

10 DOF IMU Sensor User Manual

1. Features

Driver IC	MPU6050 (3-axis accelerometer and 3-axis gyroscope)	Built-in 16-Bit AD convertor Gyroscope full-scope range: ± 250 , ± 500 , ± 1000 , $\pm 2000^\circ/\text{sec}$ Accelerometer full-scale range: ± 2 , ± 4 , ± 8 , $\pm 16g$
	HMC5883L (3-axis digital compass)	Built-in 12-Bit AD convertor Full-scope range: 360° Compass heading accuracy: $1^\circ\sim 2^\circ$
	BMP180 (Digital pressure sensor)	Built-in temperature sensor with temperature measurement compensation Pressure measuring range: 300~1100hpa (+9000m ~ -500m relating to sea level) Accuracy: 0.02hPa (0.17m)
Working voltage	3.3V or 5V	
Supported interface	I2C	
Dimensions	31mm * 18.4mm	

Table 1: Product features

2. Applications

- Quadcopter;
- Action game controller;
- Indoor inertial navigation;
- Self-balancing Robot;
- Altimeter;
- Industrial measuring instrument.

3. Interface Descriptions

Pin No.	Symbol	Descriptions
1	VCC	3.3V or 5V power supply
2	GND	Supply ground
3	SDA	I2C serial bus data
4	SCL	I2C serial bus clock input
5	INT	MPU6050 digital interrupt output
6	FSYNC	MPU6050 frame synchronous signal
7	DRDY	HMC5883L Data Ready, Interrupt Pin. Internally pulled high. Optional connection. Low for 250 μ s when data is placed in the data output registers.

Table 2: Interface descriptions

4. How to use

We will illustrate the usage of the module with an example of working with a STM32 series' development board.

- ① Download the relative codes to the development board.
- ② Connect the development board to a PC via a serial wire, and insert the module into the I2C 2 interface on the development board. Please take attention to the connection between the module and I2C 2 interface, each pin of the module should be connected to its corresponding port on the I2C 2 interface and FSYN pin and DRDY pin should be kept suspended respectively.

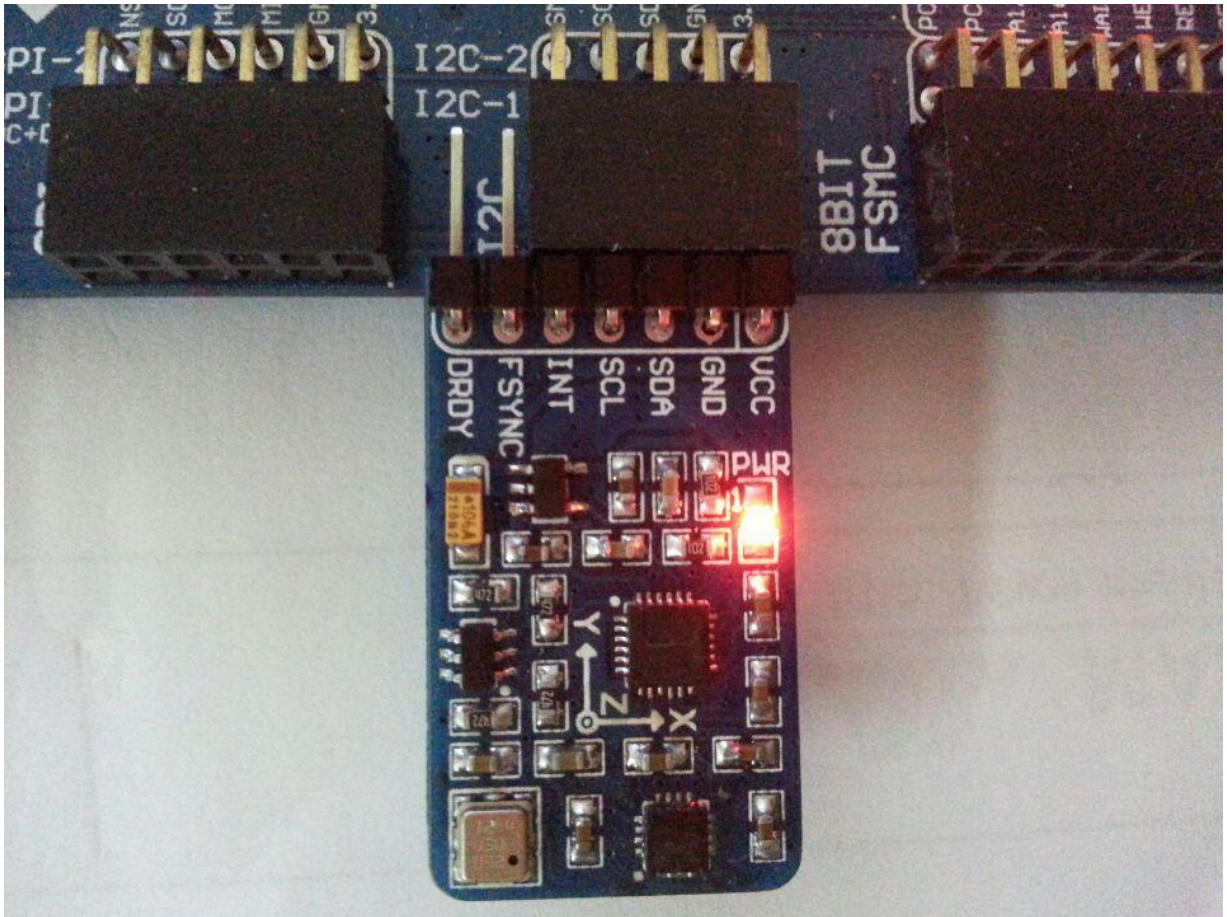


Figure 1: Connection between 10 DOF IMU sensor module and STM32

- ③ Here is the configuration of the serial port, as Table 3 shows.

Baud rate	115200
Data bit	8
Stop bit	1
Parity bit	None

Table 3: Serial port configuration

- ④ Please make sure the 10 DOF IMU Sensor is in a horizontal-static state before and during its course of powering up and no motion is allowed until its serial port outputs relative data, since 10 DOF IMU Sensor will perform horizontal alignment immediately after its powering up. The data outputted is varied with the position and angle of the module. Figure 2 shows relative data output of 10 DOF IMU Sensor in horizontal state.

```

////////////////////////////////////
Roll: -0.46 Pitch: -1.65 Yaw: 38.08

Acceleration: X: -471 Y: -114 Z: 15824

Gyroscope: X: 3 Y: 0 Z: -12

/-----/

Magnetic: X: 105 Y: 80 Z: -159

Angle: 37.3

/-----/

Pressure: 1003.90 Altitude: 24.95

Temperature: 27.3
    
```

Figure 2: 10 DOF IMU Sensor data output in horizontal state

The serial output is as followed:

Roll,	Pitch,	Roll angle (°), Pitch angle (°), Yaw angle (°)
Yaw		
Acceleration		Acceleration value (LSB, translatable into the unit: g)
Gyroscope		Gyroscope angular velocity (LSB, translatable into the unit: °/sec)
Magnetic		Digital compass title angle (°)
Angle		Direction angle (°), principally equal to Yaw angle
Pressure		Pressure value (hPa)
Altitude		Altitude value (m)
Temperature		Temperature value (°C)

Table 4: The meanings of the serial output

5. Parameter calibration and calculation

5.1 Altitude calibration

For your first time to use 10 DOF IMU Sensor, you may find that there is a large difference between the altitude value outputted by the module and the actual altitude. This is because 10 DOF IMU Sensor calculates the pressure at sea level P_0 with the Altitude of its current position and the measured pressure, providing that both module current position and pressure are known. And this P_0 will be taken as a benchmark for subsequent calculations. For more detailed information, please refer to BST-BMP180-DS000-09.pdf:

3.7 Calculating pressure at sea level

With the measured pressure p and the absolute altitude the pressure at sea level can be calculated:

$$p_0 = \frac{p}{\left(1 - \frac{\text{altitude}}{44330}\right)^{5.255}}$$

Thus, a difference in altitude of $\Delta\text{altitude} = 10\text{m}$ corresponds to 1.2hPa pressure change at sea level.

Figure 3: How to calculate the pressure at sea level

With the benchmark P_0 , you can calculate the Altitude of the module current position as well.

3.6 Calculating absolute altitude

With the measured pressure p and the pressure at sea level p_0 e.g. 1013.25hPa, the altitude in meters can be calculated with the international barometric formula:

$$\text{altitude} = 44330 * \left(1 - \left(\frac{p}{p_0}\right)^{\frac{1}{5.255}}\right)$$

Figure 4: Calculating module current position

Therefore, you should firstly set the altitude of the module current position as a benchmark in the sample code 10 DOF IMU Sensor\SRC\HardWare\BMP180\BMP180.h (normally, it should be the absolute altitude of your position now, unit: mm). For example:

```
#define LOCAL_ADS_ALTITUDE 2500 //mm altitude of your position now
```

5.2 Acceleration calculation

Acceleration measured by the program is in the unit of LSB (Least Significant Bit), however it is usually translated into the unit of gravitational acceleration (g) in practical application. In the sample code of the module, the default setting is AFS_SEL=0, of which the corresponding measurement range is 16384 LSB/g ($\pm 2g$), so the actual measured acceleration would be:

$$a = \frac{\text{Acceleration} \times 2}{16384}, \quad \text{Unit: } g$$

For more detailed information, please refer to
MPU-6000 and MPU-6050 Product Specification.pdf, Page 13
MPU6050 Register Map and Descriptions.pdf, Page 15

5.3 Gyroscope angular velocity calculation

Angular velocity measured by the program is in the unit of LSB (Least Significant Bit), however it is usually translated into the unit of angular velocity ($^{\circ}/\text{sec}$) in practical application. In the sample code of the module, the default setting is FS_SEL=2, of which the corresponding measurement range is 32.8 LSB/($^{\circ}/\text{s}$) ($\pm 1000^{\circ}/\text{sec}$), so the actual measured angular velocity would be:

$$\omega = \frac{\text{Gyroscope} \times 1000}{32.8}, \quad \text{Unit: } ^{\circ}/\text{s}$$

For more detailed information, please refer to
MPU-6000 and MPU-6050 Product Specification.pdf, Page 12
MPU6050 Register Map and Descriptions.pdf, Page 14