Features and Benefits

- **VDD range: 2.6V～3.6V**
- **Low power consumption: 2.5mA**
- **Small size: 3.3mmx3.3mm**
- **Operating temperature range:- 40℃to 85℃**
- **High resolution and dynamic range**
- **Low zero rate output drift**
- **High-performance MEMS sensor in SOI yielding a superior long-term behavior reliability and dynamic range**
- **Cost effective and Compact Solution**
- **On chip EPROM trimming**
- **On-chip 16 bits ADC**
- **SPI & I^2C interface**

Applications

- Activity monitoring, step-counting
- Navigation
- Vibration measurement, also for active damping
- Six-dimensional tracking of trajectories
- EIS & OIS camera applications
- Motion-enabled game and application framework
- Location based services, points of interest, and dead reckoning
- Handset and portable gaming
- Motion-based game controllers
- Toys

General Description

The SH200L is a very small, 6 axis inertial sensor, consisting of: A digital, triaxial 16bit acceleration sensor and a digital, triaxial 16bit, ±2000°/s gyroscope. The SH200L allows very low-noise measurement of angular rates and accelerations in 3 perpendicular axis and thus senses tilt, motion, shock and vibration in mobile phones, handhelds, computer peripherals, man-machine interfaces, remote and game controllers. A single LGA package contains a high performance silicon micro machined sensor with signal conditioning circuitry.

It provides excellent temperature stability and high resolution over the operating temperature range (-40℃~ 85℃)

It has applications-programmable full-scale-range of +-125º/s, ±250 º/s, ±500º/s, ±1000º/s and ±2000º/s. SH200L is capable of detecting rates with -3dB bandwidth up to 200Hz.

The SH200L delivers output signal proportional to angular rate. SH200L includes low-pass filters and EPROM for on-chip factory calibration for the sensor.

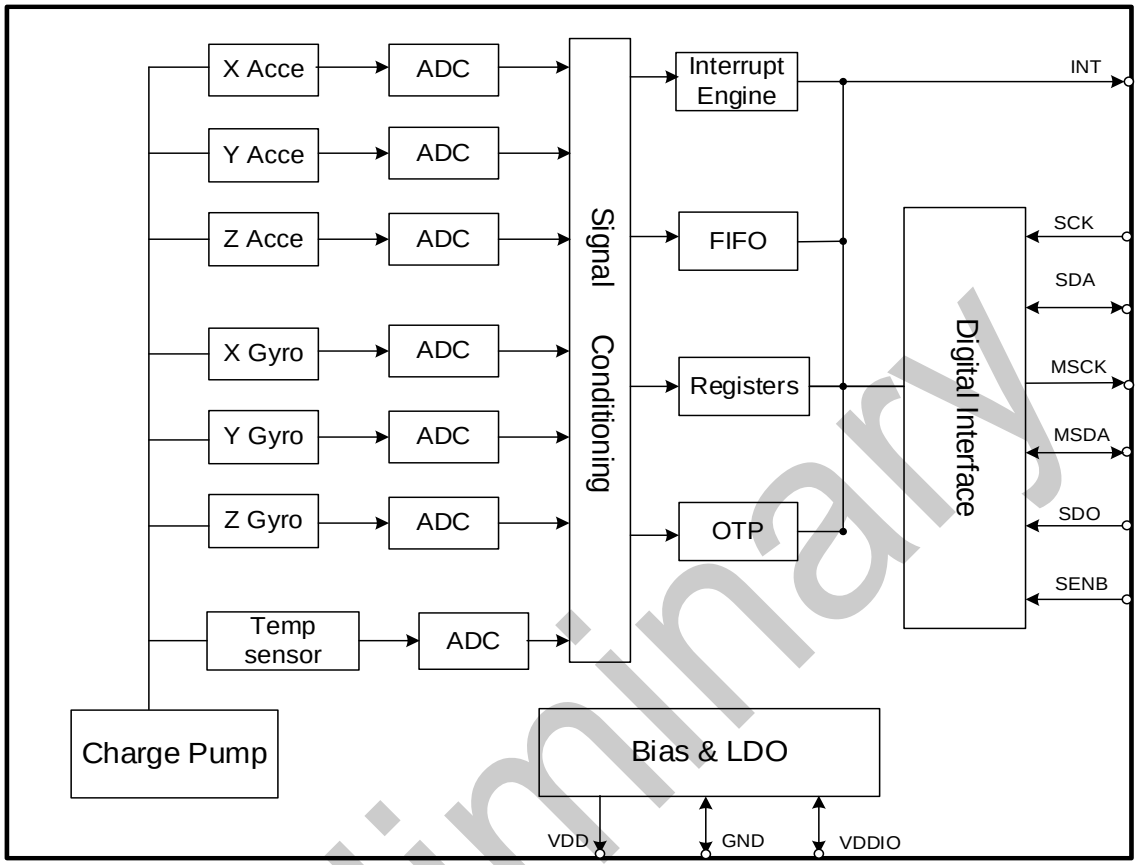
The SH200L is provided in Land Grid Array (LGA) package.

Order Information

Model Name	Full Scale Range	Package Description
SH200L	±2000 º/s / ±16g	14-pin LGA, 3.3x 3.3 x 1.21mm^3

Contents

1. Functional Diagram



2. SH200L Specifications

All parameters specified are @ VDD=3.0V and T=25℃, unless otherwise noted.

2.1 Gyroscope sensor specifications

Parameter	Conditions	Min.	Typ.	Max.	Unit
Full Scale Range			±2000 º/s ±1000º/s ±500 º/s ±250 º/s ±125 º/s		º/s
Sensitivity/Scale Factor			16.4 32.8 65.5 131 262		LSB/ º/s
Non-Linearity	Best Fit Straight Line		±0.2		% of FS
Gyro_ODR	Angular rate output rate		32 250 500 1000 8K 16K 32K		Hz
Scale Factor Drift	-40℃~85℃		0.05		%/℃
Zero Rate Temperature Drift	-40℃~85℃		0.2		º/s/℃
Bandwidth(-3dB)			200		Hz
Rate output Noise Density			0.019 @ 100Hz		dps/√Hz
Cross-sensitivity			±1		%
Initial ZRO tolerance			±5		º/s

2.2 Accelerometer sensor specifications

Parameter	Conditions	Min.	Typ.	Max.	Unit
Acceleration Range	selectable via I^2C		±4 ±8 ±16		g
Sensitivity/Scale Factor			8192 4096 2048		LSB/g
Acc_ODR	Acceleration rate output data rate		1000 500 250 125 64 32 16 8		Hz
Sensitivity Drift	-40℃~85℃		±0.02		%/℃
Zero-g offset	-40℃~85℃		±80		mg
output rate noise			150		ug/ √ Hz
Non-Linearity			±0.5		%FS

2.3 Electrical characteristics

Electrical characteristics @ VDD=3.0V, T=25℃ unless otherwise noted

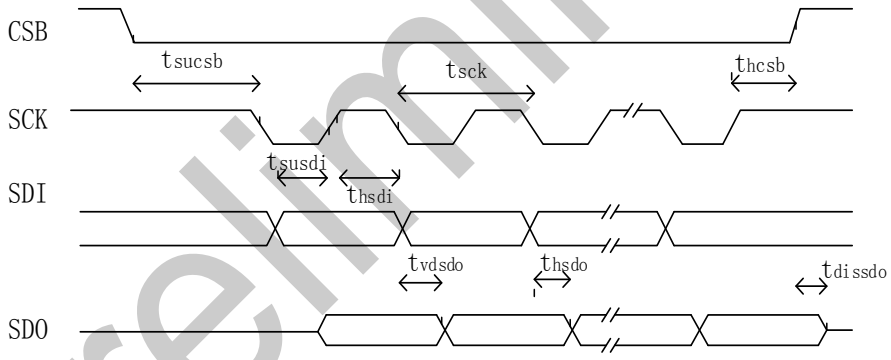
Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
VDD	Supply voltage		2.6	3	3.6	V
VDDIO			1.62	1.8	3.6	V
Idd	Supply current	VDD=3.0V		2.5		mA
Iddpd	Power down current	VDD=3.0V		3.7		uA
V_{IL}	Digital Low-level input voltage				0.3*VDDIO	V
V_{IH}	Digital high-level input voltage		0.7*VDDIO			V
V_{OL}	Digital low-level output voltage				0.2	V
V_{OH}	Digital high-level output voltage		VDDIO– 0.2			

2.4 Digital interface characteristics

2.4.1 SPI-serial peripheral interface

Subject to general operation conditions like VDD, operating temperature and PCB design.

symbol	parameter	value		unit
		Min	Max	
tsck	SPI clock period	125		ns
fsck	SPI frequency		8	MHz
tsucsb	CSB setup time	8		ns
thcsb	CSB hold time	20		ns
tsusdi	SDI setup time	8		ns
thsdi	SDI hold time	20		ns
tvdsdo	SDO valid time		60	ns
thsdo	SDO hold time	8		ns
tdissdo	SDO disable time		60	ns



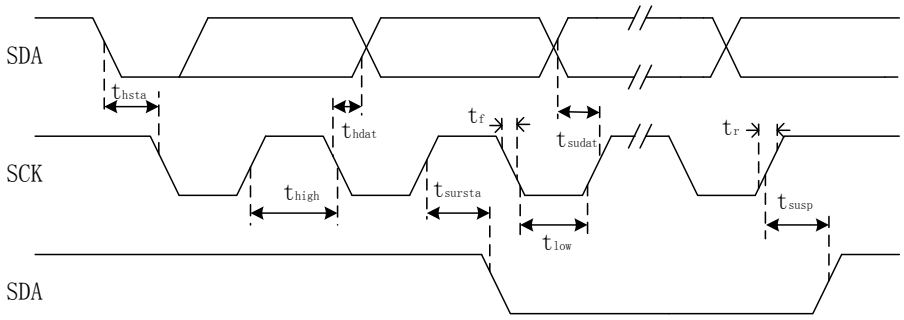
SPI timing diagram

2.4.2 I²C- Inter-IC control interface

Subject to general operation conditions like VDD, operating temperature and PCB design.

symbol	parameter	value		unit
		Min	Max	
fsck	I2C frequency		400	KHz
tlow	I2C clock low time	1.5		us
thigh	I2C clock high time	0.7		us
tsudat	SDA data setup time	150		ns
thdat	SDA data hold time	0	1	us
tsursta	repeat start condition setup time	0.6		us

thsta	start condition hold time	0.6		us
tsusp	stop condition setup time	0.6		us



I2C timing diagram

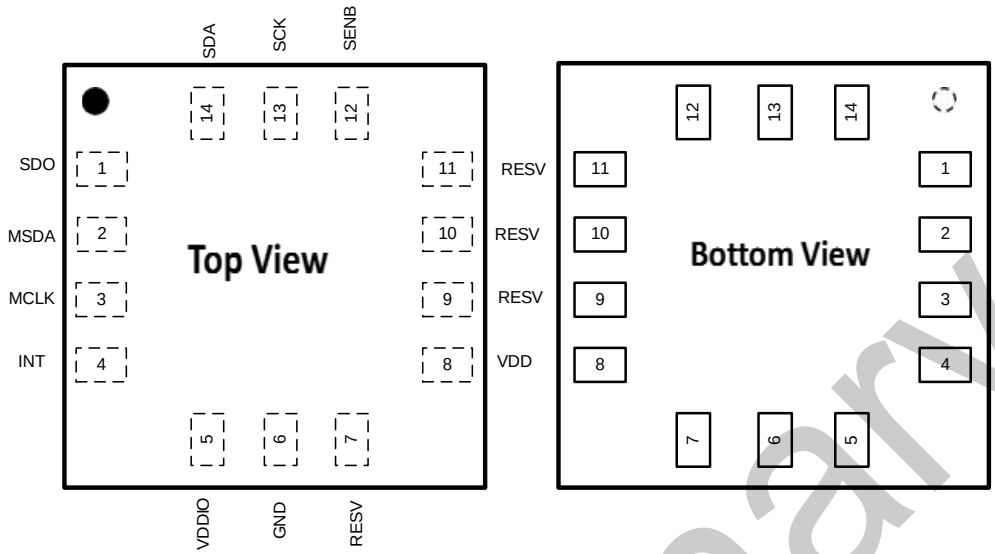
2.5 Absolute maximum ratings

Stress above those listed as “Absolute Maximum Ratings” may cause permanent damage to the device. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Parameter	Rating
Operating supply voltage	-0.3V ~ 6V
Operating Temperature Range	-40℃ ~ 85℃
Storage Temperature Range	-40℃ ~ 105℃
ESD (HBM)	2000V
ESD (MM)	200V
Latch-up	JEDEC78E Class I，±200mA

3. Pin Description

3.1 14-pin LGA



Pin No.	Pin Name	Pin Function
1	SDO	IIC slave Address LSB (A0), Serial data output in SPI.
2	MSDA	Auxiliary IIC serial data, for connecting to external sensors
3	MCLK	Auxiliary IIC serial clock, for connecting to external sensors
4	INT	Interrupt digital output(totem pole or open-drain)
5	VDDIO	Digital I/O supply voltage
6	GND	Power supply ground
7	RESV	Reserved. Do not connect
8	VDDBAT	Power supply voltage and Digital supply voltage
9	RESV	Reserved
10	RESV	Reserved. Do not connect
11	RESV	Reserved
12	SENB	I2C/SPI (CSB)Protocol select: 1: SPI idle mode/I2C communication enabled; 0: SPI communication mode/I2C disabled
13	SCK	IIC serial clock, SPI serial clock
14	SDA	IIC serial data, serial data input SDI in SPI

4. Functional Explanation

Overview

The SH200L is comprised of the several key blocks and functions:

- Three-axis MEMS angular rate sensor/acceleration sensor with 16-bit ADCs and signal conditioning
- Digital signal processor
- Auxiliary IIC interface
- FIFO
- Interrupts
- Digital-Output Temperature Sensor

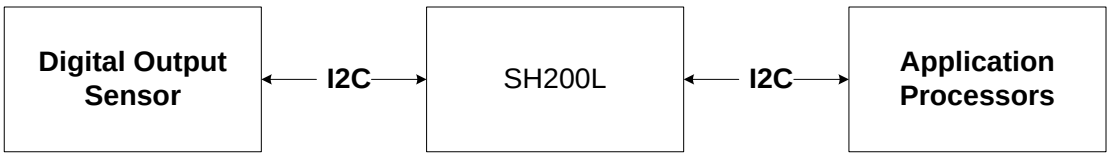
4.1 Three–Axis MEMS sensor with 16-bit ADCs and signal conditioning

The SH200L consists of three independent angular rate sensors and independent acceleration sensors. It detects rotation on the X, Y and Z axes and acceleration on the X, Y and Z axes. When the gyro is rotated around any of these sense axes, the movement caused by Coriolis Effect will be detected. And when the accelerometer is moving along any of these sense axes, the movement caused by acceleration will be detected. The resulting signal is amplified, demodulated, and filtered to produce a voltage that is proportional to the angular rate or the acceleration rate. For each axis an on-chip 16-bit ADC is used to digitize the output voltage. The full-range of the gyroscope part is ±2000º/s and the full-range of the accelerometer part is programmable at ±4/8/16g.

4.2 Auxiliary IIC serial interface

The SH200L has an auxiliary IIC bus which allows an external system processor to act as master and directly communicate to the external sensors connected to the secondary I2C bus pins (MSDA and MSCK). This is useful for configuring the external sensors, or for keeping the SH200L in a low-power mode, when only sensors are to be used. In this mode, the secondary I2C bus control logic (third-party sensor Interface block) of the SH200L is disabled, and the secondary I2C pins MSDA and MSCK are connected to the main I2C bus through analog switches.

The diagram below shows an application processor can communicate to the digital output sensor connected to SH200L through the Auxiliary IIC bus.



4.3 FIFO

The SH200L contains an embedded memory management system of 32-level FIFO for both gyroscope and accelerometer data that can be used to relieve host processor burden. It has four modes:

Bypass Mode: In Bypass mode, FIFO is not operational and it remains empty.

FIFO Mode: Data from measurements of the x-, y- and z- axis are stored in FIFO. When the number of samples in FIFO equals the level specified in the register 0x12 bit[5:0], the watermark interrupt bit is set. FIFO continues to accumulate data until it is full and then stops collecting data. The watermark interrupt continues to occur until the number of samples in FIFO is less than the value stored in the register 0x12 bit [5:0].

Stream Mode: Data from measurements of the x-, y- and z-axis are stored in FIFO. When the number of samples in FIFO equals the level specified in the register 0x12 bit [5:0], the watermark interrupt bit is set. FIFO continues accumulating samples and holds the latest 32 samples from measurements of x-, y- and z- axis, discarding older data as new data arrives; The watermark interrupt continues to occur until the number of samples in FIFO is less than the value stored in register 0x12 bit [5:0].

Trigger Mode: In Trigger mode, FIFO accumulates samples, holding the latest 32 samples from measurements of the x-, y- and z- axis. After a trigger event occurs and an interrupt is sent, FIFO keeps the last n samples (where n is the value specified by the register 0x12 bit [5:0]) and then operates in FIFO mode, collecting new samples only when FIFO is not full.

Note that the FIFO data should be read first because placing the device into bypass mode clears FIFO.

4.4 Interrupt

The SH200L contains six programmable interrupt engines and utilizes output pin INT to signal to an external microprocessor that interrupt event has been sensed. Interrupts can be enabled or disabled by configuring interrupt control registers. The status register will be read by the external microprocessor to check the types of interrupt triggered the interrupt pins.

4.4.1 General features

There are three interrupts modes: automatically clear, latched and non-latched. New data ready interrupt is automatically cleared after a fixed time. Other interrupts can be configured as latched (0x13 bit[6]to ‘0’)or non-latched(0x13 bit[6]to ‘1’) modes. Non-latched interrupts will be cleared after a defined period of time (by setting register 0x1E). For latched interrupts, there are two ways to clear the interrupts: random read clear (0x13 bit [4] to ‘1’) or status read clear (0x13 bit [4] to ‘0’).

The interrupt pins can be set as either open-drain output or push-pull output by configuring register 0x13 bits [5]. When setting register 0x13 bit [5] to '1', the output pin is open-drain output; the output pin is push-pull output if set register 0x13 bit [5]to '0'. The active level of interrupt pins is determined by register 0x13 bit [7], when register 0x13 bit [7] is '1'('0'), the active level of interrupt pins is active high(low).

4.4.2 New data interrupt

The new data interrupt is generated after a new set of data stored in the data register. The interrupt is automatically cleared when the next data acquisition cycle starts.
It is enabled (disabled) by writing ´1´ (´0´) to register 0x14bit [5]. The interrupt status is stored in register 0x2Cbit [5].

4.4.3 Activity detection interrupt

Activity detection uses consecutive acceleration values to detect changes in motion. Activity detection interrupt is enabled (disabled) by writing ´1´ (´0´) to register 0x14bit [1]. There are two types of operation for activity detection: ac-coupled and dc-coupled operation. By writing '1' ('0') to register 0x1Bbit [7], ac-coupled (dc-coupled) operation is selected.

In dc-coupled operation, the current acceleration magnitude is compared directly with register 0x17 to determine whether activity is detected.

In ac-coupled operation for activity detection, the acceleration value at the start of activity detection is taken as a reference value. New samples of acceleration are then compared to this reference value, and if the magnitude of the difference exceeds the register 0x17 value, then activity is detected.

The activity interrupt is generated only after a predefined number of consecutive acceleration values exceed the register 0x17 value. The number is set by the register 0x19.

The activity detection threshold is defined by the register 0x17. The meaning of register 0x17 depends on the range setting. 1 LSB of register 0x17 corresponds to 8 mg in 4g-range, 16 mg in 8g-range, and 32 mg in 16g-range.

Each axis can be individually selected to participate in detecting activity. The axis participates the activity detection is determined by register 0x1Bbit [6:4]. A setting of 0 excludes the selected axis from participation. If all axes are excluded, the function is disabled. For activity detection, all participating axes are logically OR'ed, causing the activity function to trigger when any of the participating axes exceeds the threshold for register 0x19 consecutive number of samples.

The interrupt status is stored in register 0x2Cbit [1]. The activity interrupt supplies additional information about the detected activity. The axis which triggered the interrupt is given by that one of register 0x2D bit [6:4] that contains a value of ´1´. The sign of the triggering slope is

held in register 0x2D bit [7] until the interrupt is retriggered. If register 0x2D bit[7] = ´0´ (´1´), the sign is positive (negative).

Activity detection cannot be enabled when inactivity detection is enabled.

4.4.4 Inactivity detection interrupt

Inactivity detection uses consecutive acceleration values to detect lack of motion. Inactivity detection interrupt is enabled (disabled) by writing ´1´ (´0´) to register 0x14 bit [0].There are two types of operation for inactivity detection: ac-coupled and dc-coupled operation. By writing '1' ('0') to register 0x1B bit[3], ac-coupled (dc-coupled) operation is selected.

In dc-coupled operation, the current acceleration magnitude is compared directly with register 0x18 to determine whether inactivity is detected.

In ac-coupled operation for inactivity detection, the acceleration value at the start of activity detection is taken as a reference value. New samples of acceleration are then compared to this reference value, and if the magnitude of the difference is less than the register 0x18 value, then inactivity is detected.

The inactivity interrupt is generated only after within a predefined period of time, all participating axis' acceleration values are less than the register 0x18 value. The time is set by the register 0x1A. The time unit is second.

The inactivity detection threshold is defined by the register 0x18. The meaning of register 0x18 depends on the range setting. 1 LSB of register 0x18 corresponds to 8 mg in 4g-range, 16 mg in 8g-range, and 32 mg in 16g-range.

Each axis can be individually selected to participate in detecting inactivity. The axis participates the inactivity detection is determined by register 0x1B bit [2:0]. A setting of 0 excludes the selected axis from participation. If all axes are excluded, the function is disabled. For inactivity detection, all participating axes are logically AND'ed, causing the inactivity function to trigger when all of the participating axes are less than the threshold for at least a period of time specified in register 0x1A.

The interrupt status is stored in register 0x2C bit [0]. The inactivity interrupt supplies additional information about the detected inactivity. The axis which triggered the interrupt is given by register 0x2D bit [6:4] that contains a value of ´1´. The sign of the triggering slope is held in register 0x2D bit [7] until the interrupt is retriggered. If register 0x2D bit [7] = ´0´ (´1´), the sign is positive (negative).

Inactivity detection cannot be enabled when activity detection is enabled.

4.4.5 Free-fall detection interrupt

Free-fall detection detects whether the device is falling. If the sum of absolute accelerations of all three axis |acc_x| + |acc_y| + |acc_z| is less than the threshold value set by register 0x1C for longer time than the value is specified in the register 0x1D, free-fall detection interrupt is generated. The free-fall detection interrupt is enabled (disabled) by writing ´1´ (´0´) to register 0x14 bit [2] and the interrupt status is stored in register 0x2C bit [2].

The register 0x1C defines the threshold value. The meaning of register 0x1C depends on the range setting. 1 LSB of register 0x1C corresponds to16 mg in 4g-range, 32 mg in 8g-range, and 64 mg in 16g-range. The sum of absolute acceleration of all axes |acc_x| + |acc_y| + |acc_z| is compared with the value in register 0x1C to determine if a free-fall event occurred.

The register 0x1D defines the time value representing the minimum time that the value of all axes must be less than register 0x1C to generate a free-fall interrupt. The scale factor is 2ms/LSB. A value of 0 may result in undesirable behavior if the free-fall interrupt is enabled. Values between 100 ms and 350 ms (0x14 to 0x46) are recommended.

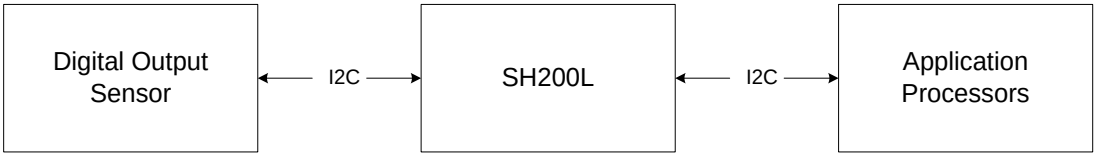
5. Digital Interface

5.1 Interfaces

SH200L has both primary interface (I2C and SPI configurable) and secondary interface. The secondary interface supports I2C only.

The secondary I2C bus allows an external system processor to act as master and directly communicate to the external device connected to the secondary I2C bus pins (MSDA and MSCK). This is useful for configuring the magnetometer along with SH200L to build a 9-DoF solution. In this mode, the secondary I2C bus control logic (third-party accelerometer Interface block) of the SH200L is disabled, and the secondary I2C pins MSDA and MSCK are connected to the main I2C bus through analog switches.

The diagram below shows an application processor can communicate to the digital output sensor connected to SH200L through the Auxiliary IIC bus.



5.2 Primary interface

By default, the SH200L operates in I2C mode. The SH200L interface can also be configurable to operate in an SPI 4-wire configuration. I2C and SPI digital interface share partly the same pins.

5.2.1 Primary interface I2C/SPI protocol selection

The protocol is automatically selected based on the chip select CSB pin behavior after power-up.

AT power-up, SH200L is in I^2C mode. If CSB is connected to VDDIO during power-up and not changed the SH200L interface works in I^2C mode. The interface switches from I2C to SPI mode when a “high” to “low” transition happens on CSB pin.

5.2.2 Primary SPI interface

The SPI interface of the SH200L is compatible with two modes, ‘00’ (CPOL =’0’ and CPHA=’0’) and ‘11’ (CPOL =’1’ and CPHA =’1’). The automatic selection between ‘00’ and ‘11’ is controlled based on the value of SCK after a falling edge of CSB.

The SH200L only supports SPI 4-wire mode. The basic write, read and multiple write, read operations are illustrated in below waveforms.

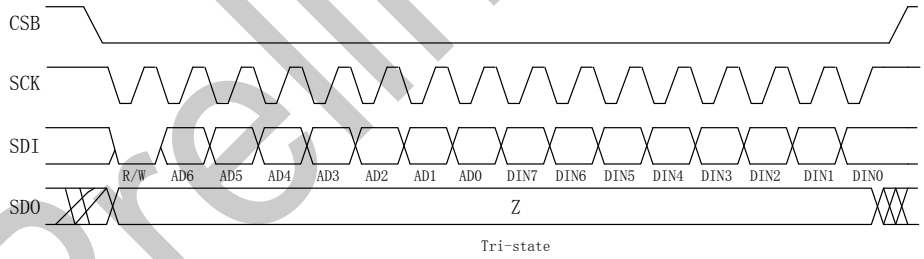


Figure 4-wire SPI write sequence (mode ’11’)

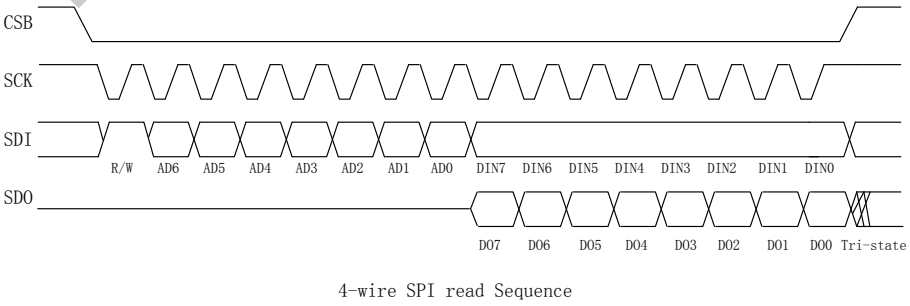
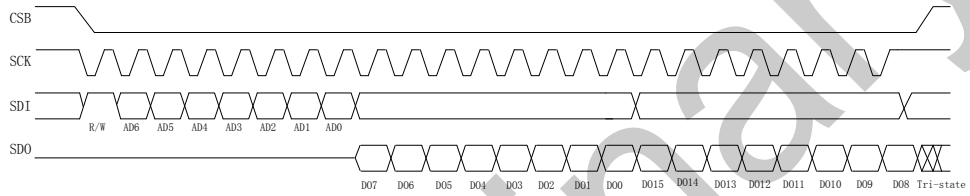


Figure 4-wire SPI read sequence (mode ‘11’)

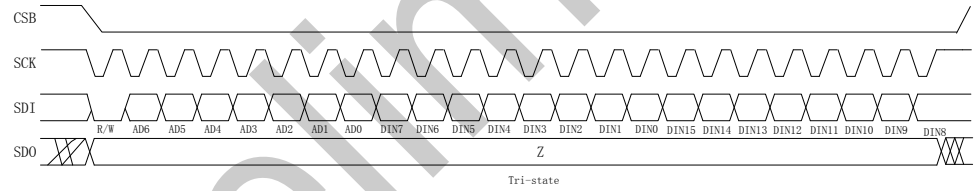
The data bits shown in above waveforms are:
Bit0: Read/Write bit. When ‘0’, the data SDI is written into the chip. When ‘1’, the data SDO are read out from them chip.
Bit1-7: Address AD[6:0].
Bit8-15: When in write mode, these are the data from SDI written into the address AD, when in read mode, these are data read from the address AD.

Multiple read and write operations are done by keeping CSB low and continuing the data transaction and only the first address is written, addresses are automatically incremented internally as long as CSB stays active.

Multiple read and write are shown in figure below:



4-wire SPI Multiple read Sequence



4-wire SPI Multiple write Sequence

5.2.3 Primary I2C interface

The SH200L I2C is a save bus. There are two signals associate with the I2C bus: the serial clock SCL and serial data SDA. The SDA is a bi-directional line used to send and receive data to or from the interface. Both lines must be connected to VDDIO through external pull-up resistors.

The default I2C address of SH200L is 0b1101100. It is used if the SDO pin is pulled to ‘GND’. The alternative address 0b1101101 is selected by pulling the SDO to VDDIO.

The I2C bus is implemented with fast mode (400 KHz) and the standard mode.

Data transfer with acknowledge is mandatory. The transmitter must release the SDA line during the acknowledge pulse. The receiver then must pull the SDA line ‘low’ so it remains

low during the high period of the acknowledge clock pulse. A receiver which has been addressed is obliged to generate an acknowledge after each byte of data received.

The transaction begins with a start (ST) condition generated by master, followed by 7 bits slave (SAD) address and 1 read/write bit, then the master sends the one byte register address (RAD). If it is a read operation, a repeated start (SR) condition must be issued after the register address byte. If it is a write operation, the master will transmit data which will be written into the register addressed by register address byte. The slave sends out slave acknowledge condition (ACK) after the slave address issued by master matches its slave address, and after master sends out register address and after receives data byte written by master. The master must assert master acknowledge condition (MACK) after receives data read from slave.

Data are transferred in byte format with MSB sent out first. The number of bytes transferred is unlimited until no master acknowledge (MNACK) condition asserted by master for read operation, or when master issues stop condition for write operation.

Master	ST	SAD + W		RADR		DATA		SP
Slave			ACK		ACK		ACK	

I2C single byte write

Master	ST	SAD + W		RADR		RS	SAD + R			MNACK	SP
Slave			ACK		ACK			ACK	DATA		

I2C single byte read

Master	ST	SAD + W		RADR		DATA		DATA		SP
Slave			ACK		ACK		ACK		ACK	

I2C multiple bytes write

Master	ST	SAD + W		RADR		RS	SAD + R			MACK		MNACK	SP
Slave			ACK		ACK			ACK	DATA		DATA		

I2C multiple bytes read

6. Register Map and Description

The register map of SH200L is listed below:

6.1 Accelerometer X-Axis data low byte

Address: 0x00
Mode: Read only
Description: bit[7:0] of X-axis of accelerometer data.

Bit	Default	Register definition
7	0	The low 8 bits of Accelerometer X-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.2 Accelerometer X-Axis data high byte

Address: 0x01
Mode: Read only
Description: bit[15:8] of X-axis of accelerometer data.

Bit	Default	Register definition
7	0	The high 8 bits of Accelerometer X-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.3 Accelerometer Y-Axis data low byte

Address: 0x02
Mode: Read only

Description: bit[7:0] of Y-axis of accelerometer data.

Bit	Default	Register definition
7	0	The low 8 bits of Accelerometer Y-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.4 Accelerometer Y-Axis data high byte

Address: 0x03
Mode: Read only
Description: bit[15:8] of Y-axis of accelerometer data.

Bit	Default	Register definition
7	0	The high 8 bits of Accelerometer Y-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.5 Accelerometer Z-Axis data low byte

Address: 0x04
Mode: Read only
Description: bit[7:0] of Z-axis of accelerometer data.

Bit	Default	Register definition
7	0	The low 8 bits of Accelerometer Z-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	

1	0	
0	0	

6.6 Accelerometer Z-Axis data high byte

Address: 0x05
Mode: Read only
Description: bit[15:8] of Z-axis of accelerometer data.

Bit	Default	Register definition
7	0	The high 8 bits of Accelerometer Z-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.7 Gyroscope X-Axis data low byte

Address: 0x06
Mode: Read only
Description: bit[7:0] of X-axis of gyroscope data.

Bit	Default	Register definition
7	0	The low 8 bits of Gyroscope X-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.8 Gyroscope X-Axis data high byte

Address: 0x07

Mode: Read only

Description: bit[15:8] of X-axis of gyroscope data.

Bit	Default	Register definition
7	0	The high 8 bits of Gyroscope X-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.9 Gyroscope Y-Axis data low byte

Address: 0x08

Mode: Read only

Description: bit[7:0] of Y-axis of gyroscope data.

Bit	Default	Register definition
7	0	The low 8 bits of Gyroscope Y-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.10 Gyroscope Y-Axis data high byte

Address: 0x09

Mode: Read only

Description: bit[15:8] of Y-axis of gyroscope data.

Bit	Default	Register definition
7	0	The high 8 bits of Gyroscope Y-Axis Data.
6	0	
5	0	
4	0	

3	0	
2	0	
1	0	
0	0	

6.11 Gyroscope Z-Axis data low byte

Address: 0x0A
Mode: Read only
Description: bit[7:0] of Z-axis of gyroscope data.

Bit	Default	Register definition
7	0	The low 8 bits of Gyroscope Z-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.12 Gyroscope Z-Axis data high byte

Address: 0x0B
Mode: Read only
Description: bit[15:8] of Z-axis of gyroscope data.

Bit	Default	Register definition
7	0	The high 8 bits of Gyroscope Z-Axis Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.13 Temperature data low byte

Address: 0x0C
Mode: Read only
Description: bit[7:0] of temperature data.

Bit	Default	Register definition
7	0	The low 8 bits of Temperature Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.14 Temperature data high byte

Address: 0x0D
Mode: Read only
Description: bit[15:8] of temperature data.

Bit	Default	Register definition
7	0	The high 8 bits of Temperature Data.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.15 Accelerometer configuration

Address: 0x0E
Mode: read/write
Description: configuration register of accelerometer

Bit	Default	Register definition

7	0	1: ACC HPF bypass, 0: ACC HPF valid
6	0	ACC filter clock selector. 1: clock from ADC, 0: internal 1MHz clock
5	0	1: Digital part PDN, 0: normal mode
4	0	ACC output data rate, when bit2 = 0: 00: 1024 Hz 01: 512 Hz 10: 256 Hz 11: 128Hz ACC output data rate, when bit2 = 1: 00: 64 Hz 01: 32 Hz 10: 16 Hz 11: 8Hz
3	0	
2	0	1: Low power mode, ACC sampling rate Fs = 125KHz. ACC filter should be disabled before switch to this mode. 0: normal mode
1	0	1: dither is enabled. 0: dither is disabled.
0	0	1: Accelerator(ACC) filter is enabled. 0: ACC filter is disabled.

6.16 Gyroscope configuration

Address: 0x0F
Mode: read/write
Description: configuration register of gyroscope

Bit	Default	Register definition
7	0	0: Normal mode. 1: auto power down GYRO when ACC goes to InActive.
6	0	Reserved
5	0	
4	0	1: GYRO HPF bypass, 0: GYRO HPF valid
3	0	GYRO output data rate will be: 000: 1000Hz, 001: 500Hz, 010: 250Hz, 011: 31.25Hz 100: 8KHz, 101: 16KHz ,
2	0	
1	0	

		110: 32KHz, 111: Reserved
0	0	1: GYRO filter is enabled. 0: GYRO filter is disabled.

6.17 GYRO configuration 1

Address: 0x11
Mode: Read/write
Description: configuration of gyroscope

<table>
<tr><th>Bit</th><th>Default</th><th>Register definition</th></tr>
<tr><td>7</td><td>0</td><td rowspan="2">reserved</td></tr>
<tr><td>6</td><td>0</td></tr>
<tr><td>5</td><td>0</td><td rowspan="2">00: reserved
01: Get data from GYRO HPF
10: Get data from GYRO IIR Filter.
11: reserved</td></tr>
<tr><td>4</td><td>0</td></tr>
<tr><td>3</td><td>0</td><td rowspan="4">DLPF setting.
Low pass filter band width table:
<table>
<tr><td rowspan="2">DLPF</td><td colspan="7">Digital low pass filter bandwidth (Hz)</td></tr>
<tr><td>1000</td><td>500</td><td>250</td><td>31.25</td><td>8K</td><td>16K</td><td>32K</td></tr>
<tr><td>0</td><td>250</td><td>125</td><td>62.5</td><td>7.8125</td><td></td><td></td><td></td></tr>
<tr><td>1</td><td>200</td><td>100</td><td>50</td><td>6.25</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>100</td><td>50</td><td>25</td><td>3.125</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>50</td><td>25</td><td>12.5</td><td>1.5625</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>25</td><td>12.5</td><td>6.25</td><td>0.78125</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>15</td><td>7.5</td><td>3.75</td><td>0.46875</td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>10</td><td>5</td><td>2.5</td><td>0.3125</td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>5</td><td>2.5</td><td>1.25</td><td>0.15625</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td></td><td></td><td></td><td>2K</td><td>2K</td><td>2K</td></tr>
<tr><td>9</td><td></td><td></td><td></td><td></td><td></td><td>4K</td><td>4K</td></tr>
<tr><td>10</td><td></td><td></td><td></td><td></td><td></td><td></td><td>8K</td></tr>
</table></td></tr>
<tr><td>2</td><td>0</td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

6.18 FIFO configuration

Address: 0x12
Mode: Read/write
Description: configuration of FIFO

Bit	Default	Register definition
7	0	Buffer mode selector. 00: No Buffer Mode; 01: FIFO mode 10: Stream Mode; 11: Trigger Mode
6	0	
5	0	Hold Level for Trigger Mode. Water Mark level for FIFO mode.
4	0	
3	0	
2	0	
1	0	
0	0	

6.19 Interrupt configuration

Address: 0x13
Mode: Read/write
Description: configuration of interrupt

Bit	Default	Register definition
7	0	0: INT output is active high. 1: INT output is active low.
6	0	0: interrupt output is latched. 1: interrupt output is non-latched.
5	0	0: Pin INT is normal output pad 1: Pin INT is open-drain pad
4	0	1: any register read operation will clear interrupt. 0: interrupt status register read will clear interrupt.
3	0	1: any register read will clear ACT interrupt. 0: INT status register read will clear ACT interrupt.
2	0	Reserved
1	0	
0	0	

6.20 Interrupt enable

Address: 0x14
Mode: Read/write
Description: configuration of interrupt

Bit	Default	Register definition
7	0	Reserved

6	0	
5	0	1: GYRO data ready interrupt enable 0: GYRO data ready interrupt disable
4	0	1: GYRO watermark interrupt enable 0: GYRO Watermark interrupt disable
3	0	1: ACC watermark interrupt enable 0: ACC watermark interrupt disable
2	0	1: Free-Fall interrupt enable 0: Free-Fall interrupt disable
1	0	1: Activityinterrupt enable 0: Activity interrupt disable
0	0	1: In-Activityinterrupt enable 0: In-Activity interrupt disable

6.21 Accelerometer data format

Address: 0x16
Mode: Read/write
Description: configuration of accelerometer data format

Bit	Default	Register definition
7	0	Reserved
6	0	
5	0	
4	0	Reserved
3	0	Reserved
2	0	Link ACT/In-ACT status. 0: one time ACT/In-ACT will trigger INT no matter what previous status is. 1: if the previous status is activity, two times In-ACT are needed to generate In-ACT interrupt. If the previous status is inactivity, two times ACT are needed to generate ACT interrupt.
1	0	ACC full scale range. 00: 4G 01: 8G 10: 16G 11: Reserved
0	0	

6.22 ACT thresh

Address: 0x17
Mode: Read/write
Description: configuration of activity interrupt threshold

Bit	Default	Register definition
7	0	The threshold value for detecting activity. The threshold value of activity event detection is: ACT thresh *8 mg in 4g-range, ACT thresh *16 mg in 8g-range, ACT thresh * 32 mg in 16g-range.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.23 InACT thresh

Address: 0x18
Mode: Read/write
Description: configuration of inactivity interrupt threshold

Bit	Default	Register definition
7	0	The threshold value for detecting inactivity. The threshold value of in-activity event detection is: InACT thresh *8 mg in 4g-range, InACT thresh *16 mg in 8g-range, InACT thresh * 32 mg in 16g-range.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.24 ACT time thresh

Address: 0x19
Mode: Read/write
Description: configuration of the amount of samples that acceleration must be greater than the value in the register 0x17 for activity to be declared

Bit	Default	Register definition
7	0	The amount of samples that acceleration must be greater than the value in the register 0x17 for activity to be declared.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.25 InACT time thresh

Address: 0x1A
Mode: Read/write
Description: configuration of the amount of time that acceleration must be less than the value in the register 0x18 for inactivity to be declared.

Bit	Default	Register definition
7	0	The amount of time that acceleration must be less than the value in the register 0x18 for inactivity to be declared. The Time of InACT time thresh is in unit of second.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.26 ACT-InACT configuration

Address: 0x1B
Mode: Read/write
Description: configuration of the activity and inactivity interrupt control.

Bit	Default	Register definition
7	0	1: Act interrupt detect by ac data 0: Act interrupt detect by dc data
6	0	1: X-axis ACT interrupt enable. 0: X-axis ACT interrupt disable.
5	0	1: Y-axis ACT interrupt enable.

		0: Y-axis ACT interrupt disable.
4	0	1: Z-axis ACT interrupt enable. 0: Z-axis ACT interrupt disable.
3	0	1: InACT interrupt detect by ac data 0: InACT interrupt detect by dc data
2	0	1: X-axis InACT interrupt enable. 0: X-axis InACT interrupt disable.
1	0	1: Y-axis InACT interrupt enable. 0: Y-axis InACT interrupt disable.
0	0	1: Z-axis InACT interrupt enable. 0: Z-axis InACT interrupt disable.

6.27 Free-Fall threshold

Address: 0x1C
Mode: Read/write
Description: configurations of the threshold of free-fall interrupt.

Bit	Default	Register definition
7	0	Free-Fall threshold. The threshold value of Free-Fall event detection is: ThreshFF *16 mg in 4g-range, ThreshFF *32 mg in 8g-range, ThreshFF *64 mg in 16g-range,
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.28 Free-Fall Time Threshold

Address: 0x1D
Mode: Read/write
Description: configurations of minimum time that the value of all axes must be less than the value in register 0x1C to generate a free-fall interrupt.

Bit	Default	Register definition
7	0	Minimum time that the value of all axes must be less than the value in register 0x1C to generate a free-fall interrupt. The time required to trigger free-fall interrupt is Time_FF * 2
6	0	
5	0	
4	0	

3	0	milliseconds.
2	0	
1	0	
0	0	

6.29 Interrupt count limit

Address: 0x1E
Mode: Read/write
Description: configuration of the interrupt pulse width when 0x13 bit 6 is set to '1'.

Bit	Default	Register definition
7	0	INT Count Limit. When register 0x13 bit 6 is high, INT will be auto-cleared when interrupt last time is more than defined in this register. This counter is based on 250Hz clock.
6	0	
5	0	
4	0	
3	0	
2	0	
1	0	
0	0	

6.30 Gyroscope full scale range

Address: 0x2B
Mode: Read/write
Description: configuration of the full scale range of gyroscope

Bit	Default	Register definition
7	0	Reserved
6	0	
5	0	
4	0	
3	0	
2	0	Precision[2:0]: Full Scale Range
1	0	000 2000
0	0	001 1000
		010 500
		011 250
		100 125
		Others reserved

6.31 Interrupt status

Address: 0x2C
Mode: Read only
Description: interrupt status register

Bit	Default	Register definition
7	0	0
6	0	0
5	0	1: Data is Ready 0: Data is not Ready
4	0	1: the valid data in gyroscope FIFO exceeds the watermark value when FIFO mode. 0: the valid data in gyroscope FIFO doesn't exceed the watermark value when FIFO mode.
3	0	1: the valid data in accelerometer FIFO exceeds the watermark value when FIFO mode. 0: the valid data in accelerometer FIFO doesn't exceed the watermark value when FIFO mode.
2	0	1: Free-Fall interrupt has been detected. 0: Free-Fall interrupt has not been detected.
1	0	1: activity interrupt has been detected. 0: activity interrupt has not been detected.
0	0	1: in-activity interrupt has been detected. 0: in-activity occurred has not been detected.

6.32 Act-InACT status

Address: 0x2D
Mode: Read only
Description: activity and inactivity interrupts status and sign for each axis of accelerometer.

Bit	Default	Register definition
7	0	activity or inactivity Sign
6	0	activity or inactivity interrupt has been detected in accelerometer X-axis
5	0	activity or inactivity interrupt has been detected in accelerometer Y-axis
4	0	activity or inactivity interrupt has been detected in accelerometer Z-axis

3	0	0
2	0	0
1	0	0
0	0	0

6.33 accelerometer FIFO Status

Address: 0x2E
Mode: Read only
Description: accelerometer FIFO status registers

Bit	Default	Register definition
7	0	1: Accelerometer FIFO is Full 0: Accelerometer FIFO is not Full
6	0	1: Accelerometer FIFO is Empty 0: Accelerometer FIFO is not empty.
5	0	Accelerometer FIFO valid data samples
4	0	
3	0	
2	0	
1	0	
0	0	

6.34 Gyroscope FIFO Status

Address: 0x2F
Mode: Read only
Description: gyroscope FIFO status registers

Bit	Default	Register definition
7	0	1: gyroscope FIFO is Full. 0: gyroscope FIFO is not full.
6	0	1: gyroscope FIFO is Empty 0: gyroscope FIFO is not Empty.
5	0	gyroscope FIFO valid data samples.
4	0	
3	0	
2	0	
1	0	
0	0	

6.35 chip ID

Address: 0x30
Mode: Read only
Description: chip ID of SH200L

Bit	Default	Register definition
7	0	8'b0001_1000
6	0	
5	0	
4	1	
3	1	
2	0	
1	0	
0	0	

7 Application Information

7.1 Orientation of Axes

The diagram below shows the orientation of the axes of sensitivity and the polarity of rotation. Note the pin 1 marker in the figure.

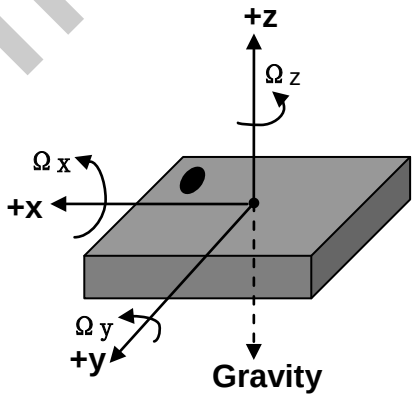


Figure 7.1.Orientation of Axes Sensitivity and Polarity of Rotation

7.2 Typical Application Circuit

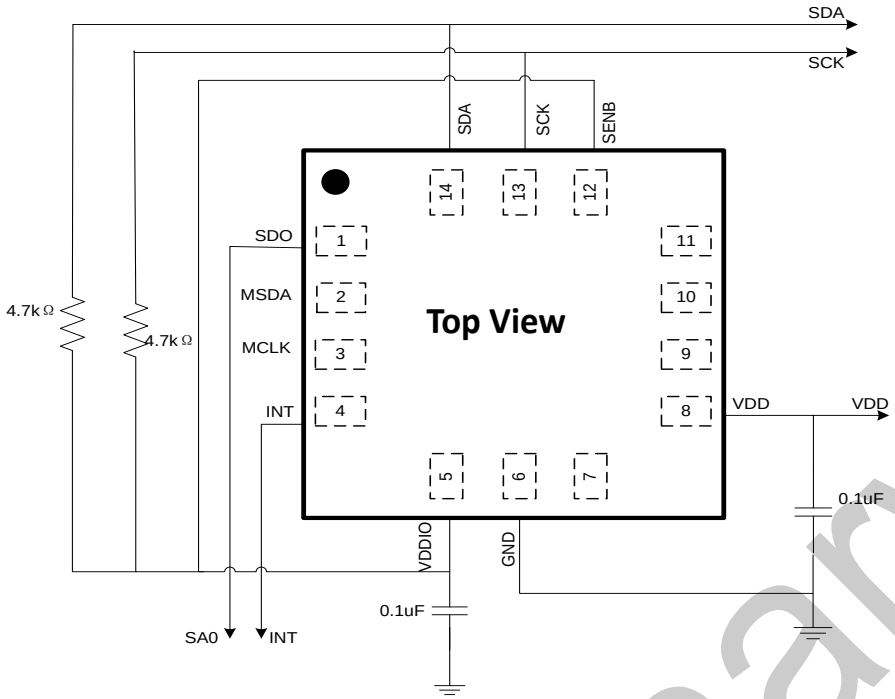


Figure 7.2.1: Reference Application Circuitry using I^{2}C interface

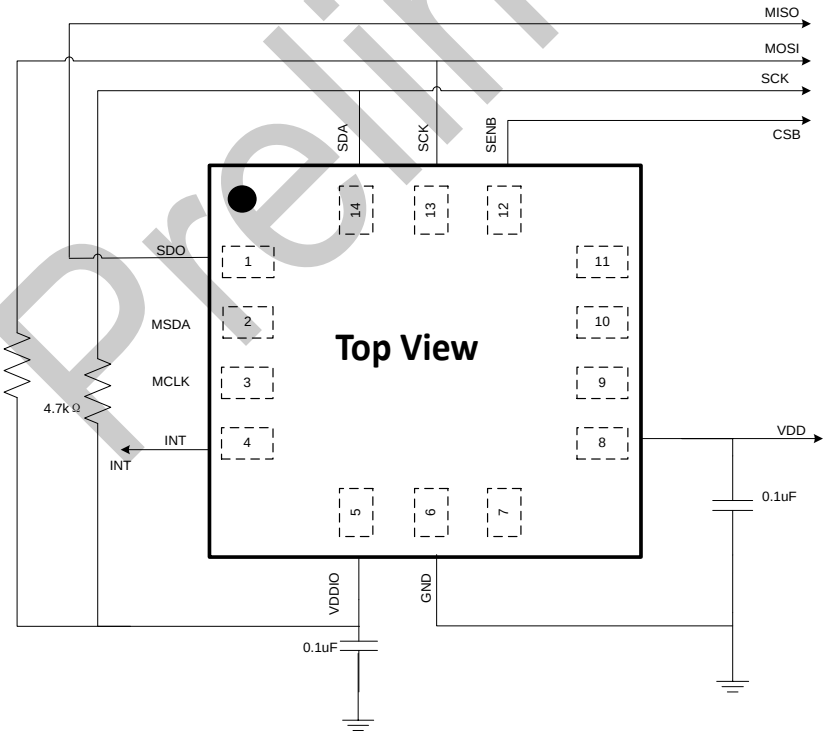


Figure 7.2.2: Reference Application Circuitry using SPI 4-wire interface

7.3 Package Outline Dimensions

7.3.1 LGA Package Outline Dimensions

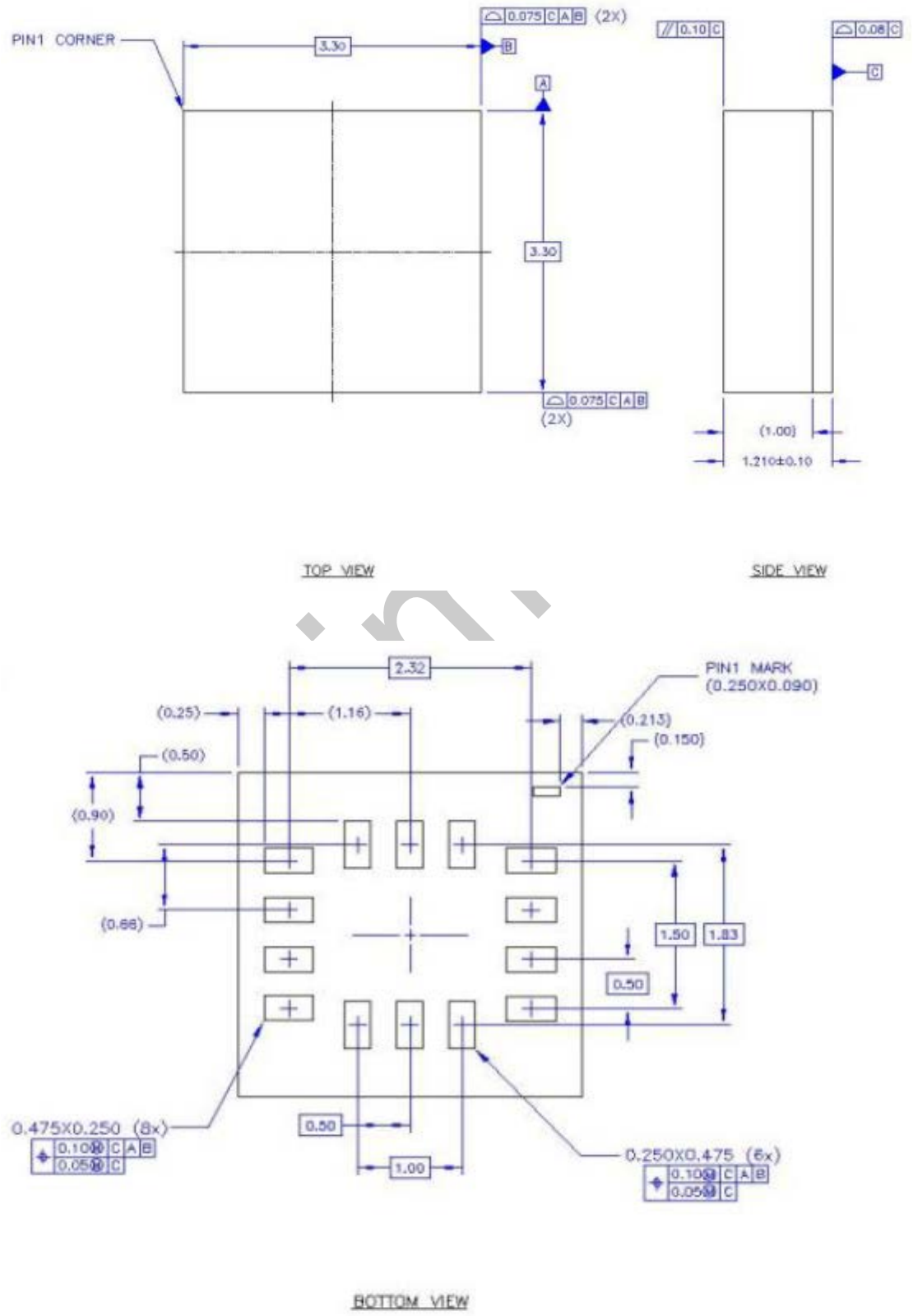


Figure 7.3.1: LGA Package Outline Dimensions

7.4 Package laser Mark

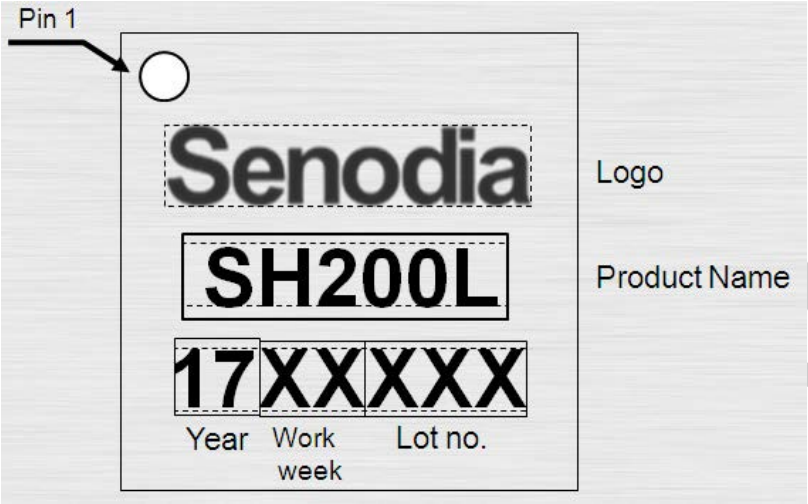


Figure 7.4.1: LGA Package laser Mark

7.5 Packing of the Chips

SH200L packing in Tape & Reel (7”), and meet EIA-481 standard.

7.5.1 Packing direction

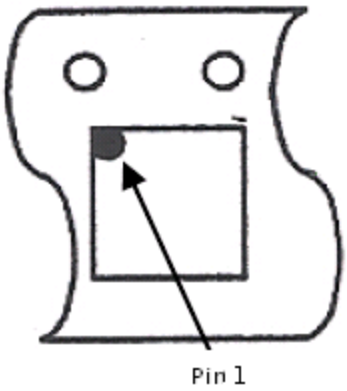


Figure 7.5.1: Packing direction

7.6 Labels

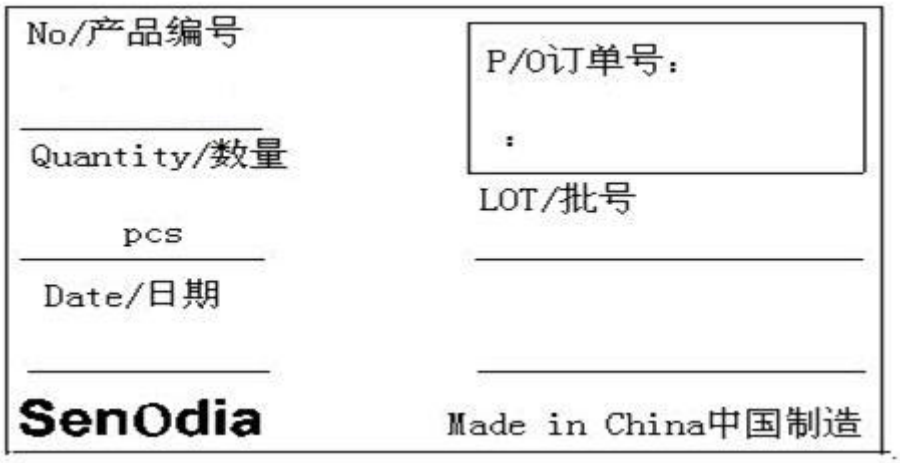


Fig. 7.6: Label sample

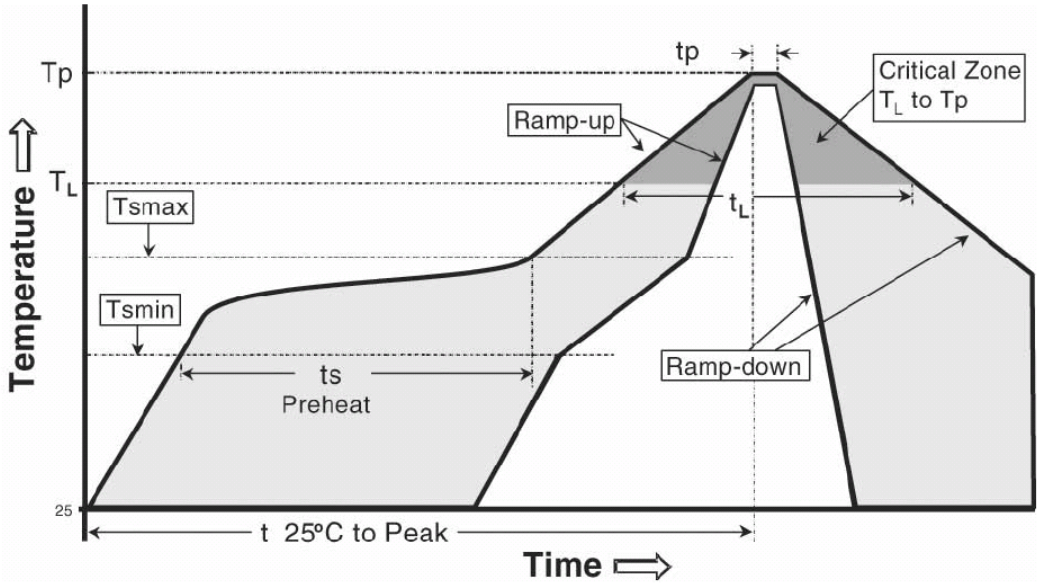
7.7 Packing

Fig. 7.7: packing of product

7.8 Solder Reflow Curve

Solder Reflow curve follows IPC/JEDEC J-STD-020 Pb-free standards.

7.8.1 Solder Reflow curve



Profile Feature	Pb-Free Assembly
Average ramp-up rate (Tsmax to Tp)	3° C/second max.
Preheat - Temperature Min (Ts_{min}) - Temperature Max (Ts_{max}) - Time (Ts_{min} to Ts_{max}) (ts)	 150 °C 200 °C 60-180 seconds
Time maintained above: - Temperature (T_L) - Time (t_L)	 217 °C 60-150 seconds
Peak Temperature (Tp)	260 °C
Time within 5°C of actual Peak Temperature $(tp)^2$	20-40 seconds
Ramp-down Rate	6 °C/second max.
Time 25°C to Peak Temperature	8 minutes max.

Figure 7.8: Solder Reflow curve

7.9 Storage condition

The storage condition follows JEDEC J-STD-020, MSL3.

8. Reliability

8.1 Reliability standard:

SH200L reliability test plan follows JEDEC 47I standards, “Stress-Test-Driven Qualification of Integrated Circuits”.

9. Environment Compliant

SH200L pass SGS certification，compliant with RoHS standards.

10 Revision History

Date	Revision	Changes
2017-7-28	1.0	Preliminary version.

11. Disclaimer

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