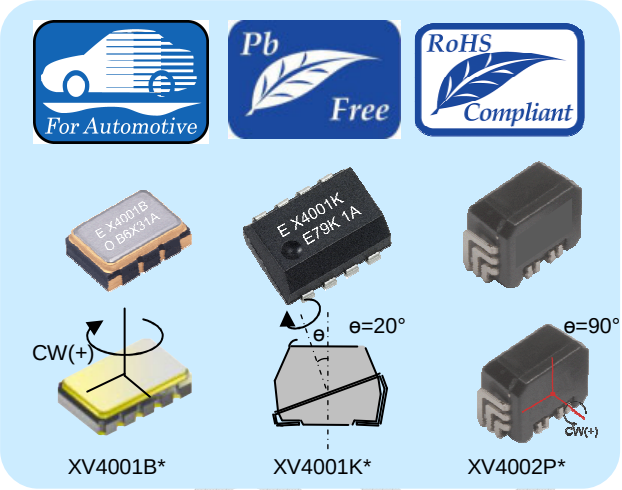
High-Performance Yaw Rate Gyro Sensor :XV4001B*/K*&XV4002P*

Under Development

Features

- SPI or I²C serial interface
- Angular rate output (16bit)
- Temperature output (11bit)
- Self-testing function
- Supply voltage (3.3V±0.3V)
- High bias stability over temperature and time
- Rate range : ±70 °/s
- Small size package
- Inclined angle 20° (XV4001K*)
- Inclined angle 90° (XV4002P*)
- Pb free
- Complies with EU RoHS directive.



Applications

- Dead Reckoning for Car Navigation System
- Dead Reckoning for GPS Module etc…

Description

The XV4000 series is a high-performance yaw rate gyro sensor. Using EPSON's proprietary quartz-based MEMS (QMEMS) process, the XV4000 series delivers superior stability in a small package.

SPI or I2C serial interface is available.
It also has self-testing function and sends the response data of DIAG to the Master.*)

The XV4001KC/KD supports 20° tilted sensing and XV4002PC/PD supports 90°tilted sensing from the PCB mounting plane and reduced detection error.

Product Name

Product name	Inclination angle	Serial Interface
XV4001BC	0°	I²C
XV4001BD	0°	SPI
XV4001KC	20°	I²C
XV4001KD	20°	SPI
XV4002PC	90°	I²C
XV4002PD	90°	SPI

* When using the I²C interface, command is needed for the acquisition of DIAG signal.

►Explanation of the mark that are using it for the catalog

Pb Free	►Pb free.
RoHS Compliant	►Complies with EU RoHS directive. *About the products without the Pb-free mark. Contains Pb in products exempted by EU RoHS directive. (Contains Pb in sealing glass, high melting temperature type solder or other.)
For Automotive	►The products have been designed for high reliability applications such as Automotive.

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/Fire work equipment and security equipment
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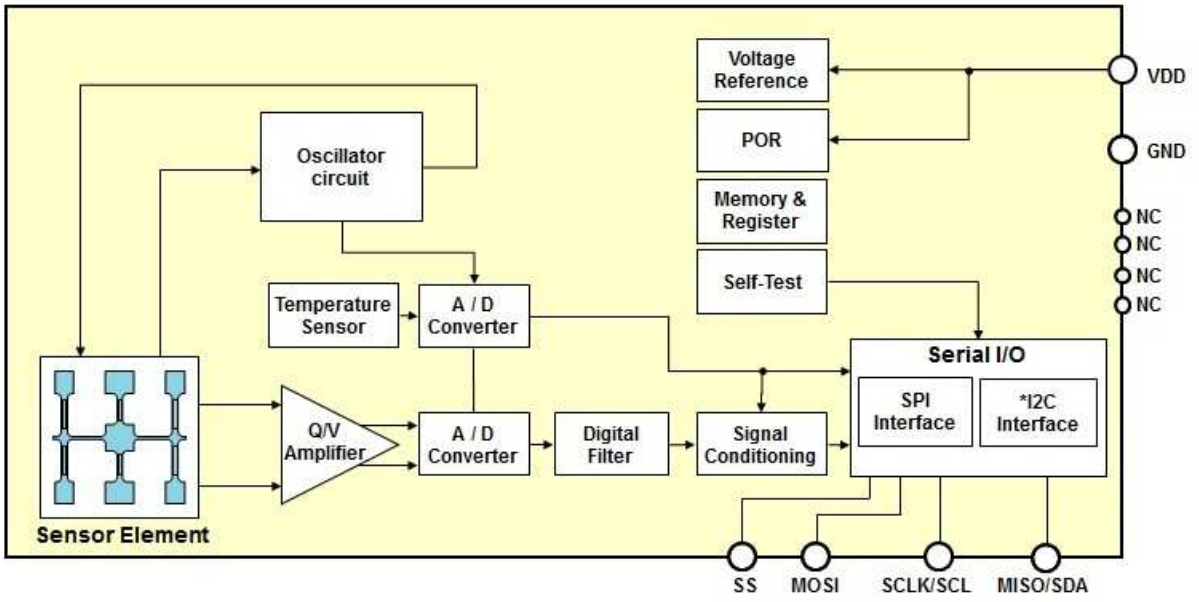
1. Block diagram

1) Functional block diagram



2) Functional explanation

Oscillation circuit

This sensor is driving the sensor element at 50.3kHz (typ.), in order to detect angular rate.

Angular rate output

Output angular data are 16 bit and 2's complements.

Digital filter

Built in the fc=10Hz digital filter.

Temperature sensor

Output temperature data are 11 bit and 2's complements.

Power On Reset

Built in the Power On Reset (henceforth, POR) circuit.

A POR signal required for initialization of a logic circuit at the time of power supply starting is outputted.

Self test

Build in the self test circuit.

A self test implementation result is transmitted in a communication response (DIAG).

Serial I/O

Serial I/O can be correspondence from SPI (4-wire, 3-wire) or I^2C system.

* Correspondence of an I^2C system is attained by setup of the nonvolatile memory at the time of factory shipments.

2. Electrical characteristics

1) Absolute maximum ratings

Parameter	unit	Standard			condition
		Min.	Typ.	Max.	
Supply voltage V_{DD}	V	-0.3		4.0	V_{SS}=GND=0V
Storage temperature	°C	-50		+125	

2) Operating conditions

Parameter	unit	Specifications			condition
		Min.	Typ.	Max.	
Supply voltage V_{DD} *1	V	3.0	3.3	3.6	V_{SS}=GND=0V
Operating temperature	℃	-40		+85	
Refresh rate of angular rate data *2	kHz			3	

*1 Analog power supply and Digital power supply are in common.
*2 We recommend acquiring angular rate output at less than 3 kHz.

3) DC Characteristics

V_{DD} = 3.0～3.6V , V_{SS} = GND = 0V , Ta = -40～+85℃

Parameter	unit	Specifications			condition
		Min.	Typ.	Max.	
Logic input voltage Hi level	V	VDD*0.7			
Logic input voltage Low level	V			VDD*0.3	
Logic output voltage Hi level (Communication terminal)	V	VDD*0.7			Load current 4mA
Logic output voltage Low level (Communication terminal)	V			VDD*0.3	Load current 4mA

4) Characteristics

Please refer to OUT-12-0360 for details.

V_{DD} = 3.3V , V_{SS} = GND = 0V , Ta = -40～+85℃

Parameter	unit	Specifications			condition
		Min.	Typ.	Max.	
Drive frequency	kHz		50.3		
Scale factor	LSB/(°/s)		370		
Scale factor tolerance	%	-1.5		+1.5	Ta=+25 ℃
Scale factor variation with temp.	%	-2.5		+2.5	Ta=+25 ℃ reference
Bias	LSB		0		Ta=+25 ℃
Bias tolerance	°/s	-1.0		+1.0	Ta=+25 ℃
Bias variation with temp.	°/s	-3.0		+3.0	Ta=+25 ℃ reference
Bias short time stability	°/s			T.B.D.	
Bias drift gradient	(°/s)/℃			T.B.D.	
Bias repeatability	°/s			T.B.D.	
Bias drift velocity	(°/s)/min			T.B.D.	
Bias stability 1	°/s		±0.6	T.B.D.	1s～5min after start-up Bias at 1s reference
Bias stability 2	°/s		±0.4	T.B.D.	5min～15min after start-up Bias at 5min reference
Rate range	°/s	-70		70	
Non linearity	%FS	-0.5		+0.5	Ta=+25 ℃ FS= ±60°/s
Frequency characteristic	Hz		10		Gain -3dB bandwidth
Cross axis sensitivity	%	-5		+5	Ta=+25 ℃
Start up time Tsta	ms			500	V_{DD}=3.3V, Ta=+25 ℃
Current consumption	mA		4	T.B.D.	not rotation and not communicating
Output noise	°/s RMS		0.05	T.B.D.	
Vibration Influence	°/s			0.3	2G(10 to 50Hz) 4G(>50 to 500Hz) 2G(>500 to 2000Hz)

5) Temperature sensor

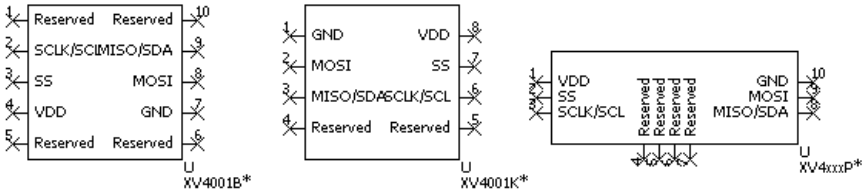
V_{DD} = 3.3V , V_{SS} = GND = 0V , Ta = -40～+85℃

Parameter	unit	Specifications			condition
		Min.	Typ.	Max.	
Output code	LSB		0		Ta=+25 ℃
Temperature output accuracy	℃	-5		5	Ta=+25 ℃
Temperature coefficient	LSB/℃		5.1		

6) Serial Interface

Serial I/F can be selected from 4-wire SPI, 3-wire SPI or I^2C.

I^2C is available non-volatile memory set at factory.
The function and terminal processing in Serial Interface terminal and each communication method are as below.

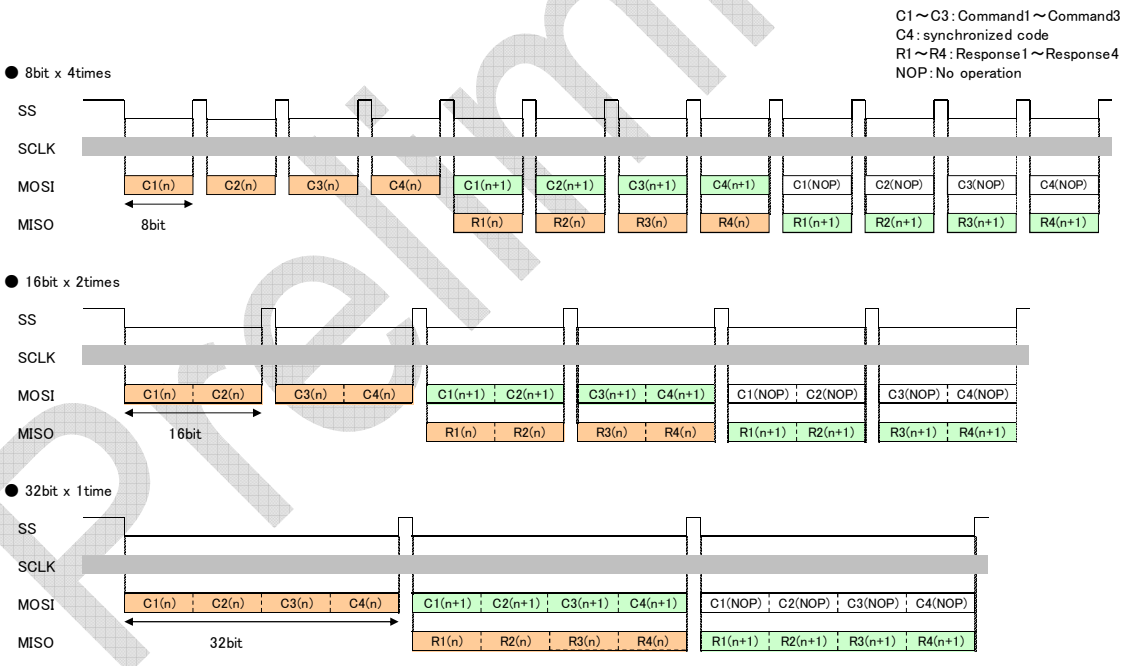


Pin name	4-Wire SPI	3-Wire SPI	I^2C
SCLK/SCL	Clock input pin	Clock input pin	Clock input pin
SS	Chip select input pin	Lo fixed	Hi fixed
MISO/SDA	Data output pin	Data output pin	Data input/output pin
MOSI	Data Input pin.	Data Input pin.	Do not connect

6-1) 4-Wire SPI

(6-1-1) Correspondence frame

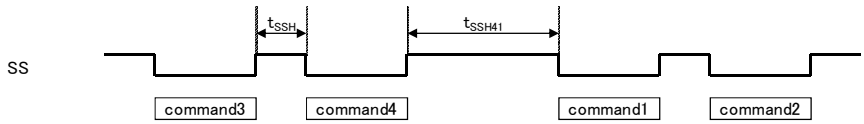
SPI communication command/response is separated by 32bit and can select 8bit X4, 16bit X 2 or 32bit X1.
Each command/response frames are as below;

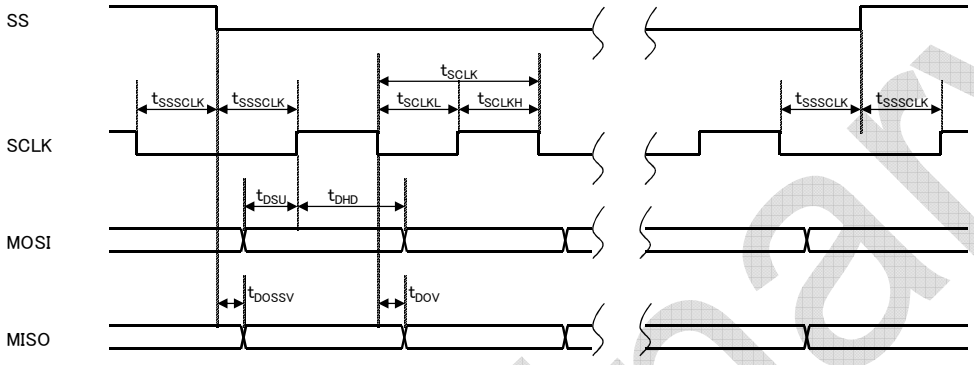


SS=L area becomes effective and the clock and data input of SS=H area are disregarded.

(6-1-2) Timing Chart

According to following condition Max. 10MHz SPI I/F is available.





Symbol	Parameter	Specifications			unit
		Min.	Typ.	Max.	
tSSH	SS H width(command-command)	100			ns
tSSH41	SS H width(command4-command1)	25			µs
tSSSCLK	SCLK before and after SS edge：(between L)	45			ns
tSCLKH	SCLK H width	45			ns
tSCLKL	SCLK L width	45			ns
tSCLK	SCLK cycle	100			ns
tDSU	Input data setup time	25			ns
tDHD	Input data hold time	25			ns
tDOSSV	Output data fixed time(SS fall)			25	ns
tDOV	Output data fixed time(SCLK fall)			25	ns

(6-1-3) Command/response list

Command /response list is as below. Command4 is stable by synchronous discernment code.
Command parameter as below (5-1-4).

Parameter	Command1 (bit31～bit24)	Command2 (bit23～bit16)	Command3 (bit15～bit8)	Command4 (bit7～bit0)
Output angular rate	(48)h	(26)h	(53)h	(58)h
Temperature sensor output	(50)h	(2A)h	(17)h	
Software reset start 1	(1C)h	(4E)h	(67)h	
Software reset start 2	(5C)h	(6E)h	(77)h	
Software reset cancel	(04)h	(42)h	(23)h	
NOP(No Operation)	(30)h	(1A)h	(0F)h	

Parameter	Response1 (bit31～bit24)					Response2 (bit23～bit16)						Response3 (bit15～bit8)								Response4 (bit7～bit0)							
Output angular rate	CEF	DIAG	0	0	ARU	0	1	0	0	1	0	CS4-0	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Temperature sensor output						0	1	0	1	0	0		0	0	0	0	0	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Software reset start 1						0	0	0	1	1	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Software reset start 2						0	1	0	1	1	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Software reset cancel						0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOP(No Operation)						0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CEF : Command error flag. Response "0" in normal case.
Response "1" if input command code is irregular (or wrong)
(Response "H" if synchronous discernment code(Command4) is irregular (or wrong)).

DIAG : Self-test result flag. Response "1" if found internal error.

ARU : Angular rate output renewal flag. Response "1" when rewrite angular rate data and response "0" after output the response for angular rate output command.

CS4-0 : Check-Sum signal consist of 5bit. Check-Sum covers Response1 bit31-24, Response2 bit23-32, Response3 bit15-8 and Resonse4 bit7-0, total 27bits.

(6-1-4)Command details

(1) Angular rate output

Output data are 2's complements. It becomes the 16bit output of mark bit +15bit.

(2) Temperature sensor output

Output data are 2's complements. It becomes the 11bit output of mark bit +10bit.

(3) Software reset

It reset a logic circuit by command.

The sequence of the reset is follows. Please send seven commands with the following turns.

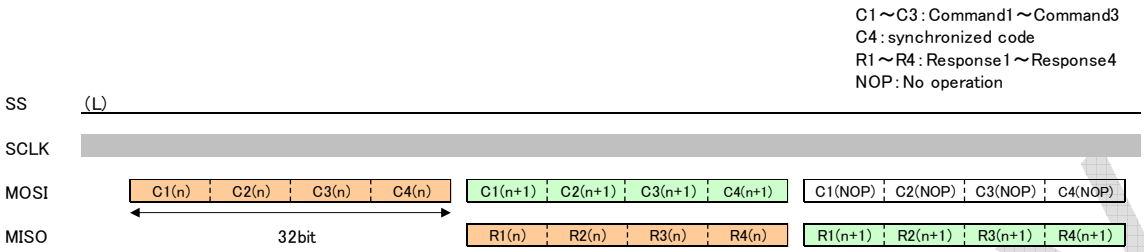
1. "NOP" 2. "Software reset start1" 3. "Software reset start2" 4. "NOP"
5. "Software reset cancel" 6. "NOP" 7. "NOP"

After the software reset command transmission, 300ms is necessary until the next command transmission.

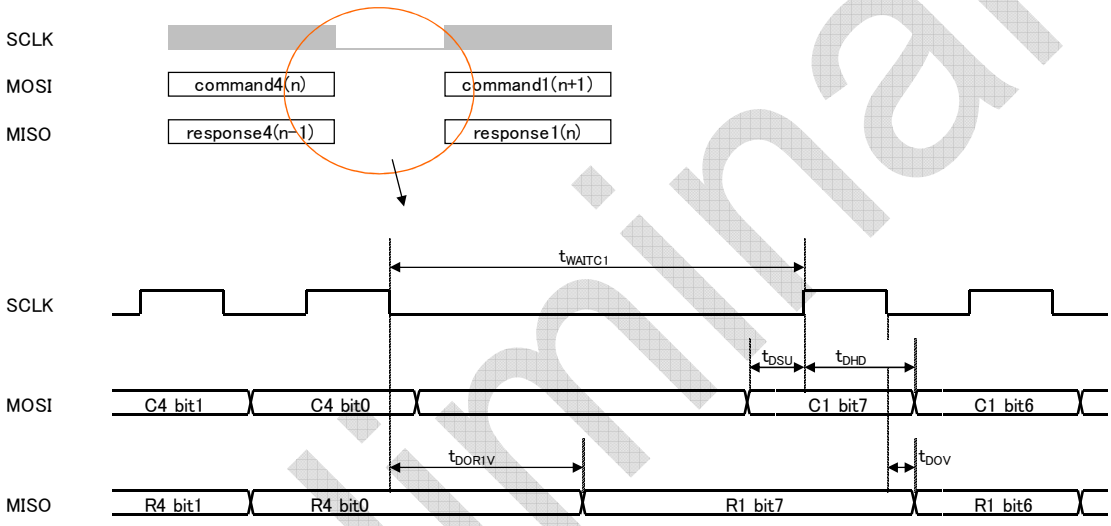
6-2) 3-Wire SPI

(6-2-1) Correspondence frame

3-Wire SPI, please set SS in Low.
3-Wire SPI communication command/response is separated by 32bit only.
Command/response frames is as below;



(6-2-2) Timing Chart



Symbol	Parameter	Specifications			unit
		Min.	Typ.	Max.	
tSCLKH	SCLK H width	45			ns
tSCLKL	SCLK L width	45			ns
tSCLK	SCLK cycle	100			ns
tDSU	Input data setup time	25			ns
tDHD	Input data hold time	25			ns
tDOV	Output data fixed time(SCLK fall)			25	ns
tWAITC1	SCLK wait time(command4-command1)	25			µs
tDOR1V	response1 bit7fixed time(SCLK fall)			20	µs

(6-2-3) Command/response list

The command/response is the same as 4-Wire SPI. Please refer to (5-1-3)

(6-2-4) Command details

The command/response is the same as 4-Wire SPI. Please refer to (5-1-4)

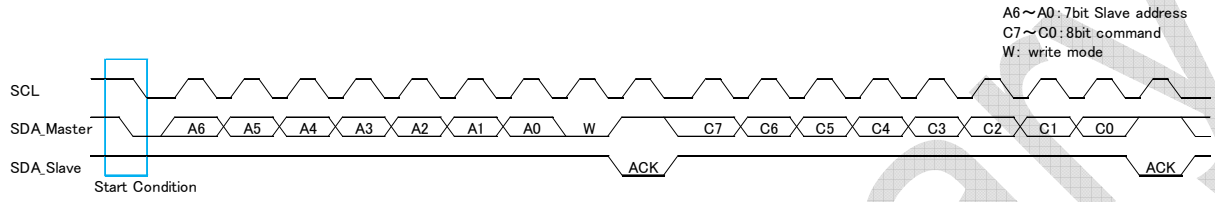
6-3) I²C

In I²C, SCLK terminal are used as SCL (clock terminal) and MISO terminal are used as SDA (data input/output terminal).
SS terminal is fixed to high level. MOSI terminal should not carry out external connection.

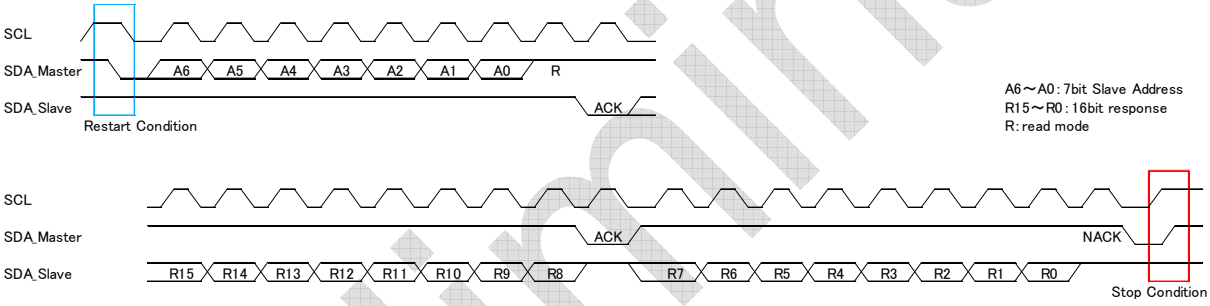
(6-3-1) Correspondence frame

An input-and-output frame is transmitted by 8-bit division. Moreover, the clock for ACK is needed every 8 bits.
Below, the input-and-output sequence from 8-bit command input to 16-bit response output is shown.

・8-bit command input (Start Condition + Slave Address + Write Mode + Command)



・16-bit response output (Restart Condition + Slave Address + Read Mode + Response + Stop Condition)



・A slave address (A6:A0) is (1101000)b. When the address overlaps, it can change into (1101001)b as a reserve. The slave address is set up at the time of factory shipments.

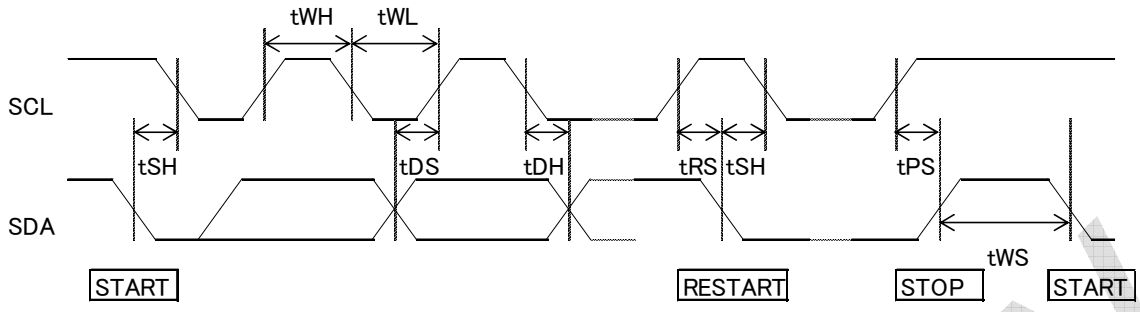
・When beginning I²C communication, it is necessary to publish the start condition from a master. It is realized by setting SDA to low from high, when SCL is high. Moreover, even when transmitting commands continuously to the same slave, the issuance of start condition is needed again. (Restart condition)

・The change of Write/Read is determined by the 1st bit immediately after a slave address input. If it is low, a command input is attained by Write mode, and if it is high, a response output is attained by Read mode.

・When finishing I²C communication, it is necessary to publish stop condition from the master side. This is realized by setting SDA to high from low, when SCL is high. Thereby, the slave device returns to the suspended state.

(6-3-2)Timing Chart

On condition of the following, it corresponds to Fast Mode of maximum speed 400 kbits/s.



Symbol	Parameter	Fast Mode 400kbit/s		unit
		Min.	Max.	
tSCL	SCL Clock Period	2.5	-	µs
tWH	SCL Clock High Time	1.3	-	µs
tWL	SCL Clock Low Time	0.6	-	µs
tDS	SDA Setup Time	100	-	ns
tDH	SDA Hold Time	0	-	µs
tSH	START condition hold time	0.6	-	µs
tRS	Repeated START setup time	0.6	-	µs
tPS	STOP condition setup time	0.6	-	µs
tWS	Between STOP and START condition	1.3	-	µs

(6-3-3) Command/response list

The command / response list of I^{2}C are shown below.

A command input is published by the 8-bit data transfer to the SDA terminal. A response is outputted to the SDA terminal at 8-bit or 16-bit. The master needs to return NACK to the last data byte according to the response data width of each command.

Parameter	Command	Response															
		bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Output angular rate	(25)h	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Temperature sensor output (11bit)	(26)h	0	0	0	0	0	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Self test judging result output	(29)h									0	0	DIAG	*1	*1	*1	*1	*1
Software reset 1	(35)h																
Software reset 2	(36)h																
Software reset 3	(37)h																
Software reset 4	(38)h																
Software reset 5	(39)h																

DIAG：Self test results flag. "1" is returned at the time of internal failure detection.

*1: These data bit is not used, please ignore it.

(6-3-4) Command details

(1)Angular rate output

Output data are 2's complements. It becomes the 16bit output of mark bit +15bit.

(2) Temperature sensor output

Output data are 2's complements. It becomes the 11bit output of mark bit +10bit.

(3)Self test judging result output

The judgment result (DIAG) of the self test is outputted. "1" is returned at the time of internal failure detection. A response is outputted at 8 bits.

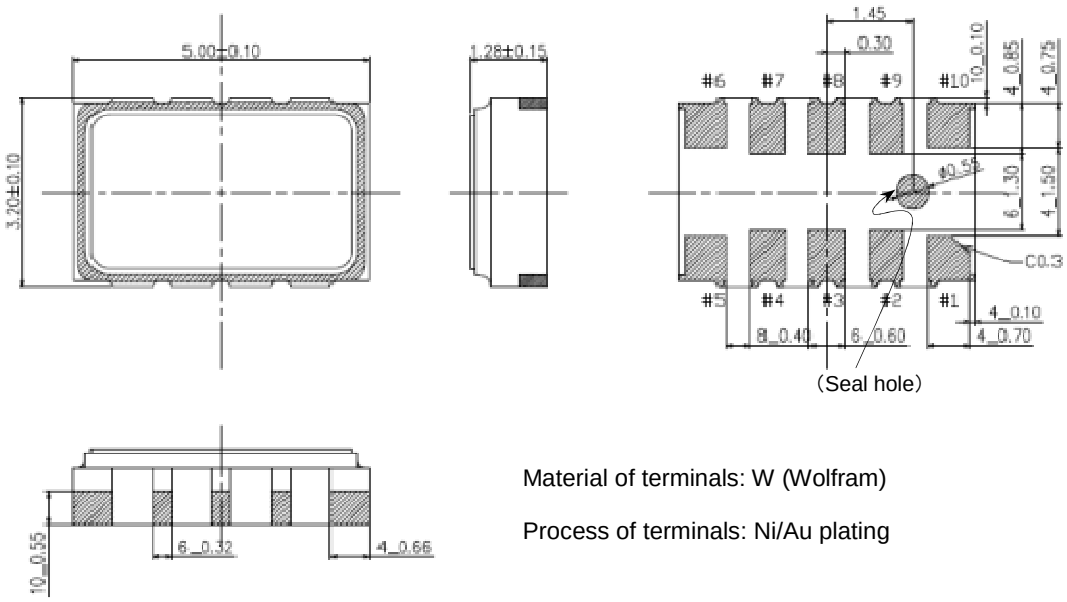
(4)Software reset

An internal logic circuit is reset by a command. To apply reset, it is necessary to transmit the command from the software reset 1 to the software reset 5 continuously in order after transmitting a receiving flag. A reset action is canceled immediately after command reception of the software reset 5. Since it finishes transmitting a series of reset commands, 300ms is needed to new command sending out. Moreover, the response to this command does not occur.

3. Outline

2-1) Outline dimensions and Pin information

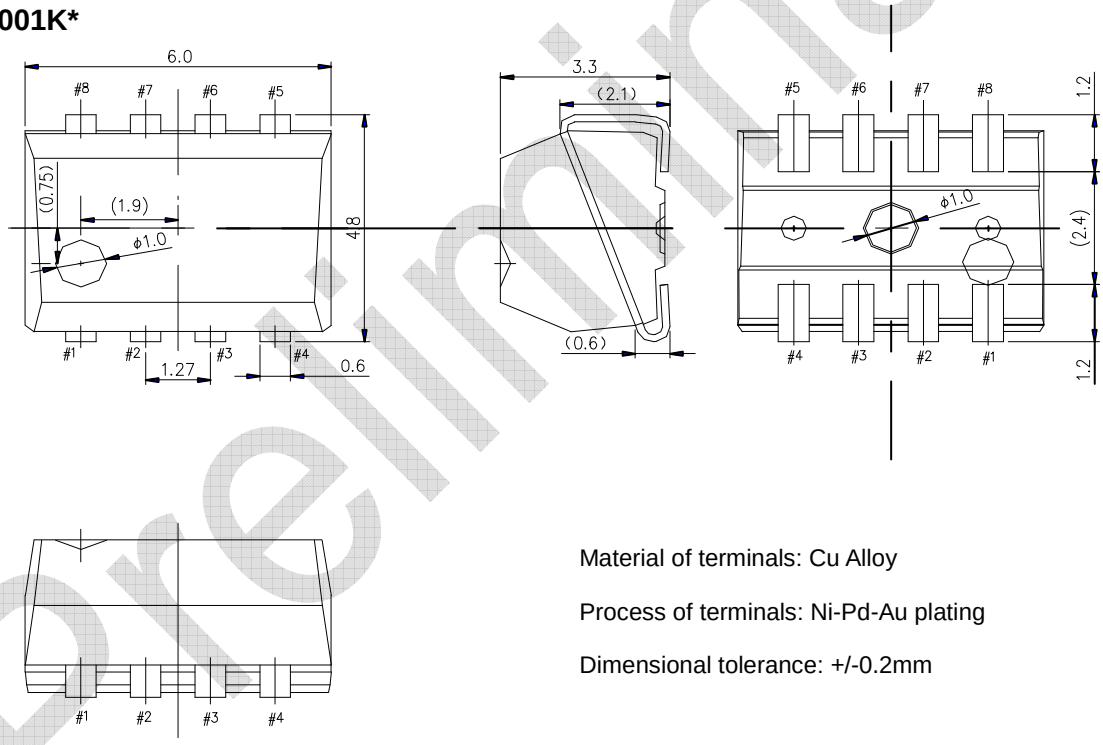
(1) XV4001B*



Material of terminals: W (Wolfram)

Process of terminals: Ni/Au plating

(2) XV4001K*



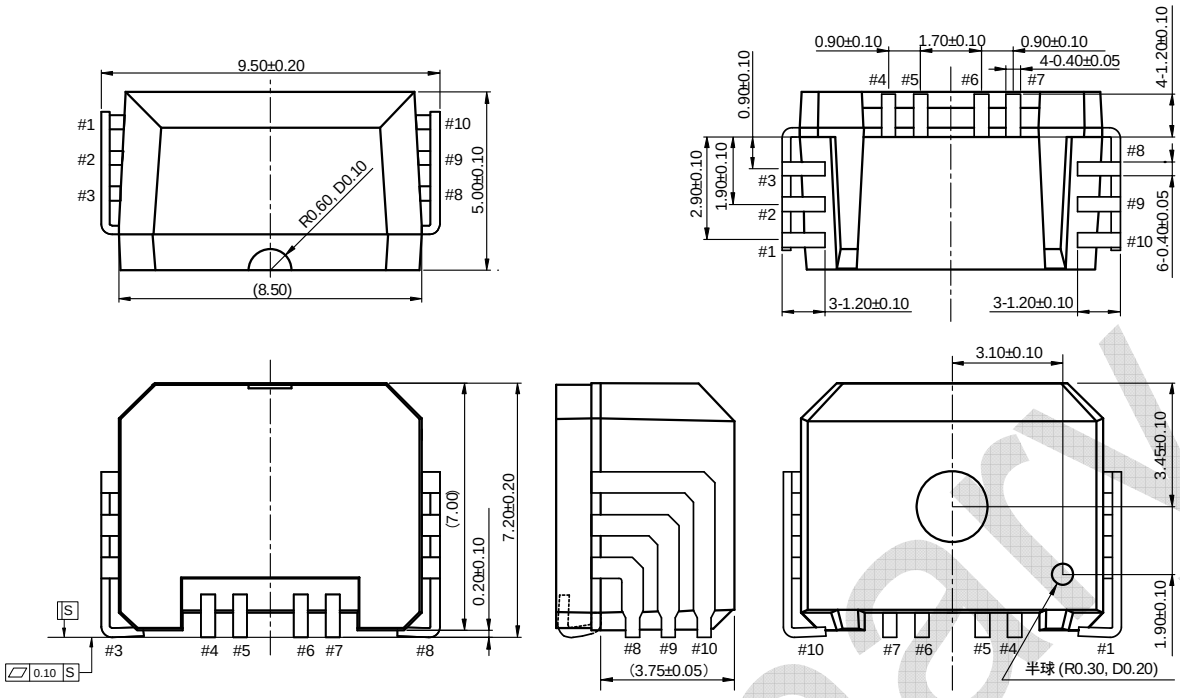
Material of terminals: Cu Alloy

Process of terminals: Ni-Pd-Au plating

Dimensional tolerance: +/-0.2mm

*The XV4001KC/XV4001KD are mold package, the moisture sensitivity level is 2. (MSL 2)

(3) XV4002P*



Material of terminals: Cu Alloy

Process of terminals: Ni-Pd-Au plating

*The XV4002PC/XV4002PD are mold package, the moisture sensitivity level is 3. (MSL 3)

2-2) Pin map and Function of terminals

Pin number XV4001B*	Name	Function
1	Reserved	Please do not connect this pin
2	SCLK SCL	Clock input
3	SS	SPI：Chip select
4	VDD	Power supply
5	Reserved	Please do not connect this pin
6	Reserved	Please do not connect this pin
7	GND	GND
8	MOSI	Command input
9	MISO SDA	SPI： Data output I^2C： Data input/output
10	Reserved	Please do not connect this pin

Pin number XV4001K*	Name	Function
1	GND	GND
2	MOSI	Command input
3	MISO SDA	SPI: Data output I^2C: Data input/output
4	Reserved	Please do not connect this pin
5	Reserved	Please do not connect this pin
6	SCLK SCL	Clock input
7	SS	SPI:Chip select
8	VDD	Power supply

Pin number XV4001P*	Pin Name	Function
1	VDD	Power supply
2	SS	SPI:Chip select
3	SCLK SCL	Clock input
4	Reserved	Please do not connect this pin
5	Reserved	Please do not connect this pin
6	Reserved	Please do not connect this pin
7	Reserved	Please do not connect this pin
8	MISO SDA	SPI: Data output I^2C: Data input/output
9	MOSI	Command input
10	GND	GND

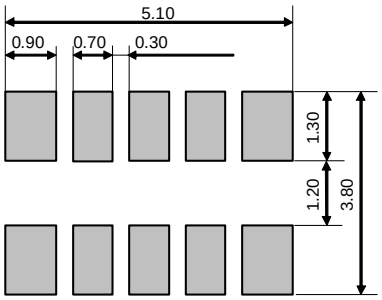
2-3) Soldering pattern

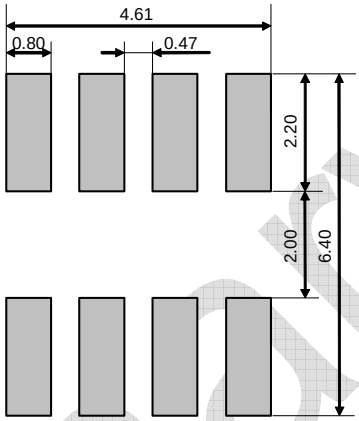
A solder pattern example is shown as below. For your actual design, please optimize the pattern to meet your design considerations such as mounting density, soldering reliability, ease of mounting, etc.

Please mount the device so that solder doesn't adhere to any portion of the seal hole (package underside)

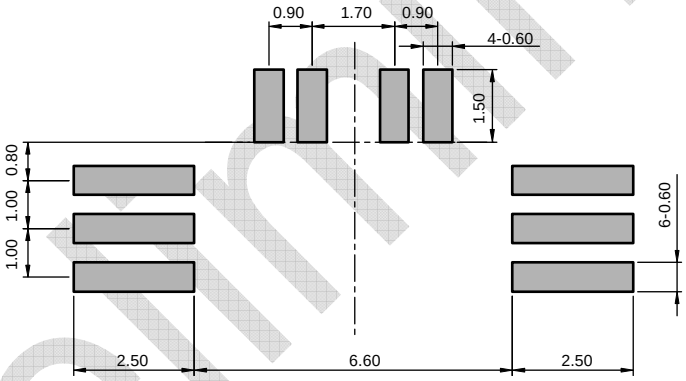
・XV4001B* **・XV4001K***

Unit : mm



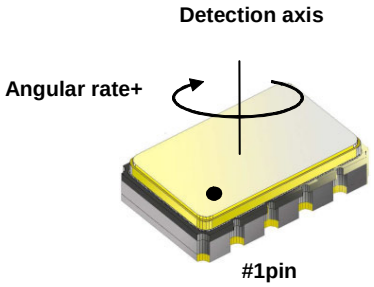


・XV4002P*

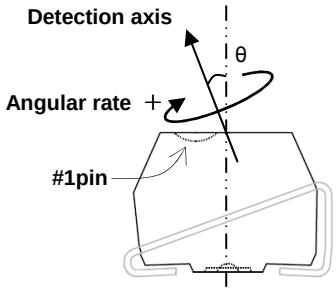


4. Detection direction

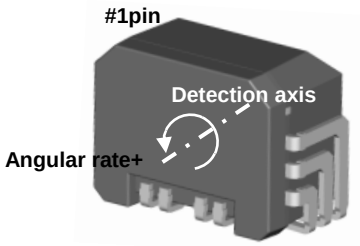
The detection direction is shown as in the following figure. Please mount carefully to meet your design requirement for detect direction



XV4001B*



XV4001K*

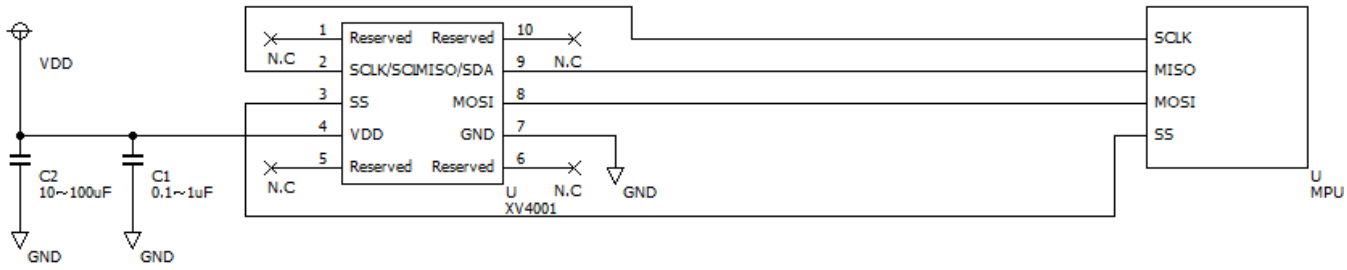


XV4002P*

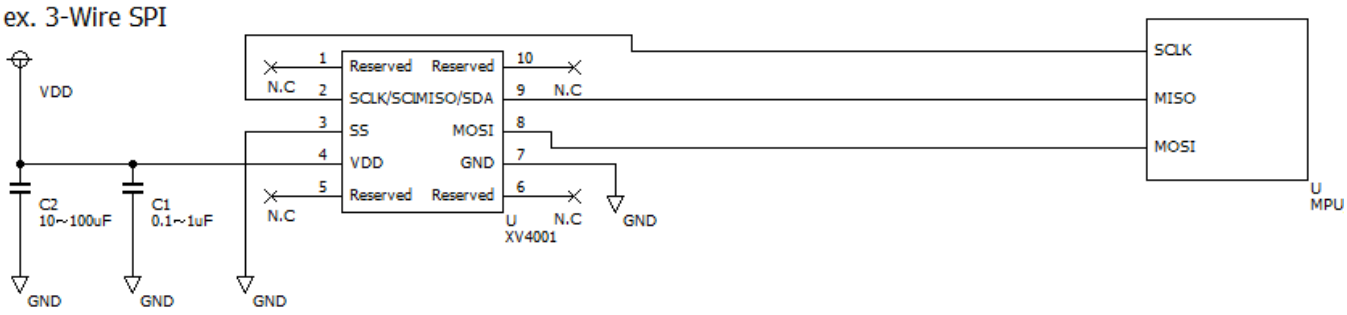
5. Reference circuit

This circuit is for XV4001B*

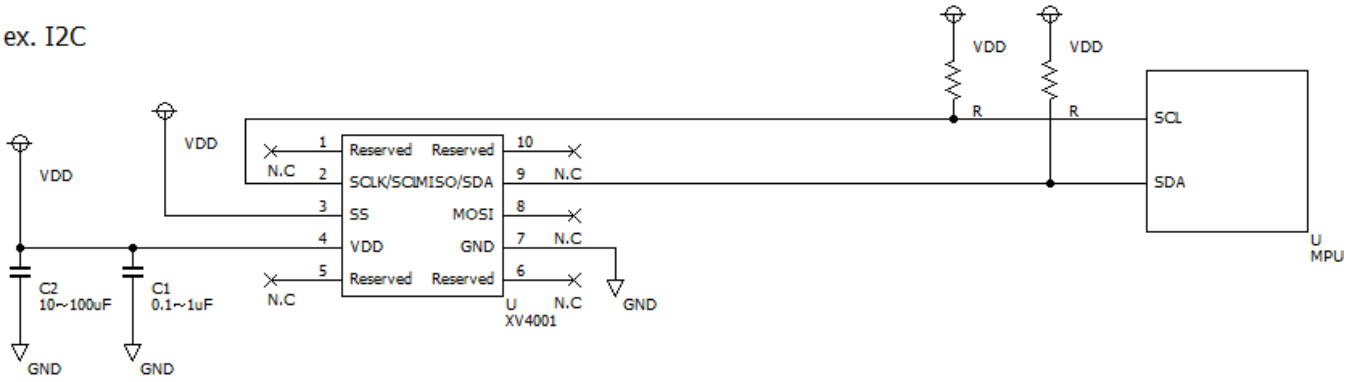
ex. 4-Wire SPI



ex. 3-Wire SPI



ex. I2C



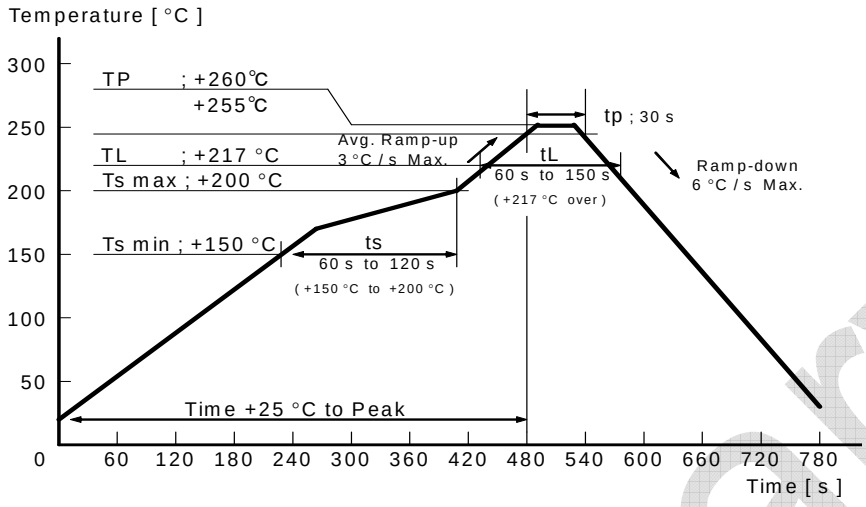
・Apply a bypass capacitor C1 with 0.1 to 1µF and good high frequency characteristic, close to the terminals of the sensor.

・The sensor dose not have a power supply back-up function, thus insert a back-up capacitor C2 .

(Recommended: 10µF to 100µF)

6. Solder heatproof

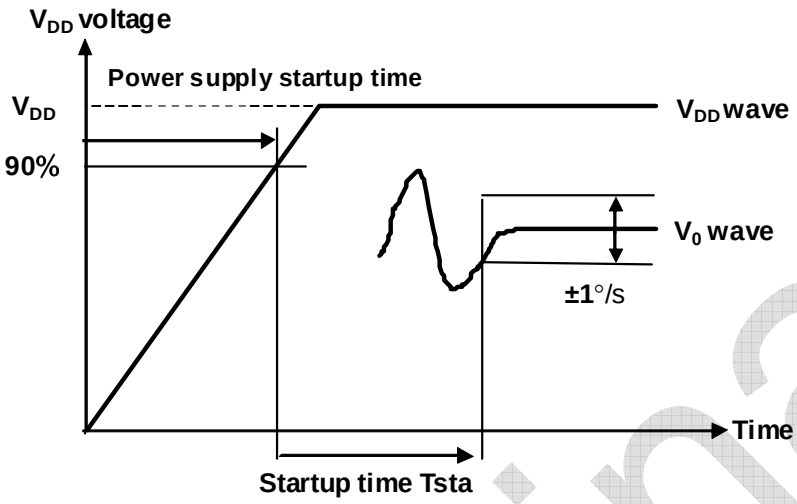
The resistance to soldering heat was qualified in accordance with the following profile.



7. Terminology

1. Method for startup time measurement

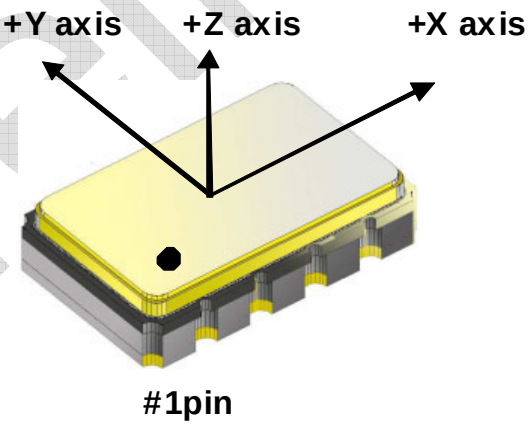
On condition that the supply voltage is rising from 0 % to 90 % within 40 msec, startup time measurement is done by measuring the time from when the power supply is ON until the angular output Vo is in a quiescent state stabilized in ±1 ℀s of zero-point counts



2. Cross axis

Cross axes sensitivity is the value of the X axis or Y axis sensitivity divided by Z axis sensitivity.

The X, Y, Z directions are as follows.



3. Drive frequency

Drive frequency is the sensor element oscillation frequency to detect Coriolis force. (Drive Mode)

8. Handling precaution

Quartz parts are precision parts. Please handle carefully paying attention to the next points

1. This product is designed in consideration of shock resistance. However it may be destroyed depending on the condition of dropping and impact. Please do not use the product, in case it falls accidentally or it is applied excessive shock, as it can not be guaranteed after these.
2. If too much shock is generated when a crystal product is mounted, it will lead to change or degradation of the characteristics. (In the case of product absorption, catching, and substrate mounting) Therefore, please set up the conditions such that shock is reduced as small as possible. Please be sure to test the product before use in your company, and check that there is no change in the characteristics. Please confirm similarly at the time of condition change. Please be careful after mounting that the crystal product does not collide with a machine object or other substrates at the time of mounting.
3. This product contains circuits that protect from static electricity destruction. However, if static electricity is excessive the IC may break. Therefore, the packing material and container carrying the product should use a conductive material. Moreover, any soldering iron and measurement circuit should use precaution against static electricity.
4. Ultrasonic washing may lead to destruction of the crystal which cannot be guaranteed by our company. When ultrasonic washing is unavoidable in your company, be sure to test and confirm operation of product before use in your company.
5. Reflow is to 3 times. The condition for use of soldering iron to correct for soldering mistake should be 350 °C or less and for less than 3 seconds.
6. We recommend the substrate be designed by the recommended soldering pattern.
7. Please do not use the product in an environment where a short-circuit can be generated between terminals from moisture and condensation.
8. If the product has noise of the same frequency as drive frequency, it is necessary to remove the noise using a suitable filter circuit.
9. If the signal with the frequency component near the harmonic or near the drive frequency is applied to a gyro sensor from the outside, change may be given to the angular rate output of a gyro sensor.
   Please take into consideration setup of the countermeasure decoupling of power supply and the communication frequency of serial interface.
10. This sensor contains the POR circuit. In order to avoid the malfunction of a POR circuit, please perform starting of power supply voltage among 0.15 - 100ms. Moreover, if there are power supply starting from middle potential, and an instant fall of power supply voltage, POR does not operate normally and abnormalities may arise in sensor operation.
11. This sensor is designed not to interfere easily even if multiple sensors are operated closely and simultaneously. However, in some cases, the sensors may interfere mechanically or electrically by vibration of circuit board or common impedance of power supply. Please check them before use.
    Please also check whether you do not have any problem with the practical condition.

12. Please use sensors that have different drive frequency, when two sensors are used on the same PCB or same power supply to avoid cross interference.
13. Please confirm the influence of vibration absorption, when there is an excessive vibration coupling to the sensor. Other high voltage level signal line may cause irregular output. Please take care to design output traces as short as possible, and keep high voltage level signal sources away from this device.
14. Please keep the ceramic package within normal operating temperature and normal moisture. The mold Package of moisture sensitivity level is 2(MSL2) and 3(MSL3).

    MSL2: The storage term after packing opening will be one year (<=30℃ / 60%). Refer to the packing standard document for the management method of proper packing state.

    MSL3: The storage term after packing opening will be 168 hours (<=30℃ / 60%). Refer to the packing standard document for the management method of proper packing state.
15. This product supplied (and any technical information furnished, if any) by SEIKO EPSON CORPORATION shall not be used for the development and manufacture of weapons of mass destruction or for other military purposes. Making available such products and technology to any third party who may use such products or technologies for the said purposes are also prohibited.
16. The products listed here are designed as components or parts for electronics equipment in automotive application. We do not expect that any of these products would be incorporated or otherwise used as a component or part for the equipment which requires extra high reliability, such as satellite, rocket and other space systems, and medical equipment with the functional purpose of maintaining life

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