



# DMC5000

## 3D High-precision Electronic Compass Technical Manual



## Introduction

The DMC5000 high-precision electronic compass is composed of an industrial-grade single-chip microcomputer with high reliability and strong anti-interference ability, and a high-precision magnetic sensor and drive chip. At the same time, it integrates the hard magnetic and soft magnetic calibration algorithms of Beiwei Sensing patented technology, and uses a three-axis accelerometer to compensate for the tilt angle, so that accurate heading data can be provided in extremely harsh environments. Through the optimized extended Kalman filter algorithm, the product outputs high-precision attitude information in real time.

DMC5000 is specially designed to improve the static measurement accuracy of magnetic compass. For fixed interference, DMC5000 can still guarantee maintain high measurement accuracy. It can be customized according to customer needs, and the electronic compass function can be integrated into various products very conveniently and quickly.

## Features

- Three-axis accelerometer, three-axis magnetometer
- Wide temperature range:  $-40^{\circ}\text{C} \sim +85^{\circ}\text{C}$
- Static measurement accuracy up to  $0.25^{\circ}$
- Volume:  $L33*W31*H13.55$  (mm)
- Offset tracking algorithm eliminates drift
- With hard magnetic, soft magnetic and tilt compensation
- High precision, low cost
- Standard RS232/TTL output interface

## Applications

- Satellite tracking
- Individual combat equipment
- Petroleum geological survey
- Marine survey
- Optical rangefinder
- Underwater navigation
- GPS assisted navigation
- Night Vision

## Specifications

### Electrical Specifications

Power supply	5VDC
Operating current	34mA (40mA Max)
Operating temperature	-40~+85°C
Power	150mW (200mW Max)

### Performance Specifications

Compass heading parameters	Heading accuracy	0.3° RMS (Horizontal)
		≤0.5° RMS (Tilt ≤ 20°)
	measuring range	0~360°
	Repeatability	0.05°(RMS)
Compass tilt parameters	Pitch accuracy	0.2°
	Roll accuracy	0.2°
	Resolution	0.01°
	measuring range	±90°
Calibration	Plane calibration	Yes
	Multi-sided calibration	Yes
	High-precision magnetometer calibration	Yes
	16 Point calibration	Yes
Physical properties	Size	L33*W31*H13.55 (mm)
	Weight	<100g
	Output form	RS232 / TTL
Interface characteristics	Startup delay	<3s
	Maximum sampling rate	50Hz
	RS-232 communication rate	9600~115200 (Default 38400)
Surroundings	Vibration resistance	2000g

**Resolution:** The measured minimum change value that the sensor can detect and resolve within the measurement range.

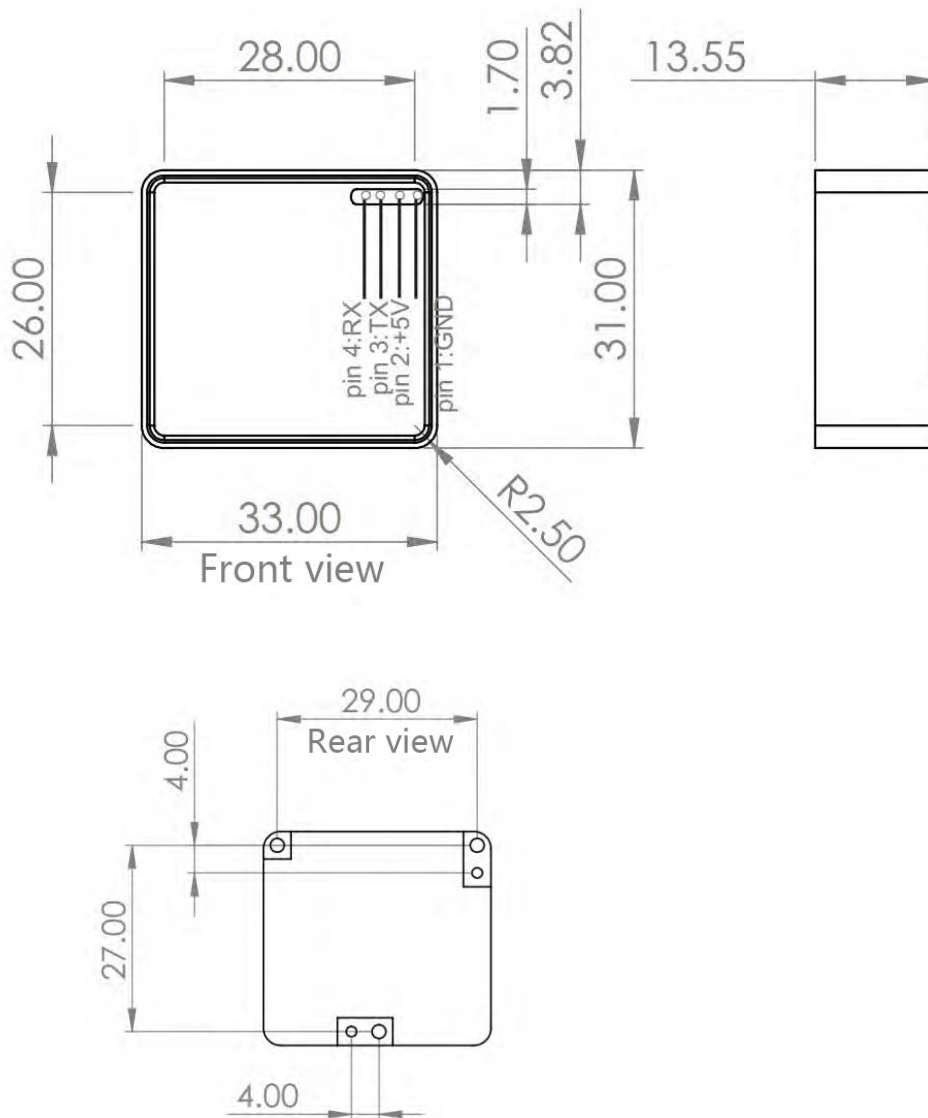
**Accuracy:** The error between the actual angle and the Root mean square(RMS) of the measured angle of the sensor (≥16 times).

### Mechanical Characteristic

Connector	Bare Wires
Protection level	IP67
Housing material	Magnesium alloy anodizing
Installation	Three M2 screws

### Package size

Product Size: L33\*W31\*H13.55 (mm) Length and width may have an error of  $\pm 1$ mm, please refer to the actual product



## Installation direction

The main sensitive components of DMC5000 sensor are magnetometer and accelerometer. The compass uses a magnetometer to sense the earth's magnetic field to calculate the sensor's pointing, uses an accelerometer to measure the angle between the compass and gravity, and provides inclination compensation when the compass calculates the azimuth. The earth's magnetic field is easily disturbed by external magnetic fields. Users still need to pay attention to the surrounding magnetic field when installing, ensure that the sensor is exposed to the earth's magnetic field, and try to avoid using it near ferromagnetic materials and changing magnetic fields, such as engines, iron plates, Install sensors near iron bolts and nuts, wires, motors, horns, and antennas. Be sure to strictly avoid magnets, motors and other strong magnetic materials within 10cm of the compass. This may cause the compass's measurement accuracy to drop irreversibly. We strongly recommend to calibrate the magnetic field after installation and after each change in the magnetic field environment. After the calibration is completed according to the method in the manual, the firmware and programs in the DMC5000 can effectively eliminate the interference of the magnetic field after calibration. As long as the position of the compass and the surrounding magnetic field environment do not change, there is no need to compensate the sensor.

The test shows that if the user performs the calibration operation in accordance with the requirements of the user manual, the compass can meet the above requirements when installing, and the sensor is calibrated correctly, the heading accuracy of the sensor will be less than 0.5 degrees (RMS), and the high precision is used After the magnetometer is calibrated, the relative angular error in the horizontal direction will be less than 0.2 degrees (RMS). Our recommended test method is to install the DMC5000 sensor horizontally on a non-magnetic material away from the interference to measure the heading angle. Please avoid additional magnetic field interference during the measurement.

## Calibration method

The sub compass has been calibrated in the factory. In places where the magnetic field environment has little impact, there is no need for environmental calibration during use, and it can be used directly. When conditions permit, calibrate again before use to further improve accuracy.

### Azimuth calibration steps:



#### I .Plane Calibration:

1. Fix the electronic compass in the use environment, and try not to carry magnetic objects such as keys and mobile phones during calibration;
2. Connect the product to the system and place the product in a horizontal state;
3. Open the serial port debugging assistant and send the start calibration command in hexadecimal format: 77 04 00 11 15;
4. Rotate the product 2-3 times in the horizontal plane (both pitch and roll angles are within  $\pm 5^\circ$ ) around the z-axis (z-axis is the vertical direction). The rotation process should be as slow and nearly uniform as possible. The time for one revolution is about 10~15 seconds;
5. Rotate the product 2-3 times around the X-axis or Y-axis. The rotation process should be as slow and nearly uniform as possible, and the time for one revolution is about 10-15 seconds;
6. After completing the calibration, send the command to save the calibration: 77 04 00 12 16.



#### II.Multi-Faceted Calibration

1. Fix the electronic compass in the use environment, and try not to carry magnetic objects such as keys and mobile phones during calibration;

2. Connect the product to the system and place the product in a horizontal state (within  $\pm 5^\circ$ );
3. Open the serial port debugging assistant, send the start calibration c format: 77 04 00 08 0C, the return value is 77 05 00 88 00 8D;
4. The product is placed in a horizontal state, the front is facing upwards (both pitch and roll are within  $\pm 5^\circ$ ), and it rotates approximately at a constant speed, and it takes more than 10 seconds to rotate once;
5. The product is placed in a horizontal state with the installation surface facing upwards (both pitch and roll are within  $\pm 5^\circ$ ), and it rotates approximately at a constant speed for one revolution, and it takes more than 10 seconds for one revolution;
6. The product is placed in a vertical state, with the smooth side of the shell facing down (both pitch and roll are within  $\pm 5^\circ$ ), and it rotates at approximately a constant speed, and it takes more than 10 seconds to rotate once;
7. The product is placed in a vertical state, with the other smooth side of the shell facing down (both pitch and roll are within  $\pm 5^\circ$ ), and it rotates approximately at a constant speed, and it takes more than 10 seconds to rotate once;

**Among them, step 4.5.6.7 can be exchanged;**

8. After the four faces are rotated, send the save calibration command 77 04 00 09 0D, and return to 77 05 00 89 XX YY. Where XX represents the calibration error coefficient, the smaller the value, the better, less than 1 is ideal, FF represents the calibration failure, YY is the checksum of the command;
9. The calibration is complete.



### III. High Precision Magnetometer Calibration:

High-precision magnetometer calibration is suitable for products that have already been packaged. Please use other methods for bare boards.

1. Fix the electronic compass in the use environment, and try not to carry magnetic objects such as keys and mobile phones during calibration;
2. Connect the product to the system and place the product in a horizontal state (within  $\pm 5^\circ$ );
3. Open the serial port debugging assistant and send the start calibration command in hexadecimal format: 77 04 00 A0 A4 rotates as slowly and nearly as possible at a uniform speed, and the time for one rotation is about 10 to 15 seconds;
4. Starting from the 0 degree defined by yourself, send a collection command every 30 degrees, and wait for the return command to continue to rotate until the product rotates around the Z axis for a total of 13 points.  
Acquisition command: 77 04 00 A1 A5, return command: 77 05 00 A1 XX YY, XX is the hexadecimal number corresponding to the acquisition point, and the return value corresponding to the last point is 0D.
5. Send the end calibration command: 77 04 00 A2 A6, and receive the return value: 77 05 00 A2 00 A7.
6. Wait about 20~30s until the sensor returns the end command: 77 05 00 A2 01 A8, the calibration is complete. Do not power off or send other commands before receiving the end command to prevent the sensor from losing data.





#### IV. 16-sided Magnetic Calibration

Calibration uses the 16-position calibration method.

1、 Fix the electronic compass , and try not to carry magnetic objects such as keys and cell phones when calibrating.

2、 Connet the compass, and place the product in a horizontal state (within  $\pm 5^\circ$ ).

3, first send the start calibration command: 77 04 00 A5 A9, return: 77 04 00 A5 A9, indicating that the calibration has started, please note that no additional interference should be introduced into the calibration at this time, otherwise it will affect the calibration quality.

rated.

4. Rotate the heading angle to 0 degrees, then rotate the pitch angle of the sensor to +45 degrees (within the error range of  $\pm 15$  degrees), and keep the roll angle at 0 degrees. The heading angle sends a collection command every 90 degrees, waits for the return command to be received, and then continues to rotate until the product rotates once around the Z axis, and a total of 4 points are collected;

5. Rotate the heading angle to 0 degrees, then rotate the pitch angle of the sensor to -45 degrees (within the error range of  $\pm 15$  degrees), and keep the roll angle at 0 degrees. The heading angle sends a collection command every 90 degrees, waits for the return command to be received, and then continues to rotate until the product rotates once around the Z axis, and a total of 4 points are collected;

6. Rotate the heading angle to 0 degrees, then rotate the roll angle of the sensor to +45 degrees (within the error range of  $\pm 15$  degrees), and keep the pitch angle at 0 degrees. Send a collection command every 90 degrees of the heading angle, wait for the return command to be received, and then continue to rotate until the product rotates once around the Z axis, and a total of 4 points are collected;

7. Rotate the heading angle to 0 degrees, then rotate the roll angle of the sensor to -45 degrees (within the error range of  $\pm 15$  degrees), and keep the pitch angle at 0 degrees. Send a collection command every 90 degrees of the heading angle, wait for the return command to be received, and then continue to rotate until the product rotates once around the Z axis, and a total of 4 points are collected;

Acquisition command: 77 04 00 A6 AA, return command: 77 05 00 A6 XX YY, XX is the hexadecimal number corresponding to the acquisition point, if it returns FF, it indicates that the point acquisition failed, and the sensor needs to be stabilized again before sampling, and finally The return value corresponding to a point is 10, and YY is the currently collected checksum.

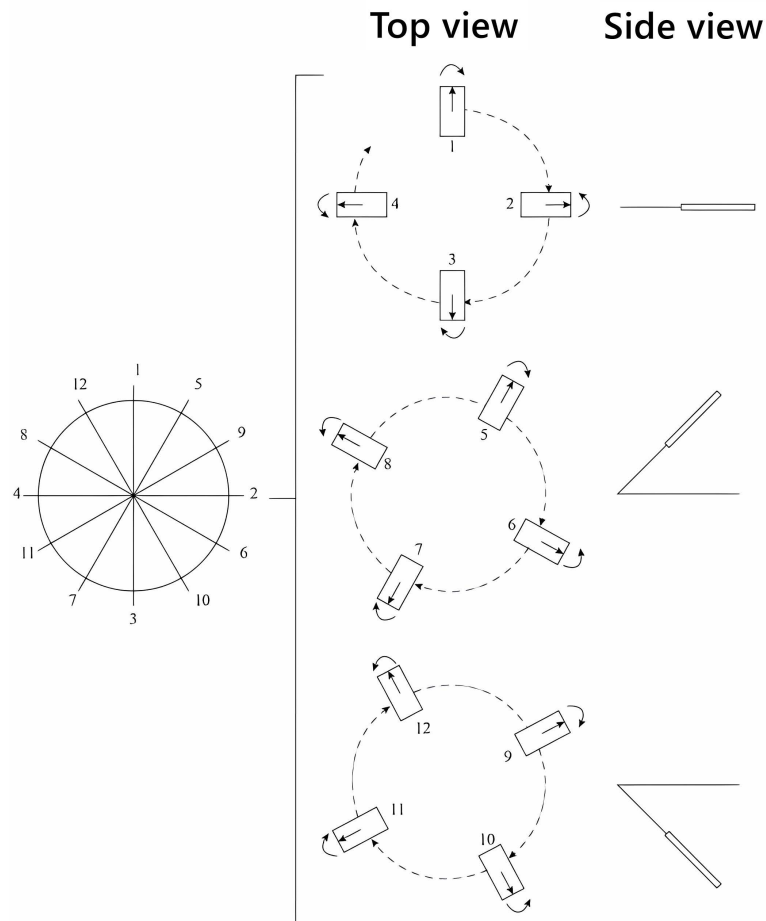
8. After completion, send the end calibration command: 77 04 00 A7 AB, indicating that the calibration is completed. The sensor returns: 77 05 00 A6 XX AC , where XX is the calibration result, less than 10 is better, if it returns FF, it means that the calibration fails and needs to be re-calibrated;

9. Calibration is completed.

## V. 12-sided magnetic calibration: (Recommended)

The calibration uses a 12-position calibration method.

- 1、 Fix the electronic compass in the environment of use, and try not to carry magnetic objects such as keys and mobile phones when calibrating;
- 2、 Plug the product into the system, with the product placed in a horizontal position (within  $\pm 5^\circ$ );
- 3、 First send the start calibration command: 77 04 00 3C 40, return: 77 05 00 3C 00 41, indicating that the calibration has started, please note that no additional interference should be introduced into the calibration at this time, otherwise the calibration quality will be affected;
- 4、 Start picking points, divided into twelve positions (twelve attitudes), as follows:



Attitude 1: to make the magnetic compass azimuth point at  $0^\circ$ , pitch  $0^\circ$  and roll  $0^\circ$ ;

Attitude 2: to make the magnetic compass azimuth point at  $90^\circ$ , pitch  $0^\circ$  and roll  $0^\circ$ ;

Attitude 3: to make the magnetic compass azimuth point at  $180^\circ$ , pitch  $0^\circ$ , roll  $0^\circ$ ;

Attitude 4: to make the magnetic compass azimuth point at  $270^\circ$ , pitch  $0^\circ$ , roll  $0^\circ$ ;

Attitude 5: to make the magnetic compass azimuth point at  $30^\circ$ , pitch  $45^\circ$  and roll  $0^\circ$ ;

Attitude 6: to make the magnetic compass azimuth point at  $120^\circ$ , pitch  $45^\circ$  and roll  $0^\circ$ ;

Attitude 7: to make the magnetic compass azimuth point at  $210^\circ$ , pitch  $45^\circ$  and roll  $0^\circ$ ;

Attitude 8: to make the magnetic compass azimuth point at  $300^\circ$ , pitch  $45^\circ$  and roll  $0^\circ$ ;

Attitude 9: to make the magnetic compass azimuth point at  $60^\circ$ , pitch  $-45^\circ$ , traverse  $0^\circ$ ;

Attitude 10: to make the magnetic compass azimuth point at  $150^\circ$ , pitch  $-45^\circ$ , traverse  $0^\circ$ ;

Attitude 11: to make the magnetic compass azimuth point at  $240^\circ$ , pitch  $-45^\circ$ , traverse  $0^\circ$ ;

Attitude 12: makes the magnetic compass azimuth point at  $330^\circ$ , pitch  $-45^\circ$  and roll  $0^\circ$ .



Acquisition command: 77 04 00 3E 42, return command: 77 05 00 3E XX YY, XX is the hexadecimal number corresponding to the acquisition point, stabilize the pose of an attitude, send an acquisition command, the corresponding return a command, if the same value is returned continuously, it indicates that the current position acquisition point failed, need to re-stabilize the sensor and then sample, the last point corresponding to the return value is 0B. YY is the calibration sum of the current collection, calibration process if you want to terminate the calibration send: 77 04 00 3D 41, return: 77 05 00 3D 00 42.

5、Twelve points after the completion of the collection, 3-5s automatically return to the calibration score, example: 77 07 00 3F 00 00 03 49

3F is the command word, the data field is 3 bytes to return the score value, for the compressed BCD code, four integer bits, two decimal bits, such as 00 00 03, means the score 0.03, the closer the score is to 0 means the better the calibration effect, greater than 1 suggest recalibration.

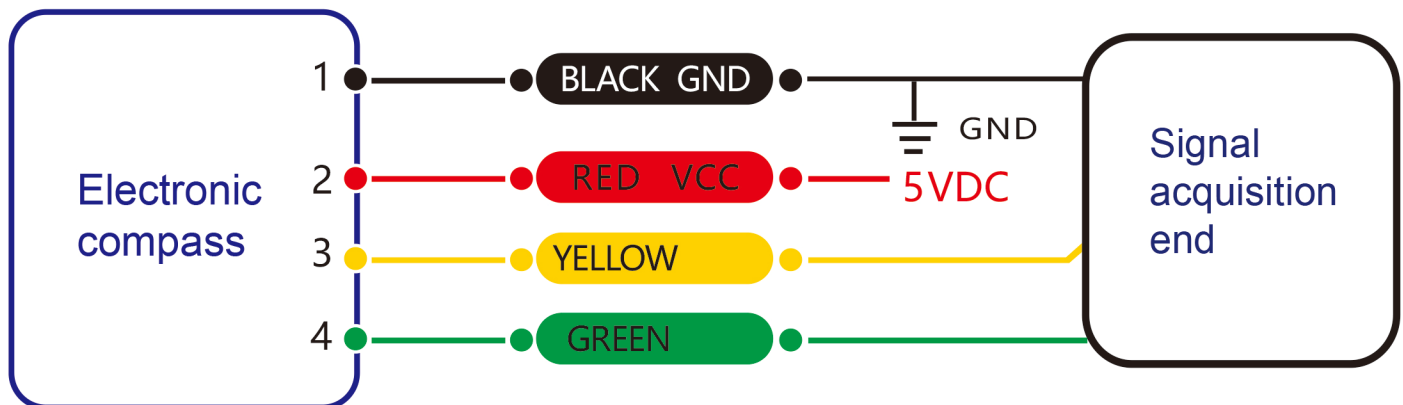
6、Calibration is complete.

Note: The azimuth angles mentioned in the above postures are not absolute azimuth angles, but relative angles. For example, in posture 1, the magnetic compass azimuth can point to any angle, e.g. 42°, but in posture 2, the magnetic compass azimuth needs to be placed at about 132°, and so on. The azimuth, pitch and roll angles do not need to be particularly strict in each of the above attitudes, and an error of  $\pm 15^\circ$  is acceptable for each angle.

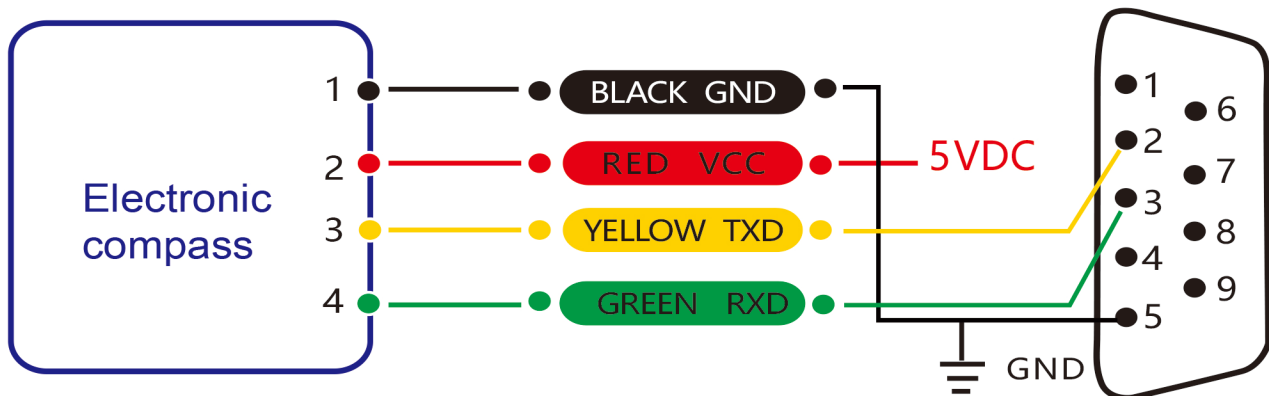
## Electrical connections

### Electrical interfaces

Cable color & Function	BLACK	RED	YELLOW	GREEN
	1	2	3	4
	GND	VCC 5VDC	TXD (A, D+)	RXD (B, D-)



TTL wiring diagram



RS 232 wiring diagram

## Protocol

**1 Data Frame Format:** (8 data bits, 1 stop bit, No parity check, default baud rate 9600)

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (Nbyte)	Checksum (1byte)
0x77					

**Data Format:** Hexadecimal(The following command interprets Table 0X as a hexadecimal identifier. You do not need to enter 0X, such as 0x77, you only need to enter 77.)

**Identifier:** Fixed to 77

**Frame Length:** Length from Frame Length to Checksum (included)

**Address Code:** Address of acquiring module, default 0x00

**Data:** Content and length variable according to Command

**Checksum:** Sum of Frame Length, Address Code, Command and Data. (Please pay attention that when the command or data changes, the checksum will change. )

## 2 Command Format

**2.1 Read angle of X axis Command: 77 04 00 01 05**

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x01	-	

**Command response:**

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (4byte)	Checksum (1byte)
0x77	0x08		0x81	SXXX.YY	

**Note:** The data field is a 4-byte return angle value, which is a compressed BCD code. S is the sign bit (0 means positive, 1 means negative), XXX is the three digit integer part, YY is the two fractional part. The data of other axis is the same format. For example, 10 26 87 means -026.87 °, 00 34 77 means +34.77.

**2.2 Read angle of Y axis Command: 77 04 00 02 06**

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x02	-	

**Command response:**

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (4byte)	Checksum (1byte)
0x77	0x08	0x00	0x82	SXXX.YYYY	

### 2.3 Read heading azimuth angle Command: 77 04 00 03 07

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x03		

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (12byte)	Checksum (1byte)
0x77	0x10		0x83	SXXX.YY	

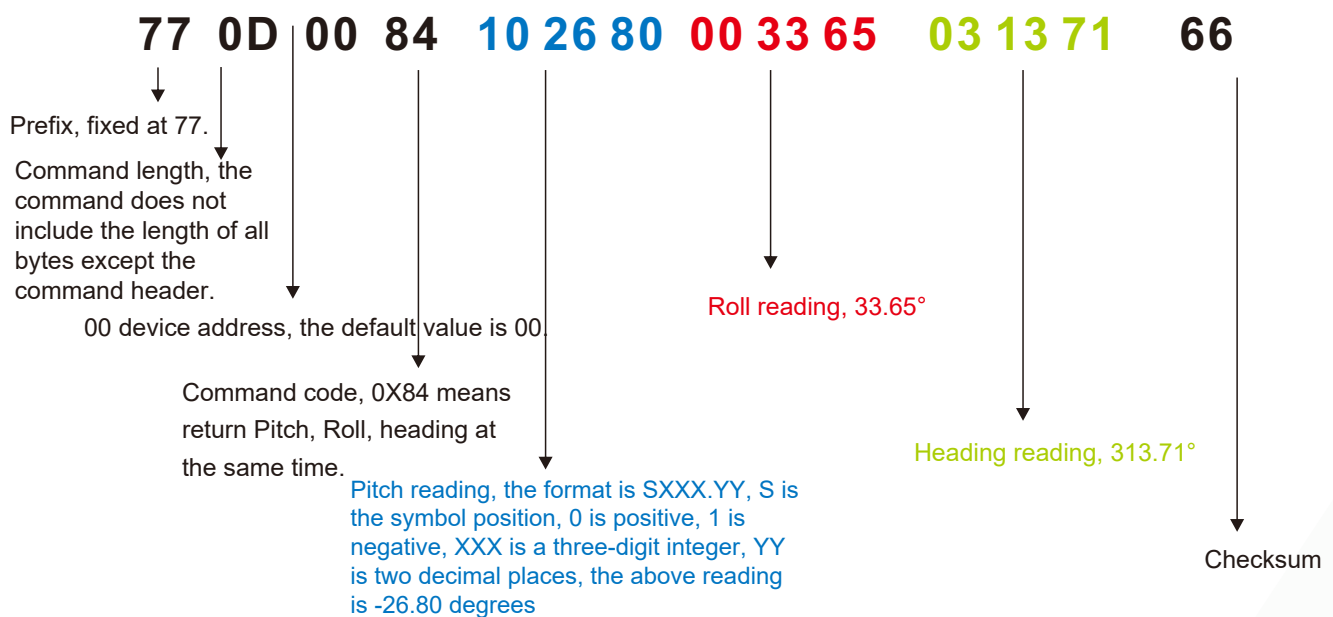
### 2.4 Read PITCH, ROLL and Heading axis angle Command: 77 04 00 04 08

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x04		

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (12byte)	Checksum (1byte)
0x77	0x0D		0x84	*	

**Note:** The data field contains 9 bytes which are pitch (Pitch), roll (Roll) and azimuth (Heading) angle values, which are compressed BCD codes, each of which is a group of three bytes, for example, the return command is 77 0D 00 84 10 26 80 00 33 65 03 13 71 66, where Pitch is 10 26 80, Roll is 00 33 65, and Heading is 03 13 71. For the three bytes of the return value for each angle, the format is SX XX YY, S is the sign bit (0 positive, 1 negative) XXX is a three-digit integer value, and YY is a decimal value. The corresponding readings of the three angles in this example are: -26.8°, 33.65°, and 313.71°.



### 2.5 Set magnetic declination Command: 77 06 00 06 02 08 16

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (2byte)	Checksum (1byte)
0x77	0x06		0x06	SX XY	

Note: S represents the sign, 0 is positive and 1 is negative, XX is a two-digit integer, and Y is a decimal. For example, 02 08 is +20.8°. The checksum of this command is 16 (hexadecimal). 16 = 06+00+06+02+08. If the declination angle is set to -3.2°, the command is 77 06 00 06 10 32 4E, where 4E = 06+00+06+10+32. The same goes for other magnetic declination angles.

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (12byte)	Checksum (1byte)
0x77	0x05		0x86	0x00: success 0xFF: failure	

### 2.6 Declination Command: 77 04 00 07 0B

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x07		

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (2byte)	Checksum (1byte)
0x77	0x05		0x87	SX XY	

**Note:** The format of SX XY is the same as the format of the magnetic declination to be set in the 2.5 command.

### 2.7 Set communication rate Command: 77 05 00 0B 02 12

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x0B		

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x8B	0x00: success 0xFF: failure	

**Note:** Baud rate: 00 means 2400, 01 means 4800, 02 means 9600, 03 means 19200, 04 means 115200, 05 means 38400, 06 means 57600. If the baud rate is set to 19200, the command is 77 05 00 0B 03 13, where 13 = 05+ 00+ 0B+ 03, and the same goes for setting other baud rates. Note: After setting the baud rate, the device will return the response command at the original baud rate. After that, the baud rate setting will take effect, and the host computer needs to make corresponding baud rate changes to communicate with the device again.

### 2.8 Set module address Command: 77 05 00 0F 01 15

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x0F	XX	

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x8F	0x00: success 0xFF: failure	

### 2.9 Query current address Command: 77 04 00 1F 23

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x1F		

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x1F		

Note: The default address in the sensor is 0x00. When sending the query address command, the returned Data is the hexadecimal device address.

### 2.10 Set output angle mode Command: 77 05 00 0C 00 11

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77H	0x05		0x0C	0x00: Question-and-answer 0x01: 5Hz Data Rate 0x02: 10Hz Data Rate 0x03: 20Hz Data Rate 0x04: 25Hz Data Rate 0x05: 50Hz Data Rate	

\*The default output mode is 00.

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77H	0x05		0x8C	0x00: success 0xFF: failure	

**Note:** 5Hz Data Rate means automatically output data 5 times per second, and so on. When the product is set to automatic output mode, there will be no output within 10 seconds after the product is powered on. At this time, the product can effectively receive external setting commands.

### 2.11 Save Settings Command: 77 04 00 0A 0E

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x0A		

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x8A	0x00: success 0xFF: failure	

\*For various parameter settings, if the save setting command is not sent after the setting is completed, these settings will disappear after power off.

### 2.12 Switch calibration output Command: 77 04 00 A3 A7

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0xA3		

#### Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05	0x00	0xA3	0x00 (close) 0x01 (open)	0xA9



## Executive standard

- Enterprise Quality System Standard: ISO9001:2008 Standard (Certificate No.10114Q16846ROS)
- CE certification (certificate number: 3854210814)
- RoHS (certificate number: G190930099)

# DMC5000

**3D High-precision  
Electronic Compass**

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