MOD-1600 Datasheet

Revision 1.0

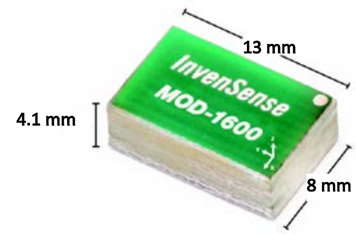
GENERAL DESCRIPTION

The MOD-1600 is the industry smallest 6-axis temperature stabilized MotionTracking module that is ideally suited for Drones, Head Mount Displays, and IoT applications. The MOD-1600 eliminates the need for sensor data calibration due to temperature variation.

By maintaining the operating temperature constant within 0.2°C tolerance using patent pending algorithm and packaging process, the MOD-1600 module provides an extremely stable gyroscope and accelerometer output to enable superior OEM product performance.

- 3-axis gyroscope, 3-axis accelerometer temperature stabilized module in a 13 x 8 x 4.1 mm, 16-pin package
- Stable temperature with 0.2°C tolerance.
- Increases sensor data output accuracy and stability during platform operation
- Reduces 6-axis calibration needs during operation.
- Enhances drone flight stability and hovering capabilities
- Refines HMD user experience

The device requires two operating voltages of one at 1.8 V to 3.3 V and the second at 5 V.



APPLICATIONS

Drones

Head Mount Displays

FEATURES

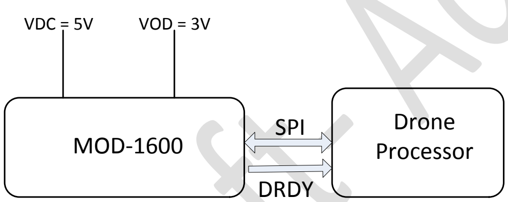
- 3-Axis Gyroscope with Programmable FSR of ±250dps, ±500dps, ±1000dps and ±2000dps
- 3-Axis Accelerometer with Programmable FSR of ±2g, ±4g, ±8g and ±16g
- Sensor sampling rate up to 1 kHz
- Drone code ready
- 8 MHz SPI Support
- MEMS structure hermetically sealed and bonded at wafer level
- Eliminates gyroscope bias and sensitivity drift over temperature
- Eliminates accelerometer bias and sensitivity drift over temperature
- Plug and play eval board for Pixhawk PX4 platform

ORDERING INFORMATION

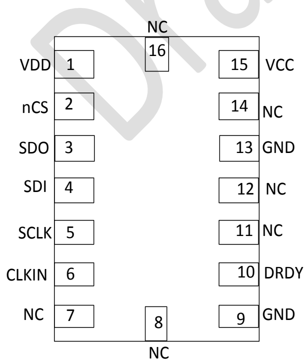
PART	TEMP RANGE	PACKAGE
MOD-1600†	−20°C to +65°C	16-Pin

†Denotes RoHS and Green-Compliant Package

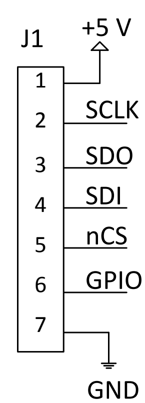
SYSTEM ARCHITECTURE



MODULE PIN OUT



EVALUATION BOARD



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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This document is a preliminary product specification, providing a description, specifications, and design related information on the MOD-1600 MotionTracking device.

Specifications are subject to change without notice. Final specifications will be updated based upon characterization of production silicon.

1.2 PRODUCT OVERVIEW

The MOD-1600 eliminates the need for sensor data calibration due to temperature variation. By maintaining the operating temperature constant within 0.2°C tolerance using patent pending algorithm and packaging process, the MOD-1600 module provides an extremely stable gyroscope and accelerometer output to enable superior OEM product performance.

- 3-axis gyroscope, 3-axis accelerometer temperature stabilized module in a 13 x 8 x 4.1 mm, 16-pin package
- Stable temperature with 0.2°C tolerance.
- Increases sensor data output accuracy and stability during platform operation
- Reduces 6-axis calibration needs during operation.
- Enhances drone flight stability and hovering capabilities
- Refines HMD user experience

The gyroscope has a programmable full-scale range of ±250, ±500, ±1000, and ±2000 degrees/sec. The accelerometer has a user-programmable accelerometer full-scale range of ±2*g*, ±4*g*, ±8*g*, and ±16*g*.

The device requires two operating voltages of one at 1.8 V to 3.3 V and the second at 5 V.

Other key features of the module are:

- Sensor sampling rate up to 1 kHz
- Drone code ready
- 8 MHz SPI Support
- MEMS structure hermetically sealed and bonded at wafer level
- Eliminates gyroscope bias and sensitivity drift over temperature
- Eliminates accelerometer bias and sensitivity drift over temperature
- Plug and play eval board for Pixhawk PX4 platform

1.3 APPLICATIONS

- Drones
- Headmount Displays
- Internet of Things (IoT)

2 FEATURES

2.1 GYROSCOPE 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
- 1% Sensitivity Error
- Self-test
- Temperature is controlled within 0.2°C

2.2 ACCELEROMETER FEATURES

- Digital-output X-, Y-, and Z-axis accelerometer with a programmable full scale range of ±2*g*, ±4*g*, ±8*g* and ±16*g* and integrated 16-bit ADCs
- Self-test
- Temperature is maintained within 0.2°C

2.3 CLOCK REQUIREMENT UNIT

- External 32.768 kHz digital clock input

2.4 SERIAL INTERFACES

- One 4-wire SPI slave controller operating at speeds of up to 8 MHz for communication with application processor

2.5 DIGITAL PERIPHERALS

- 1 GPIO for Data Ready Interrupt

3 ELECTRICAL CHARACTERISTICS

3.1 GYROSCOPE SPECIFICATIONS

Typical Operating Circuit of section 4.2, VDD = 3.3 V, VDDIO = 3.3 V, T_A=25°C, once internal temperature of the module is stabilized, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
GYROSCOPE SENSITIVITY						
Full-Scale Range			±250		°/s	1
			±500		°/s	1
			±1000		°/s	1
			±2000		°/s	1
Gyroscope ADC Word Length			16		bits	1
Sensitivity Scale Factor	Full-Scale Range = ±250º/s		131		LSB/(°s)	1
	Full-Scale Range = ±500º/s		65.5		LSB/(°s)	1
	Full-Scale Range = ±1000º/s		32.8		LSB/(°s)	1
	Full-Scale Range = ±2000º/s		16.4		LSB/(°s)	1
Sensitivity Scale Factor Tolerance	25°C		TBD		%	2, 4
Sensitivity Scale Factor Variation Over Temperature	-20 to +65°C		TBD		%	2, 4
Nonlinearity	Best fit straight line; 25°C		±0.2		%	2, 3, 4
Cross-Axis Sensitivity			±2		%	2, 3, 4
ZERO-RATE OUTPUT (ZRO)						
Initial ZRO Tolerance	25°C		22.5		°/s	2, 4
ZRO Variation Over Temperature	-20 to +65°C			1	°/s	2, 4
GYROSCOPE NOISE PERFORMANCE (GYRO_FS_SEL=0)						
Total RMS Noise	Noise Bandwidth = 197 Hz Calculated from Noise Spectral Density		0.07		°/s-rms	2, 3, 4
GYROSCOPE MECHANICAL FREQUENCIES		25	27	29	kHz	2
LOW PASS FILTER RESPONSE			197		Hz	1, 3
OUTPUT DATA RATE	Low-Noise mode		1000		Hz	1

Table 1. Gyroscope Specifications

Notes:

1. Guaranteed by design
2. Derived from validation or characterization of parts, not guaranteed in production
3. Low-noise mode specification
4. Target spec, to be characterized.

3.2 ACCELEROMETER SPECIFICATIONS

Typical Operating Circuit of section 4.2, VDD = 3.3 V, VDDIO = 3.3 V, T_A=25°C, once internal temperature of the module is stabilized, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
ACCELEROMETER SENSITIVITY						
Full-Scale Range			±2		*g*	1
			±4		*g*	1
			±8		*g*	1
			±16		*g*	1
ADC Word Length	Output in two's complement format		16		bits	1
Sensitivity Scale Factor	Full-Scale Range = ±2g		16,384		LSB/*g*	1
	Full-Scale Range = ±4g		8,192		LSB/*g*	1
	Full-Scale Range = ±8g		4,096		LSB/*g*	1
	Full-Scale Range = ±16g		2,048		LSB/*g*	1
Initial Tolerance	Board Level		TBD		%	2, 4
Sensitivity Change vs. Temperature	-20 to +65°C			±1	%	2, 4
Nonlinearity	Best Fit Straight Line		±0.5		%	2, 3
Cross-Axis Sensitivity			±2		%	2, 3
ZERO-G OUTPUT						
Initial Tolerance	Board Level		TBD		mg	2, 4
Zero-G Level Change vs. Temperature	-20 to +65°C		TBD		mg/ºC	2, 4
ACCELEROMETER NOISE PERFORMANCE						
Total RMS Noise	X and Y axis (Noise Bandwidth = 246 Hz)		3.5		mg-rms	2, 3
	Z-axis (Noise Bandwidth = 246 Hz)		TBD			2
LOW PASS FILTER RESPONSE			246		Hz	1, 3
OUTPUT DATA RATE	Low-Noise mode		1000		Hz	1

Table 2. Accelerometer Specifications

Notes:

1. Guaranteed by design
2. Derived from validation or characterization of parts, not guaranteed in production
3. Low-noise mode specification
4. Target spec, to be characterized.

3.3 ELECTRICAL SPECIFICATIONS

3.3.1 D.C. Electrical Characteristics

Typical Operating Circuit of section 4.2, VDD = 3.3 V, VDDIO = 3.3 V, T_A=25°C, once internal temperature of the module is stabilized, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
SUPPLY VOLTAGES						
VDD		1.8		3.3	V	1
VDDIO			VDD		V	1
VCC			5		V	1
SUPPLY CURRENTS						
I_{VDD}			TBD		mA	2, 3
I_{Vcc}			TBD	525	mA	2, 3
Full-Chip Deep Sleep Mode			30		µA	2
Power Down Mode			10		µA	2
TEMPERATURE RANGE						
Specified Temperature Range	Performance parameters are not applicable beyond Specified Temperature Range	-20		+65	°C	1

Table 3. D.C. Electrical Characteristics

Notes:

1. Guaranteed by design
2. Derived from validation or characterization of parts, not guaranteed in production
3. Target spec, to be characterized.

3.3.2 A.C. Electrical Characteristics

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A=25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
TEMPERATURE SENSOR						
Operating Range	Ambient	-20		+65	°C	1
Sensitivity	Untrimmed		333.87		LSB/°C	1
Room Temp Offset	21°C		0		LSB	1
Power-On RESET						
Supply Ramp Time (T_{RAMP})	Valid power-on RESET	0.1	20	100	ms	1
Start-up time for register read/write	From power-up		11	100	ms	1
DIGITAL INPUTS (SCLK, SDI, CS)						
V_{IH}, High Level Input Voltage		0.7*VDDIO			V	1
V_{IL}, Low Level Input Voltage				0.3*VDDIO	V	1
C_I, Input Capacitance			< 10		pF	1
DIGITAL OUTPUT (SDO, GPIO)						
V_{OH}, High Level Output Voltage	R_{LOAD} = 1 MΩ;	0.9*VDDIO			V	1
V_{OL1}, LOW-Level Output Voltage	R_{LOAD} = 1 MΩ;			0.1*VDDIO	V	1
$V_{OL.INT1}$, INT Low-Level Output Voltage	OPEN = 1, 0.3 mA sink Current			0.1	V	1
Output Leakage Current	OPEN = 1		100		nA	1
t_{INT}, INT Pulse Width		1		16	µs	1
EXTERNAL CLOCK SOURCE						
Oscillator	Frequency		32.768		kHz	

Table 4. A.C. Electrical Characteristics

Notes:

1. Derived from validation or characterization of parts, not guaranteed in production.

3.4 SPI TIMING CHARACTERIZATION

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A=25°C, unless otherwise noted.

Parameters	Conditions	Min	Typical	Max	Units	Notes
SPI TIMING						
f_{SPC}, SPC Clock Frequency				8	MHz	
t_{LOW}, SPC Low Period		56			ns	
t_{HIGH}, SPC High Period		56			ns	
$t_{SU.CS}$, CS Setup Time		2			ns	
$t_{HD.CS}$, CS Hold Time		63			ns	
$t_{SU.SDI}$, SDI Setup Time		3			ns	
$t_{HD.SDI}$, SDI Hold Time		7			ns	
$t_{VD.SDO}$, SDO Valid Time	C_{load} = 20 pF			40	ns	
$t_{DIS.SDO}$, SDO Output Disable Time				20	ns	

Table 5. SPI Timing Characteristics

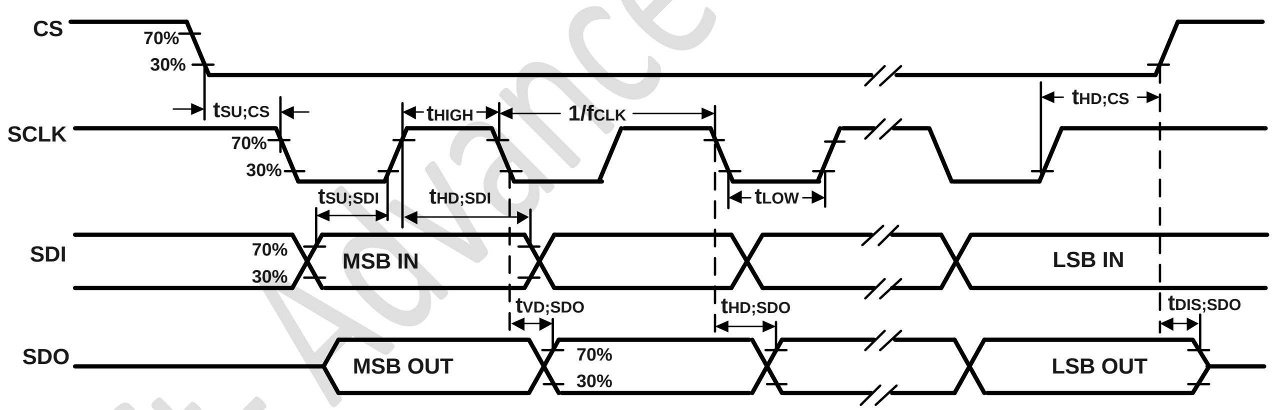


Figure 1. SPI Bus Timing Diagram

3.5 ABSOLUTE MAXIMUM RATINGS

Stress above those listed as "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to the absolute maximum ratings conditions for extended periods may affect device reliability.

PARAMETER	RATING
Supply Voltage, VDD	-0.5 V to +4 V
Supply Voltage, VCC	VDD to +15 V
Input Voltage Level (,, SDI, SDO)	-0.5 V to VDD + 0.5 V
Acceleration (Any Axis, unpowered)	10,000g for 0.2 ms
Operating Temperature Range	-40°C to +105°C
Storage Temperature Range	-40°C to +125°C
Electrostatic Discharge (ESD) Protection	2 kV (HBM); 200 V (MM)
Latch-up	JEDEC Class II (2),125°C ±100 mA

Table 6. Absolute Maximum Ratings

4 APPLICATIONS INFORMATION

4.1 PIN OUT DIAGRAM AND SIGNAL DESCRIPTION

PIN NUMBER	PIN NAME	PIN DESCRIPTION
1	VDD	VDD
2	nCS	SPI slave CSN
3	SDO	SPI slave SDO
4	SDI	SPI slave SDI
5	SCLK	SPI slave SCLK
6	CLKIN	Clock input 32.768 kHz
7	NC	No Connect
8	NC	No Connect
9	GND	GND Power Supply Ground
10	DRDY	Data Ready Interrupt
11	NC	No Connect
12	NC	No Connect
13	GND	GND Power Supply Ground
14	NC	No Connect
15	VCC	+5V supply for heating element
16	NC	No Connect

Table 7. Signal Descriptions

Note: Power up with SCLK and nCS pins held low is not a supported use case.

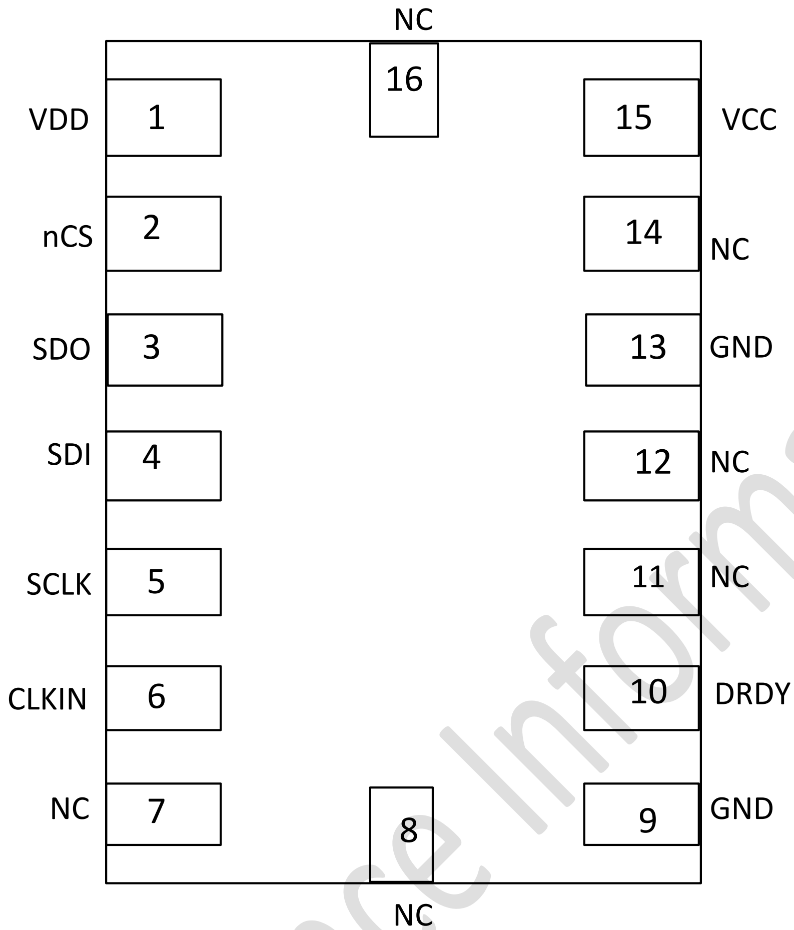


Figure 2. Pinout Diagram for MOD-1600

4.2 TYPICAL OPERATING CIRCUIT

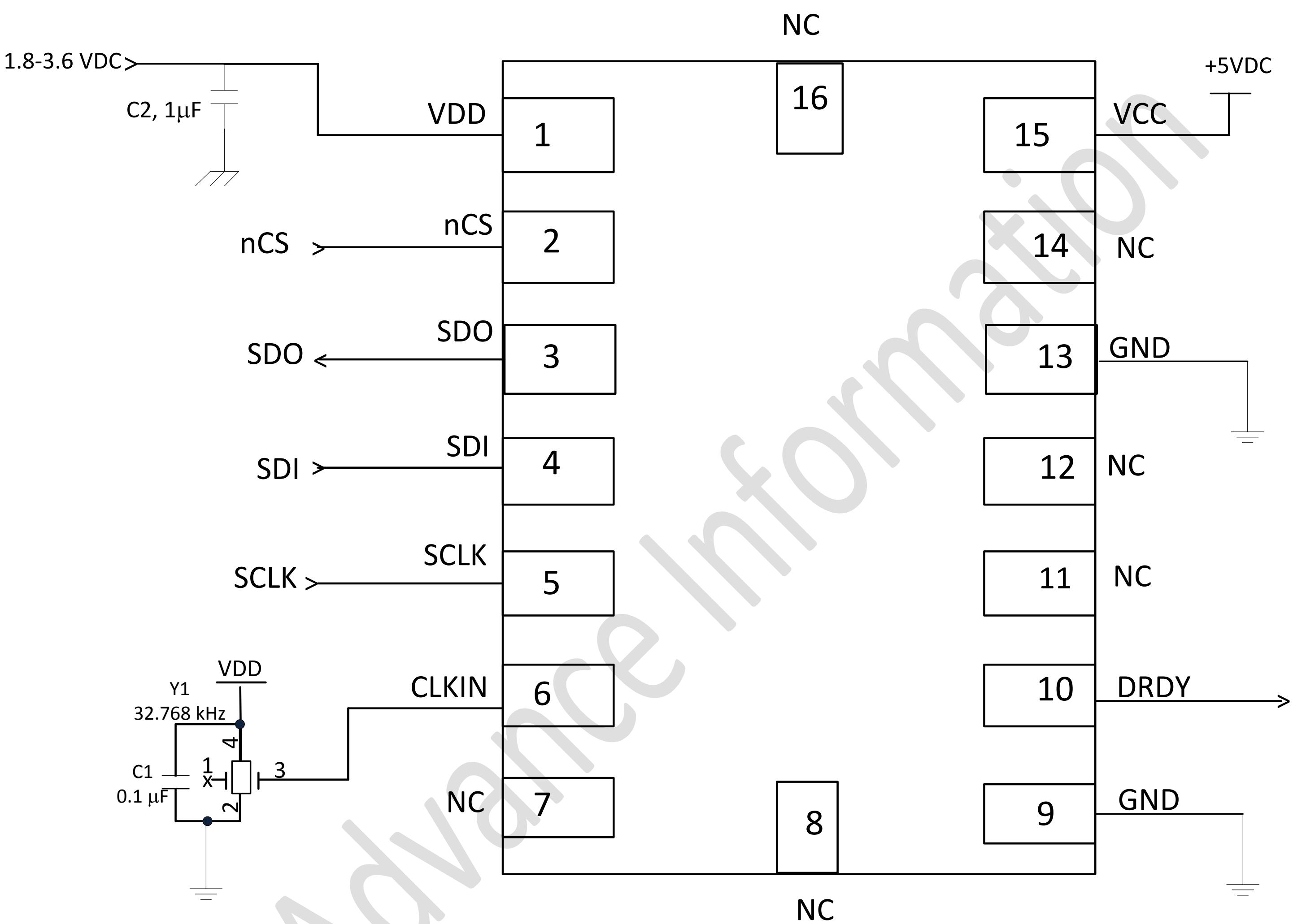


Figure 3. MOD-1600 Application Schematic: SPI operation

4.3 BILL OF MATERIALS FOR EXTERNAL COMPONENTS

COMPONENT	LABEL	SPECIFICATION	QUANTITY
Decoupling Capacitor	C1	Ceramic, X7R, 1µF ±10%, 10V	1
Decoupling Capacitor for Oscillator	C2	0.1µF	1
Oscillator	X1	KC2520B32K7680CM2E00, or equivalent	1

Table 8. Bill of Materials

4.4 MOD-1600 BLOCK DIAGRAM

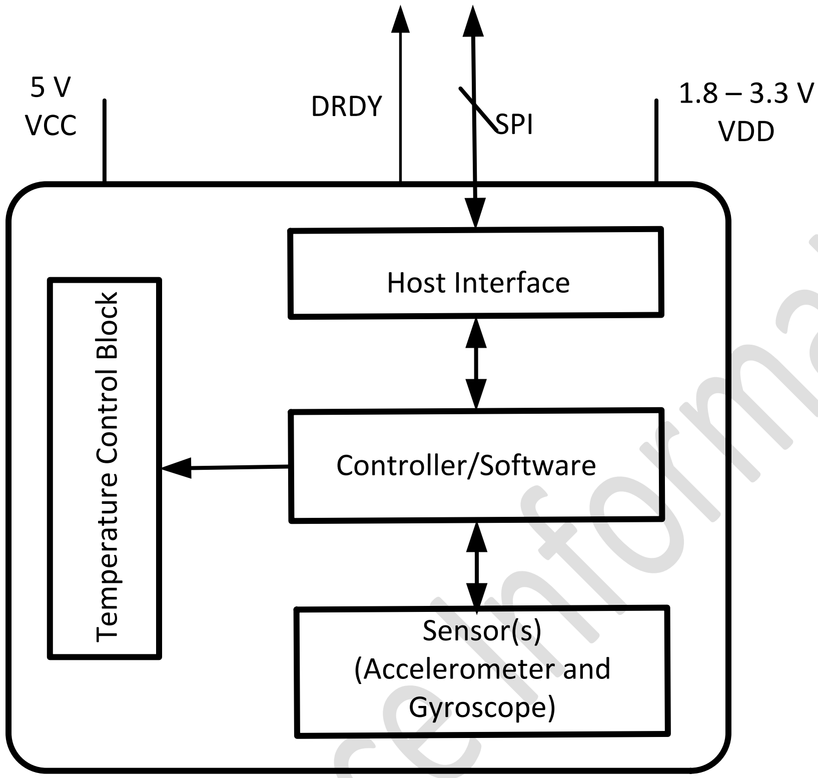


Figure 4. MOD-1600 Block Diagram

4.5 OVERVIEW

The MOD-1600 device consists of the following key blocks and functions:

- Three-axis MEMS rate gyroscope sensor with 16-bit ADCs and signal conditioning
- Three-axis MEMS accelerometer sensor with 16-bit ADCs and signal conditioning
- Temperature control block
- FIFO
- 1 DRDY
- Slave SPI serial communications interface
- Self-Test
- Clocking
- Power Modes

4.5.1 Three-Axis MEMS Gyroscope with 16-bit ADCs and Signal Conditioning

The MOD-1600 consists of three independent vibratory MEMS rate gyroscopes, which detect rotation about the X-, Y-, and Z- Axes. When the gyros are rotated about any of the sense axes, the Coriolis Effect causes a vibration that is detected by a capacitive pickoff. The resulting signal is amplified, demodulated, and filtered to produce a voltage that is proportional to the angular rate. This voltage is digitized using individual on-chip 16-bit Analog-to-Digital Converters (ADCs) to sample each axis. The full-scale range of the gyro sensors may be digitally programmed to ±250, ±500, ±1000, or ±2000 degrees per second (dps).

4.5.2 Three-Axis MEMS Accelerometer with 16-bit ADCs and Signal Conditioning

The MOD-1600's 3-Axis accelerometer uses separate proof masses for each axis. Acceleration along a particular axis induces displacement on the corresponding proof mass, and capacitive sensors detect the displacement differentially. The MOD-1600's architecture reduces the accelerometers' susceptibility to fabrication variations as well as to thermal drift. When the device is placed on a flat surface, it will measure 0*g* on the X- and Y-axes and +1*g* on the Z-axis. Each sensor has a dedicated sigma-delta ADC for providing digital outputs. The full scale range of the digital output can be adjusted to ±2*g*, ±4*g*, ±8*g*, or ±16*g*.

4.5.3 Temperature control block

This block consists of a very tightly integrated heating element and software control. The temperature control block is responsible for maintaining a near-constant temperature in the module for the sensor element. The temperature control block is resilient to ambient temperature changes seen by the MOD-1600 module and maintains a 0.2 °C tolerance on the set temperature. VCC voltage of 5V is required for the temperature control block to be functional.

4.5.4 FIFO

The MOD-1600 contains a FIFO that is accessible via the SPI interfaces. The FIFO is used to keep a history of most recent sensors output.

4.5.5 DRDY

The MOD-1600 supports a data ready interrupt.

4.5.6 SLAVE SPI Serial Communications Interfaces

The MOD-1600 communicates to a host application processor through an SPI serial interface. The MOD-1600 always acts as a slave when communicating to the application processor. The SPI slave interface can be used by the application processor to program the MOD-1600 or to read its on-chip memory.

4.5.7 On-Chip Oscillators

The MOD-1600 includes 3 on-chip oscillators:

- Internal oscillator for accurate time stamping functions
    - Requires external 32 kHz clock input from crystal or any other clock source

4.5.8 Standard Power Modes

The MOD-1600 supports the following power modes:

- **Power Down Mode:** All digital circuitry is off, but analog POR is on and listening to external input to wake up the system on an interrupt. There is no data retention in this mode except for Flash.
- **Deep Sleep Mode:** ROM and Flash are powered off but the rest of the digital circuitry is on for data retention. RC oscillator is powered off.
- **Sleep Mode:** All digital circuitry is powered on and idle. RC oscillator is powered off.

5 DIGITAL INTERFACE

5.1 SPI INTERFACE

SPI is a 4-wire synchronous serial interface that uses two control lines and two data lines. The MOD-1600 always operates as a Slave device during standard Master-Slave SPI operation.

With respect to the Master, the Serial Clock output (SCLK), the Serial Data Output (SDO) and the Serial Data Input (SDI) are shared among the Slave devices. Each SPI slave device requires its own Chip Select (CS) line from the master.

CS goes low (active) at the start of transmission and goes back high (inactive) at the end. Only one CS line is active at a time, ensuring that only one slave is selected at any given time. The CS lines of the non-selected slave devices are held high, causing their SDO lines to remain in a high-impedance (high-z) state so that they do not interfere with any active devices.

SPI Operational Features

1. Data is delivered MSB first and LSB last
2. Data is latched on the rising edge of SCLK
3. Data should be transitioned on the falling edge of SCLK
4. The maximum frequency of SCLK is 8 MHz
5. SPI read and write operations are completed in 16 or more clock cycles (two or more bytes). The first byte contains the SPI Address, and the following byte(s) contain(s) the SPI data. The first bit of the first byte contains the Read/Write bit and indicates the Read (1) or Write (0) operation. The following 7 bits contain the Register Address. In cases of multiple-byte Read/Writes, data is two or more bytes:

SPI Address format

MSB							**LSB**
R/W	A6	A5	A4	A3	A2	A1	A0

SPI Data format

MSB							**LSB**
D7	D6	D5	D4	D3	D2	D1	D0

6. Supports Single or Burst Read/Writes.

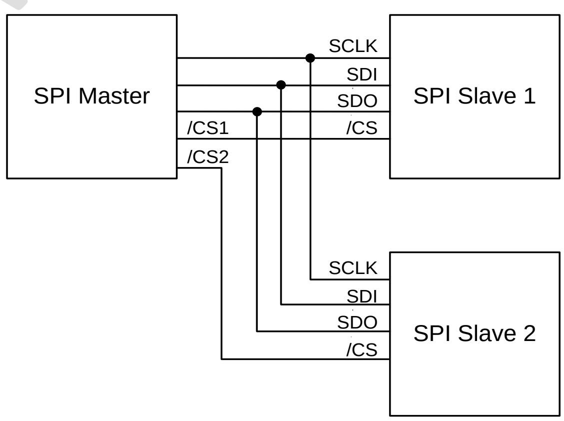


Figure 5. Typical SPI Master / Slave Configuration

6 SYSTEM DIAGRAM

The figure below depicts a sample circuit of MOD-1600, with interfaces to the Application Processor (AP).

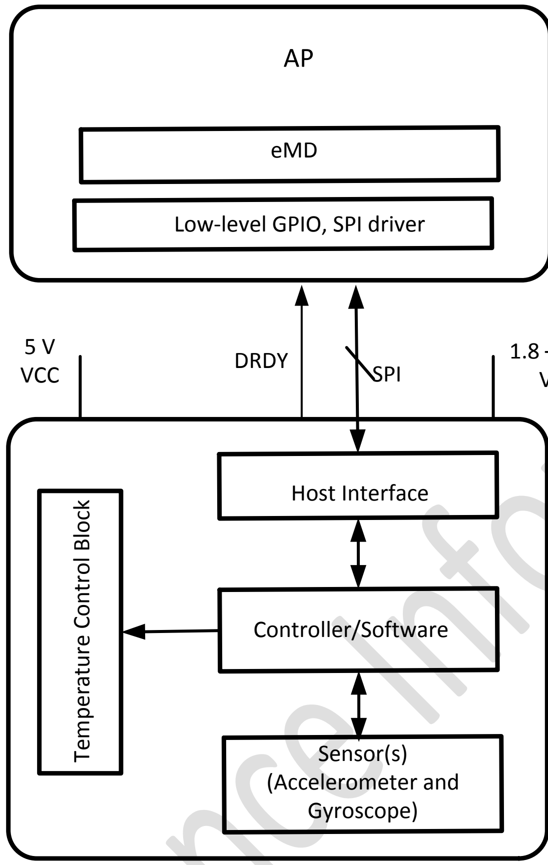


Figure 6. MOD-1600 System Diagram

AP/HOST: Application process or host processor that interfaces with the MOD-1600.

AP would need the embedded driver (LibIDD) code provided with the software package for the device. Requirement for the image and documentation of the driver will be in the software package. Except for the firmware image, the driver will be provided in source. The SW package consists of the following content:

1. Embedded driver (LibIDD): Has the required protocols interfacing with MOD-1600, load the firmware image provided and gets raw sensor data which include accelerometer, gyroscope and temperature
2. MOD-1600 firmware image that is provided in the package. The driver code checks and loads the image if does not match the MOD-1600's existing image.

MOD-1600:

It contains cortex-M0, which is connected to the 6 axes sensors. AP is responsible to program the MOD-1600 using the LibIDD driver code and the provided firmware image. MOD-1600 by default starts in deep sleep mode and host is responsible for waking the device in operating mode. Provided driver implementation shows the procedure.

Please contact sales@invensense.com for the required software package.

7 ORIENTATION OF AXES

The diagram below shows the orientation of the axes of sensitivity and the polarity of rotation. Note the pin 1 identifier (•) in the figure.

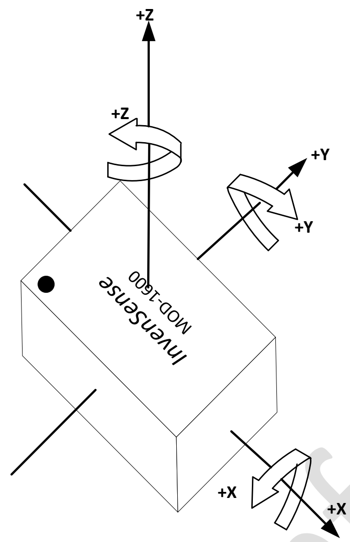


Figure 7. Orientation of Axes of Sensitivity and Polarity of Rotation

8 PACKAGE DIMENSIONS

This section provides package dimensions for the MOD-1600.

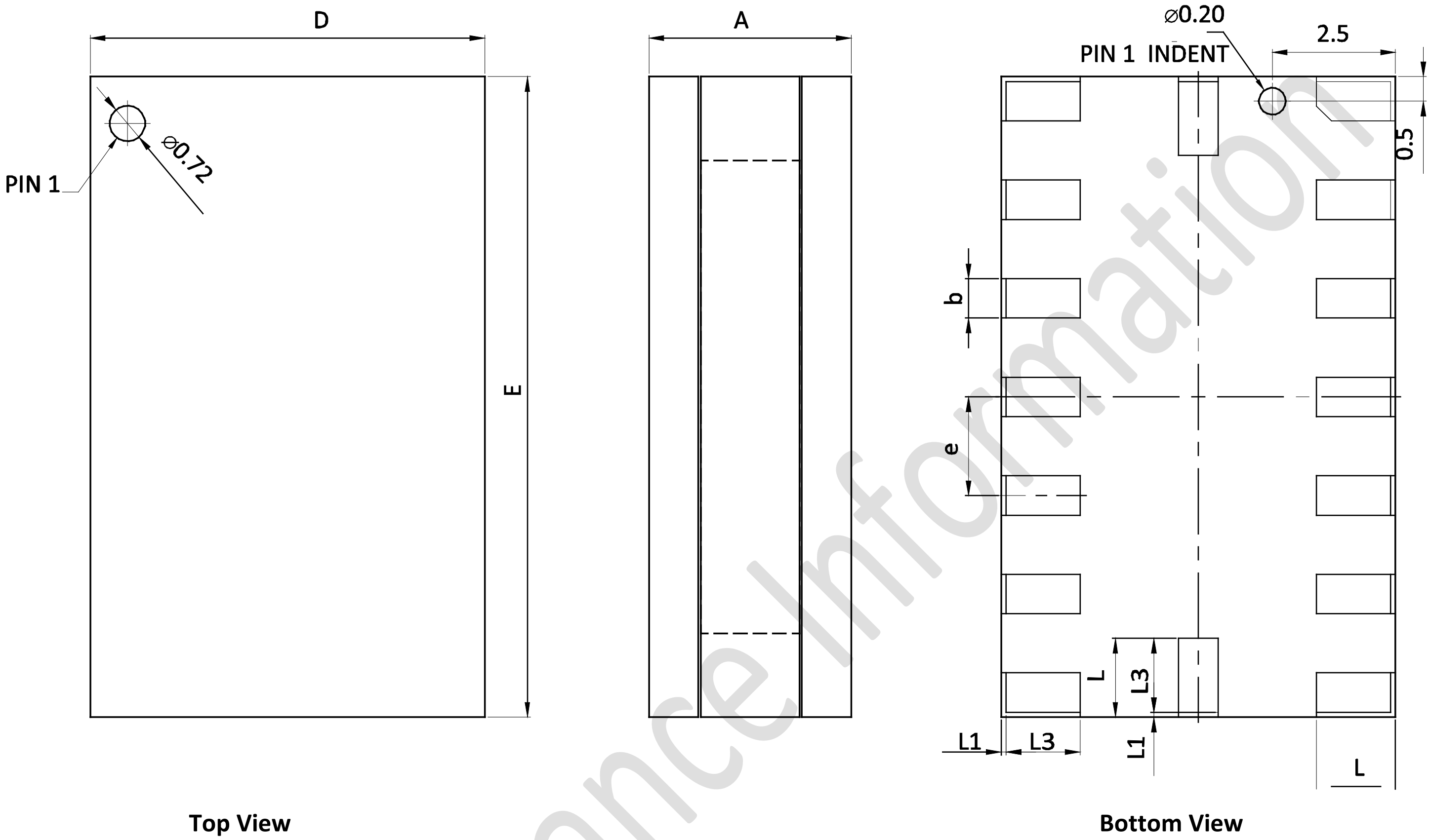


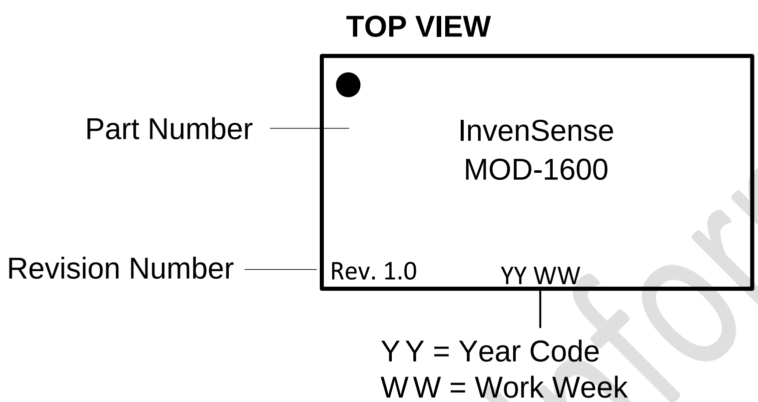
Figure 8. Package Diagram

SYMBOLS	Dimensions in Millimeters		
	MIN.	**NOM.**	**MAX.**
A	4.00	4.10	4.20
b	0.75	0.80	0.85
D	7.90	8.00	8.10
E	12.90	13.00	13.10
e	---	2.00	---
L	1.55	1.60	1.65
L1	---	0.10	---
L3	1.45	1.50	1.55

9 PART NUMBER PART MARKINGS

The part number part markings for MOD-1600 devices are summarized below:

PART NUMBER	PART NUMBER PART MARKING
MOD-1600	MOD-1600



10 REFERENCES

Please refer to “InvenSense MOD-1600 Handling Application Note (TBD)” for the following information:

- Manufacturing Recommendations
  - Assembly Guidelines and Recommendations
  - PCB Design Guidelines and Recommendations
  - MEMS Handling Instructions
  - ESD Considerations
  - Reflow Specification
  - Storage Specifications
  - Package Marking Specification
  - Tape & Reel Specification
  - Reel & Pizza Box Label
  - Packaging
  - Representative Shipping Carton Label
- Compliance
  - Environmental Compliance
  - DRC Compliance
  - Compliance Declaration Disclaimer

11 DOCUMENT INFORMATION

11.1 REVISION HISTORY

REVISION DATE	REV NUMBER	DESCRIPTION
02/03/2016	1.0	Initial Draft

11.2 COMPLIANCE DECLARATION DISCLAIMER

InvenSense believes the environmental and other compliance information given in this document to be correct but cannot guarantee accuracy or completeness. Conformity documents substantiating the specifications and component characteristics are on file. InvenSense subcontracts manufacturing and the information contained herein is based on data received from vendors and suppliers, which has not been validated by InvenSense.

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