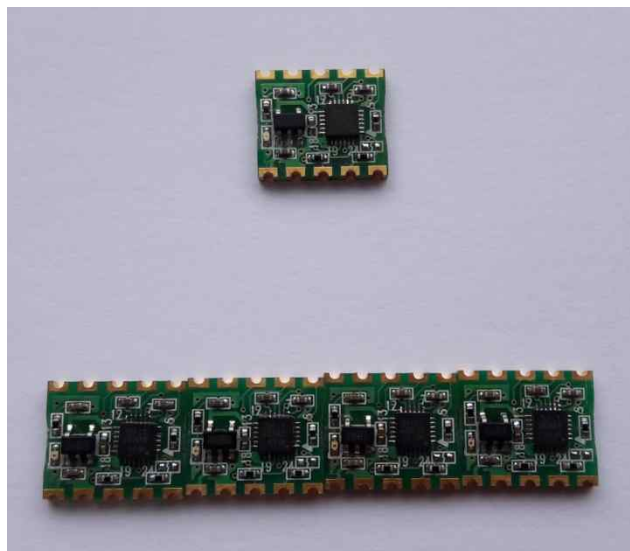# OSTSen-9250   User Guide

Ver 1.0

Onsystech

1. OSTSen-9250   Overview

OSTSen-9250 is a motion tracking module, which is based on InvenSense MPU-9250. The MPU-9250 is a multi-chip(MCM) consisting of two dies integrated into a single QFN package. One die houses the 3-Axis gyroscope and the 3-Axis accelerometer. The other die houses the AK8963 3-Axis magnetometer from Asahi Kasei Microdevices Corporation. Hence, the MPU-9250 is a 9-axis Motion Tracking device that combines a 3-Axis gyroscope, 3-Axis accelerometer and a Digital Motion Processor™(DMP) all in a small 3x3x1mm package available as a pin-compatible upgrade from the MPU-6515. With its dedicated I2C sensor bus, the MPU-9250 directly provides complete 9-Axis MotionFusion™ output. The MPU-9250 Motion Tracking device, with its 9-axis integration, on-chip Motion Fusion™, and run-time calibration firmware, enables manufacturers to eliminate the costly and complex selection, qualification, MPU-9250 is also designed to interface with multiple non-inertial digital sensors, such as pressure sensors, on its auxiliary I2C port.

MPU-9250 features three 16-bit analog-to-digital converters(ADCs) for digitalizing the gyroscope outputs, three 16-bit ADCs for digitalizing the magnetometer outputs. For precision tracking of both fast and slow motions, the parts feature a user-programmable gyroscope full-scale range of ±250, ±500, ±1000, and ±2000°/sec(dps), a user-programmable accelerometer full-scale range of ±2g, ±4g, ±8g and ±16g, and a magnetometer full-scale range of ±4800uT.

Other industry-leading features include programmable digital filters, a precision clock with 1% drift from -40°C to 85°C, an embedded temperature sensor, and programmable interrupts. The device features I2C and SPI serial interfaces, a VDD operating range of 2.4V to 3.6V, and separate digital IO supply, VDDIO from 1.71V to VDD.

Communication with all register of the device is performed using either I2C at 400kHz or SPI at 1MHz. For application requiring faster communications, the sensor and interrupt registers may be read using SPI at 20MHz.

By leveraging its patented and volume-proven CMOS-MEMS fabrication platform, which integrates MEMS wafers with companion CMOS electronics through wafer-level bonding, InvenSense has driven the package size down to a footprint and thickness of 3x3x1mm, to provide a very small yet high performance low cost package. The device provides high robustness by supporting 10,000g shock reliability.

2. Application
- Location based services, points of interest, and dead reckoning
- Handset and portable gaming
- Motion-based game controllers
- 3D remote controls for Internet connected DTVs and set top boxes, 3D mice
- Wearable sensors for health, fitness and sports

3. Features of MPU9250
3.1 Gyroscope Features

The triple-axis MEMS gyroscope in the MPU-9250 includes a wide range of features:

- Digital-output X-, Y-, and Z-Axis angular rate sensors (gyroscopes) with a user-programmable full-scale range of ±250, ±500, ±1000, and ±2000°/sec and integrated 16-bit ADCs
- Digitally-programmable low-pass filter

- Gyroscope operating current: 3.2mA
- Sleep mode current: 8uA
- Factory calibrated sensitivity scale factor
- Self-test

3.2 Accelerometer Features
The triple-axis MEMS accelerometer in MPU-9250 includes a wide range of features:
- Digital-output triple-axis accelerometer with a programmable full scale range of ±2g, ±4g, ±8g and ±16g and integrated 16-bit ADCs
- Accelerometer normal operating current: 450uA
- Low power accelerometer mode current: 8.4uA at 0.98Hz, 19.8uA at 31.25Hz
- Sleep mode current: 8uA
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of application processor
- Self-test

3.3 Magnetometer Features
The triple-axis MEMS magnetometer in MPU-9250 includes a wide range of features:
- 3-axis silicon monolithic Hall-effect magnetic sensor with a magnetic concentrator
- Wide dynamic measurement range and high resolution with low current consumption
- Output data resolution is 14 bit (0.6µT/LSB)
- Full scale measurement range is ±4800 µT
- Magnetometer normal operating current: 280uA at 8Hz repetition rate
- Self-test function with internal magnetic source to confirm magnetic sensor operation on end products
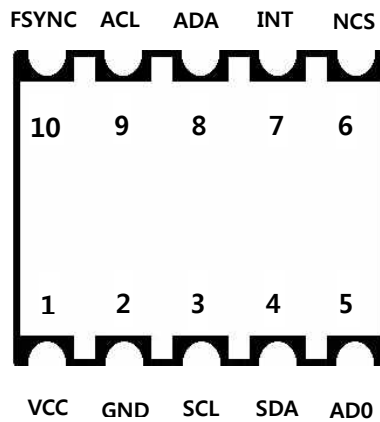
3.4 Additional Features
The MPU-9250 includes the following additional features:
- Auxiliary master I2C bus for reading data from external sensors (e.g., pressure sensor)
- 3.5mA operating current when all 9 motion sensing axes and the DMP are enabled
- VDD supply voltage range of 2.4 ~ 3.6v
- VDDIO reference voltage for auxiliary I2C devices
- Smallest and thinnest QFN package for portable devices: 3x3x1mm
- Minimal cross-axis sensitivity between the accelerometer, gyroscope and magnetometer axes
- 512 byte FIFO buffer enables the application processor to read the data in bursts
- Digital-output temperature sensor
- User-programmable digital filters for gyroscope, accelerometer, and temp sensor
- 10,000 g shock tolerant
- 400kHz Fast Mode I2C for communicating with all registers
- 1MHz SPI serial interface for communication with all registers
- 20MHz SPI serial interface for reading sensor and interrupt registers
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

4. Application Information
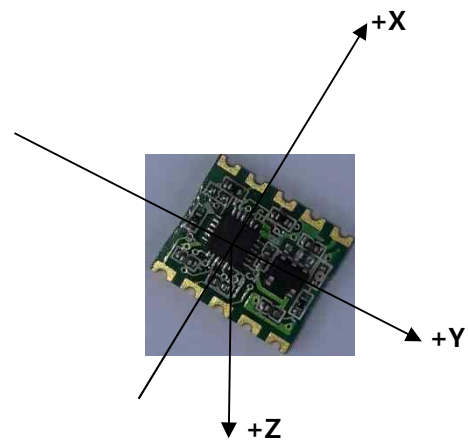## 4.1 Module Pin Out and Signal Description

Pin Number	Pin Name	Pin Description
1	VCC	Power supply voltage
2	GND	Power supply ground
3	SCL	I2C serial clock(SCL); SPI serial clock(SCLK)
4	SDA	I2C serial data(SDA); SPI serial data input(SDI)
5	AD0	I2C Slave Address LSB (AD0); SPI serial data output(SDO)
6	NCS	Chip select (SPI mode only)
7	INT	Interrupt digital output (totem pole or open-drain)
8	ADA	Auxiliary I2C master serial data
9	ACL	Auxiliary I2C master serial clock
10	FSYNC	Frame synchronization digital input. Connect to GND if unused
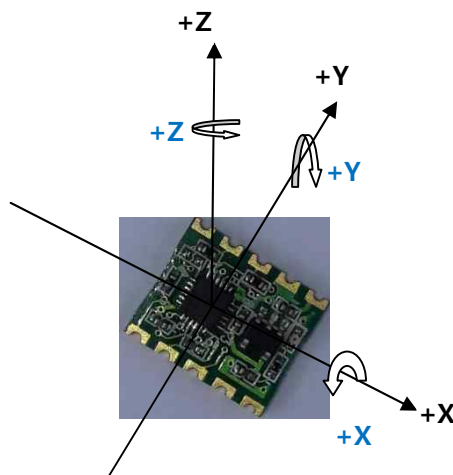
FSYNC   ACL   ADA   INT   NCS

10   9   8   7   6

1   2   3   4   5

VCC   GND   SCL   SDA   AD0

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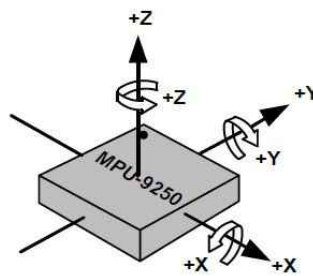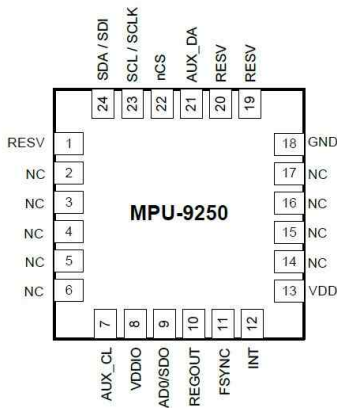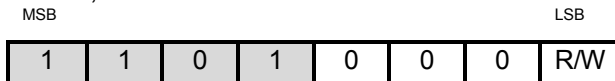**Orientation of Axes of Sensitivity and Polarity of Rotation for Accel & Gyro**

Orientation of Axes of Sensitivity for Magnetometer

4.2 MPU-9250 Pin out and Signal Description

Pin Number	Pin Name	Pin Description
1	RESV	Reserved. Connect to VDDIO
7	AUX_CL	I2C master serial clock for connecting to external sensors
8	VDDIO	Digital I/O supply voltage
9	AD0/SDO	I2C Slave Address LSB (AD0); SPI serial data output(SDO)
10	REGOUT	Regulator filter capacitor connection
11	FSYNC	Frame synchronization digital input. Connect to GND if unused
12	INT	Interrupt digital output (totem pole or open-drain)
13	VDD	Power supply voltage and Digital I/O supply voltage
18	GND	Power supply ground
19	RESV	Reserved. Do not connect
20	RESV	Reserved. Connect to GND
21	AUX_DA	I2C master serial data, for connecting to external sensors
22	nCS	Chip select (SPI mode only)
23	SCL/SCLK	I2C serial clock(SCL); SPI serial clock(SCLK)
24	SDA/SDI	I2C serial data(SDA); SPI serial data input(SDI)
2~6, 14~17	NC	Not internally connected May be used for PCB trace routing

● **MPU-9250   I2C 7bit device address: 0x69 (in module : AD0 is HIGH)**
0x68 (in module : AD0 is LOW)

In case, 7bit device address is 0x68:

MSB   LSB

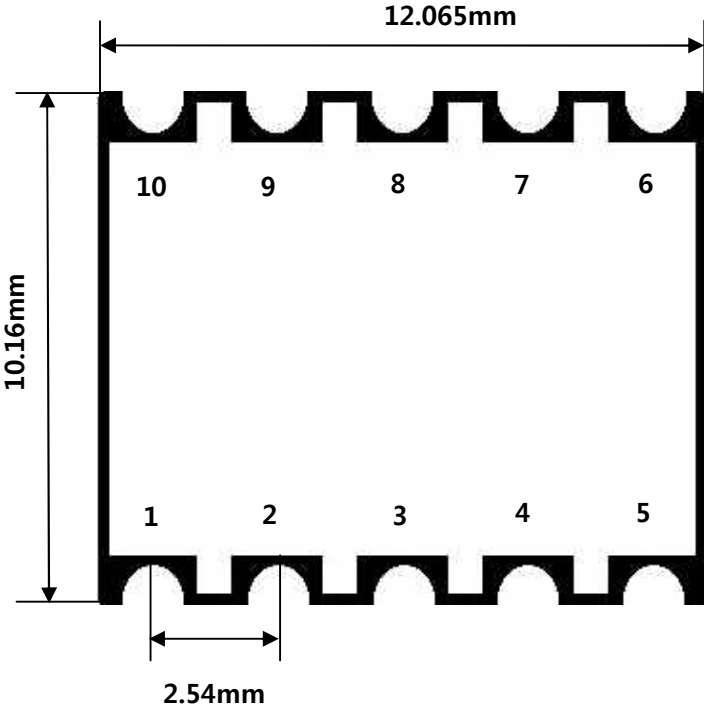| 1	1	0	1	0	0	0	R/W

Orientation of Axes of Sensitivity and Polarity of Rotation for Accel & Gyro
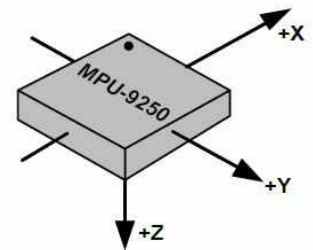
Orientation of Axes of Sensitivity for Magnetometer

5. Module Dimension

12.065mm

10.16mm

2.54mm

| 10 | 9 | 8 | 7 | 6 |

| 1 | 2 | 3 | 4 | 5 |

< OSTSen-9250 module >

6. I2C Communications
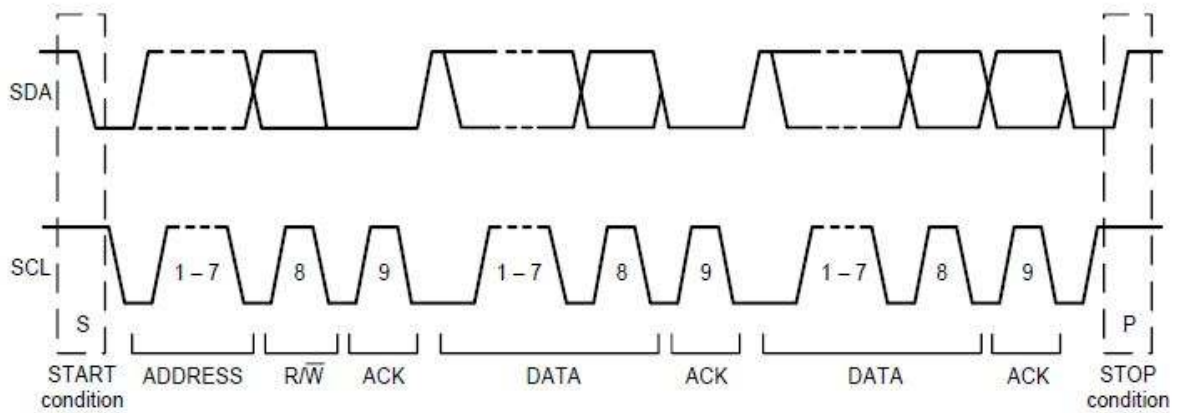
Single-Byte Write Sequence

Master	S	AD+W		RA		DATA		P
Slave			ACK		ACK		ACK	

Burst Write Sequence

Master	S	AD+W		RA		DATA		DATA		P
Slave			ACK		ACK		ACK		ACK	

Single-Byte Read Sequence

Master	S	AD+W		RA		S	AD+R			NACK	P
Slave			ACK		ACK			ACK	DATA		

Burst Read Sequence

Master	S	AD+W		RA		S	AD+R			ACK		NACK	P
Slave			ACK		ACK			ACK	DATA		DATA		

7. Demo System
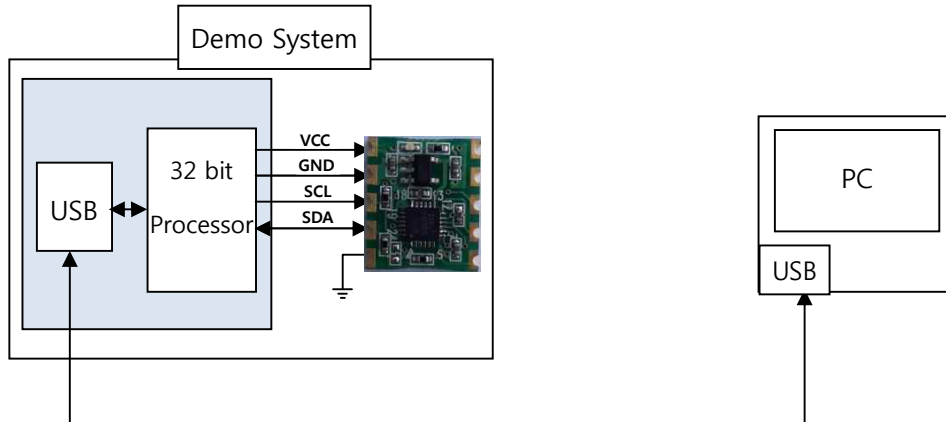
OSTSen-9250 Data Display on PC

8. Reference
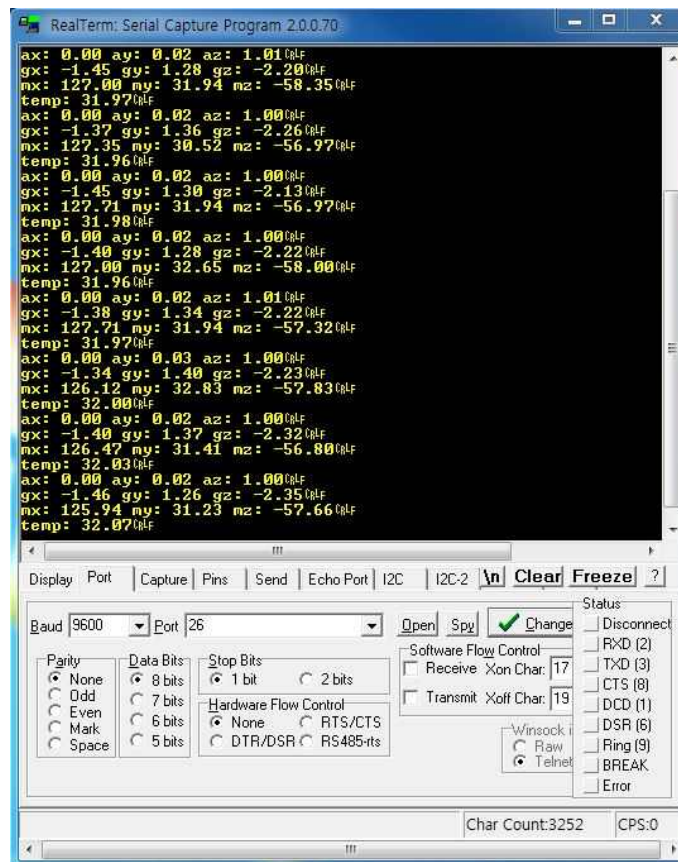
1) https://www.invensense.com/products/motion-tracking/9-axis/mpu-9250/
2) https://www.invensense.com/wp-content/uploads/2015/02/PS-MPU-9250A-01-v1.1.pdf
3) https://www.invensense.com/wp-content/uploads/2015/02/AN-IVS-0001EVB-00-v1-3.pdf
4) https://github.com/kriswiner/MPU9250
5) https://github.com/sparkfun/SparkFun_MPU-9250-DMP_Arduino_Library
6) https://github.com/sparkfun/SparkFun_MPU-9250_Breakout_Arduino_Library/tree/113e836e989699913660c60bacda12da4a919c91

- If you need some information or have some questions about OSTSen-9250, contact ostsen@naver.com.