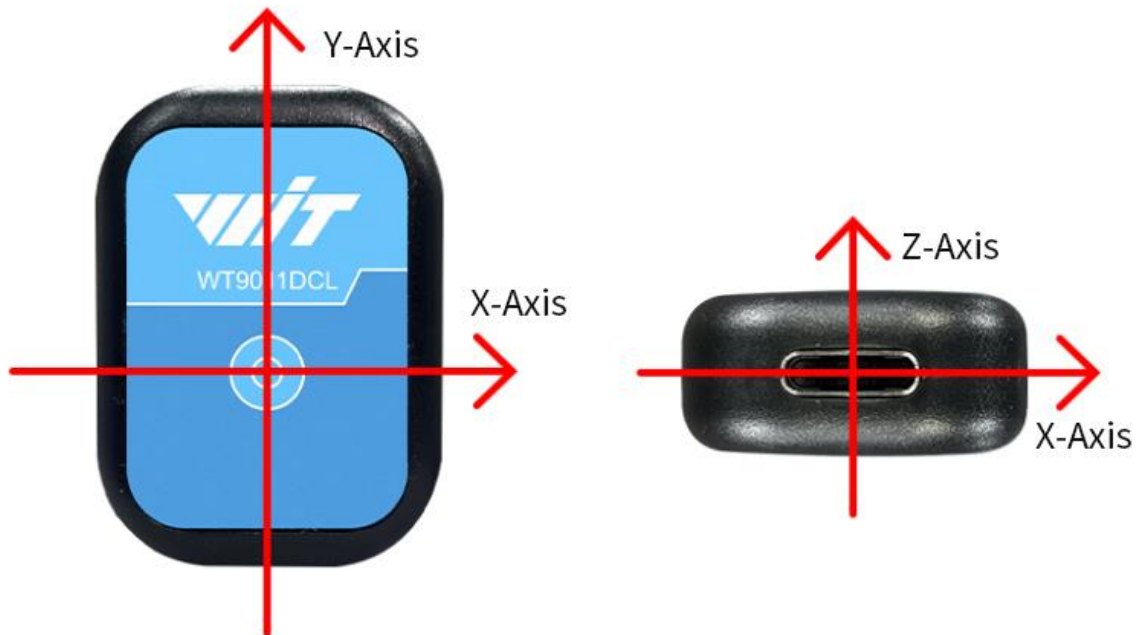
## 3.2 Size



| Parameter | Specification | Tolerance | Comment           |
|-----------|---------------|-----------|-------------------|
| Length    | 32.5          | $\pm 0.2$ | Unit: millimeter. |
| Width     | 23.5          | $\pm 0.2$ |                   |
| Height    | 11.6          | $\pm 0.2$ |                   |
| Weight    | 9             | $\pm 0.2$ | Unit: gram        |

### 3.3 Axial Direction

As shown in the product size drawing. The direction of rotation is defined by the rule of the right hand, that is, the thumb of the right hand points to the axis, and the direction of the four fingers bending is the direction of rotation around the axis.

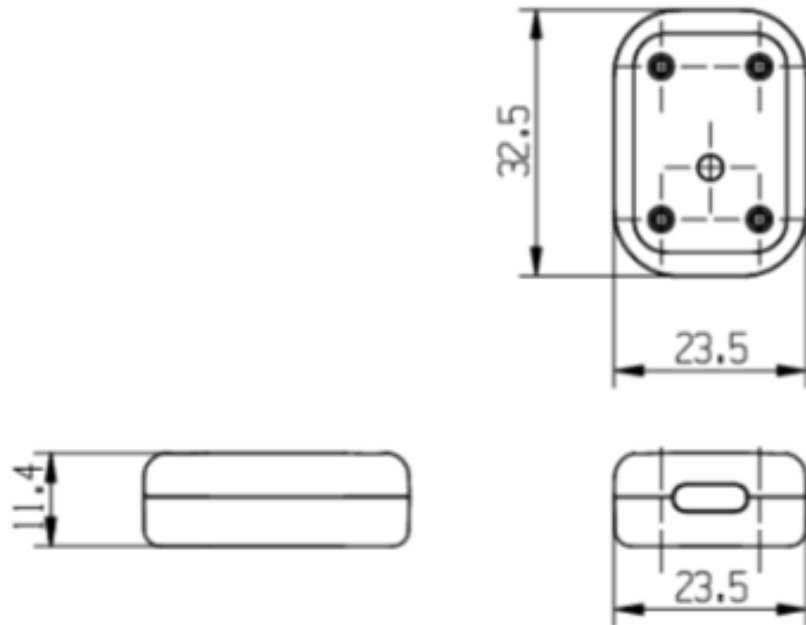


## 4 Port Definition



| PIN      | Function            |
|----------|---------------------|
| ➤ Type-C | 3.3-5V input supply |

## 5 Casing Specification



## 6 Communication Protocol

### 6.1 Data Format

Sensor upload Flag=0x61 (Angle, Angular velocity, Acceleration) data default.

Flag=0x71(Magnetic field) need to send the corresponding register instruction.

Upload data format of Bluetooth: uploads up to 20 bytes per data

#### 6.1.1 Data Packet(Default)

| Packet heading 1Byte | Flag bit 1Byte | axL  | axH  | ..... | YawL | YawH |
|----------------------|----------------|------|------|-------|------|------|
| 0x55                 | Flag           | 0xNN | 0xNN | ..... | 0xNN | 0xNN |

Note: 0xNN is an accurate value received. Data return sequence: Acceleration X Y Z, Angular velocity X Y Z, Angle X Y Z, low byte first, high byte last.

Flag = 0x61 Data content: 18Byte is Acceleration, Angular velocity, Angle.

|        |                                |
|--------|--------------------------------|
| 0x55   | Packet header                  |
| 0x61   | Mark bit                       |
| axL    | X Acceleration low 8 byte      |
| axH    | X Acceleration high 8 byte     |
| ayL    | Y Acceleration low 8 byte      |
| ayH    | Y Acceleration high 8 byte     |
| azL    | Z Acceleration low 8 byte      |
| azH    | Z Acceleration high 8 byte     |
| wxL    | X Angular velocity low 8 byte  |
| wxH    | X Angular velocity high 8 byte |
| wyL    | Y Angular velocity low 8 byte  |
| wyH    | Y Angular velocity high 8 byte |
| wzL    | Z Angular velocity low 8 byte  |
| wzH    | Z Angular velocity high 8 byte |
| RollL  | X Angle low 8 byte             |
| RollH  | X Angle high 8 byte            |
| PitchL | Y Angle low 8 byte             |
| PitchH | Y Angle high 8 byte            |
| YawL   | Z Angle low 8 byte             |
| YawH   | Z Angle high 8 byte            |

Acceleration calculation method: Unit: g

$$a_x = ((axH \ll 8) | axL) / 32768 * 16g \text{ (g is Gravity acceleration, } 9.8m/s^2 \text{)}$$

$$a_y = ((ayH \ll 8) | ayL) / 32768 * 16g \text{ (g is Gravity acceleration, } 9.8m/s^2 \text{)}$$

$$a_z = ((azH \ll 8) | azL) / 32768 * 16g \text{ (g is Gravity acceleration, } 9.8m/s^2 \text{)}$$

Angular Calculation method: Unit: °/s

$$w_x = ((wxH \ll 8) | wxL) / 32768 * 2000 \text{ (°/s)}$$

$$w_y = ((wyH \ll 8) | wyL) / 32768 * 2000 \text{ (°/s)}$$

$$w_z = ((wzH \ll 8) | wzL) / 32768 * 2000 \text{ (°/s)}$$

Angle Calculation method: Unit: °

$$\text{Roll (X axis) Roll} = ((RollH \ll 8) | RollL) / 32768 * 180 \text{ (°)}$$

$$\text{Pitch (Y axis) Pitch} = ((PitchH \ll 8) | PitchL) / 32768 * 180 \text{ (°)}$$

$$\text{Yaw angle (Z axis) Yaw} = ((YawH \ll 8) | YawL) / 32768 * 180 \text{ (°)}$$

Note:

1. The coordinate system used in the settlement of attitude Angle is the northeast sky coordinate system, and the sensor is placed in the positive direction. As shown in "4 pin Description", the left axis is the X axis, the forward axis is the Y axis, and the upward axis is the Z axis. When Euler Angle represents the attitude, the rotation order of the coordinate system is defined as Z-Y-X, that is, first rotate around the Z axis, then rotate around the Y axis, then rotate around the X axis.
2. Although the range of the roll Angle is  $\pm 180$  degrees, in fact, because the coordinate rotation order is Z-Y-X, the range of the pitch Angle (Y-axis) is only  $\pm 90$  degrees when the attitude is expressed. When it exceeds 90 degrees, it will be changed to less than 90 degrees, and the Angle of the X-axis will be greater than 180 degrees. The detailed principle please Baidu Euler Angle and attitude of the relevant information.
3. Since the three axes are coupled, they only exhibit independent changes when the Angle is small, and the attitude Angle will change coupled when the Angle is large. For example, when the Y-axis is close to 90 degrees, even if the attitude only rotates around the Y-axis, the Angle of the X-axis will also change greatly, which is the inherent characteristic of the attitude represented by Euler Angle.

Description:

1. The data is sent in hexadecimal not ASCII code.
2. Each data is transmitted in order of low byte and high byte, and the two are combined into a signed short type data. For example, the X-axis acceleration data  $A_x$ , where  $A_{xL}$  is the low byte and  $A_{xH}$  is the high byte. The conversion method is as follows:

For example:

Assuming that Data is actual data, DataH is the high byte part, and DataL is the low byte part, then:  $\text{Data} = ((\text{short}) \text{DataH} \ll 8) \mid \text{DataL}$ . It must be noted here that DataH needs to be converted to a signed short data first and then shifted, and the data type of Data is also a signed short type, so that it can represent negative numbers.

## 6.1.2 Single Return Register Data Packet

Single return data packet needs to send register instruction first:

|                |
|----------------|
| FF AA 27 XX 00 |
|----------------|

--XX is register number. The register number please refer to 7.3. Example as below:

| Function                       | Instruction                      |
|--------------------------------|----------------------------------|
| Read Magnetic Field            | FF AA 27 3A 00                   |
| Read Quaternion                | FF AA 27 51 00                   |
| Read Temperature               | FF AA 27 40 00                   |
| Read the amount of electricity | FF AA 27 64 00                   |
| Read the version number        | FF AA 27 2E 00<br>FF AA 27 2F 00 |

After sending the instructions, the sensor will turn back a data packet 0x55 0x71. There are register addresses and 7 registers data (Fixed upload 8 registers). Return data format as below:

Start register(2 byte) + register data(16 byte, 8 registers)

| Packet header | Sign | Start register low byte | Start register high byte | Start (No.1) register data low byte | Start (No.1) register data high byte | ..... | No.8 register data low byte | No.8 register data high byte |
|---------------|------|-------------------------|--------------------------|-------------------------------------|--------------------------------------|-------|-----------------------------|------------------------------|
| 0x55          | 0x71 | RegL                    | RegH                     | 0xNN                                | 0xNN                                 | ..... | 0xNN                        | 0xNN                         |

Note: 0xNN is the specific value received, with the low byte first and the high byte second.

### 6.1.2.1 Magnetic Field Output

Note: The unit of magnetic field data calculated from raw data is milligauss, which is different from the unit displayed on the computer. If you need to convert the unit to the same as the computer, you need to calculate it according to the following method.

[https://drive.google.com/file/d/1YW5FI9IPqjwAbpBS1bPPzixDOEWZZ7yW/view?usp=drive\\_link](https://drive.google.com/file/d/1YW5FI9IPqjwAbpBS1bPPzixDOEWZZ7yW/view?usp=drive_link)

|      |      |      |      |     |     |     |     |     |     |       |
|------|------|------|------|-----|-----|-----|-----|-----|-----|-------|
| 0x55 | 0x71 | 0x3A | 0x00 | HxL | HxH | HyL | HyH | HzL | HzH | ..... |
|------|------|------|------|-----|-----|-----|-----|-----|-----|-------|

Calculated formular: Unit: mG

Magnetic field (x axis)  $H_x = ((H_{xH} \ll 8) | H_{xL})$

Magnetic field (y axis)  $H_y = ((H_{yH} \ll 8) | H_{yL})$

Magnetic field (z axis)  $H_z = ((H_{zH} \ll 8) | H_{zL})$

For example: Send instruction to read magnetic field in APP: FF AA 27 3A 00 (Please refer to 6.1.2)

The sensor return data to APP: 55, 71 00 68 01 00 69 3 a 7 a 00 00 00 00 00 00 00 00 00 00, a total of 20 bytes.

Calculate the no.5 to no.10 bytes as described above, magnetic field  $x=360$ ,  $y=105$ ,  $z=122$

### 6.1.2.2 Quaternion Output

|      |      |      |      |     |     |     |     |     |     |     |     |
|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|
| 0x55 | 0x71 | 0x51 | 0x00 | Q0L | Q0H | Q1L | Q1H | Q2L | Q2H | Q3L | Q3H |
|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|

Calculated formular:

$Q_0 = ((Q_{0H} \ll 8) | Q_{0L}) / 32768$

$Q_1 = ((Q_{1H} \ll 8) | Q_{1L}) / 32768$

$Q_2 = ((Q_{2H} \ll 8) | Q_{2L}) / 32768$

$Q_3 = ((Q_{3H} \ll 8) | Q_{3L}) / 32768$

Checksum:

WT9011DCL-BT5.0 | Datasheet v23-0608 | [www.wit-motion.com](http://www.wit-motion.com)

Sum=0x55+0x59+Q0L+Q0H+Q1L +Q1H +Q2L+Q2H+Q3L+Q3H

### 6.1.2.3 Temperature Output

|      |      |      |      |    |    |       |
|------|------|------|------|----|----|-------|
| 0x55 | 0x71 | 0x40 | 0x00 | TL | TH | ..... |
|------|------|------|------|----|----|-------|

Calculated formular:

$$T = ((TH \ll 8) | TL) / 100^{\circ}\text{C}$$

### 6.1.2.4 Temperature Output

|      |      |      |      |           |           |       |
|------|------|------|------|-----------|-----------|-------|
| 0x55 | 0x71 | 0x2E | 0x00 | Version1L | Version1H | ..... |
| 0x55 | 0x71 | 0x2F | 0x00 | Version2L | Version2H | ..... |

Version number calculation formula:

$$\text{Version1} = ((\text{Version1H} \ll 8) | \text{Version1L})$$

$$\text{VERSION} = \text{Version1} . \text{Version2H} . \text{Version2L}$$

## 6.2 Commands

### 6.2.1 Read Register Value

|                |                     |
|----------------|---------------------|
| FF AA 27 XX 00 | Read register value |
|----------------|---------------------|

--XX is register.

For example::

Read magnetic field: FF AA 27 3A 00

Read quaternion: FF AA 27 51 00

Read temperature: FF AA 27 40 00

After sending this instruction, the sensor will send back a data packet starting with 0x55 0x71, which contains the data of the corresponding start register address, the start register address and the following 7 registers (8 registers are fixed to be uploaded). The format of the return data is referred to 7.1.2.

### 6.2.2 Calibration

|                |                                     |
|----------------|-------------------------------------|
| FF AA 01 01 00 | Accelerometer Calibration           |
| FF AA 01 07 00 | Magnetic Field Calibration          |
| FF AA 01 00 00 | Complete Magnetic Field Calibration |

For example, to calibrate the magnetic field,

Step 1. Send FF AA 01 07 00

Step 2. Rotate the sensor 360 degree around three axis  
(it is recommended to rotate 3 circle, 360 degree \*3)

Step 3. Send FF AA 01 00 00 to quit the calibration

## 6.2.3 Save Settings

|                  |               |
|------------------|---------------|
| FF AA 00 SAVE 00 | Save Settings |
|------------------|---------------|

SAVE: Set

0: Save current configuration

1: Restore default configuration and save

## 6.2.4 Return Rate

|                  |                 |
|------------------|-----------------|
| FF AA 03 RATE 00 | Set return rate |
|------------------|-----------------|

RATE: return rate

0x01: 0.2Hz

0x02: 0.5Hz

0x03: 1Hz

0x04: 2Hz

0x05: 5Hz

0x06: 10Hz(default)

0x07: 20Hz

0x08: 50Hz

0x09: 100Hz

0x0B: 200Hz

0x0C: Single return

## 6.2.4 Return Rate

|                |                      |
|----------------|----------------------|
| FF AA 27 64 00 | Reading sensor power |
|----------------|----------------------|

The corresponding relationship between voltage and power percentage is:

| Register value | Voltage value | Battery percentage |
|----------------|---------------|--------------------|
| > 396          | > 3.96V       | 100%               |
| 393-396        | 3.93V-3.96V   | 90%                |
| 387-393        | 3.87V-3.93V   | 75%                |
| 382-387        | 3.82V-3.87V   | 60%                |
| 379-382        | 3.79V-3.82V   | 50%                |
| 377-379        | 3.77V-3.79V   | 40%                |
| 373-377        | 3.73V-3.77V   | 30%                |
| 370-373        | 3.70V-3.73V   | 20%                |
| 368-370        | 3.68V-3.70V   | 15%                |
| 350-368        | 3.50V-3.68V   | 10%                |
| 340-350        | 3.40V-3.50V   | 5%                 |
| <340           | <3.40V        | 0%                 |

## 6.3 Register Address

| Address | Symbol   | Function                                   |
|---------|----------|--------------------------------------------|
| 0x00    | SAVE     | Save the current configuration             |
| 0x01    | CALSW    | The calibration                            |
| 0x03    | RATE     | Data return rate                           |
| 0x05    | AXOFFSET | The X-axis acceleration is zero partial    |
| 0x06    | AYOFFSET | The Y-axis acceleration is zero offset     |
| 0x07    | AZOFFSET | The z-axis acceleration is zero offset     |
| 0x08    | GXOFFSET | The X-axis angular velocity is zero offset |
| 0x09    | GYOFFSET | The Y-axis angular velocity is zero offset |
| 0x0a    | GZOFFSET | The Z axis angular velocity is zero offset |

WT9011DCL-BT5.0 | Datasheet v23-0608 | [www.wit-motion.com](http://www.wit-motion.com)

|      |          |                                                           |
|------|----------|-----------------------------------------------------------|
| 0x0b | HXOFFSET | The X-axis magnetic field is zero offset                  |
| 0x0c | HYOFFSET | Y-axis magnetic field zero deviation                      |
| 0x0d | HZOFFSET | Z-axis magnetic field zero deviation                      |
| 0x30 | YYMM     | Year and month                                            |
| 0x31 | DDHH     | Day and hour                                              |
| 0x32 | MMSS     | Minutes, seconds                                          |
| 0x33 | MS       | ms                                                        |
| 0x34 | AX       | X axis acceleration                                       |
| 0x35 | AY       | Y-axis acceleration                                       |
| 0x36 | AZ       | Z axis acceleration                                       |
| 0x37 | GX       | X angular velocity                                        |
| 0x38 | GY       | Y-axis angular velocity                                   |
| 0x39 | GZ       | Z axis angular velocity                                   |
| 0x3a | HX       | X-axis magnetic field                                     |
| 0x3b | HY       | Y-axis magnetic field                                     |
| 0x3c | HZ       | Z axis magnetic field                                     |
| 0x3d | Roll     | X axis Angle                                              |
| 0x3e | Pitch    | Y axis Angle                                              |
| 0x3f | Yaw      | Z axis Angle                                              |
| 0x51 | Q0       | Four elements Q0                                          |
| 0x52 | Q1       | Four elements Q1                                          |
| 0x53 | Q2       | Four element Q2                                           |
| 0x54 | Q3       | Four elements Q3                                          |
| 0x04 | BAUD     | Serial port baud rate                                     |
| 0x2e | VERSION1 | version number                                            |
| 0x2f | VERSION2 | Firmware version number branch<br>Hardware version number |