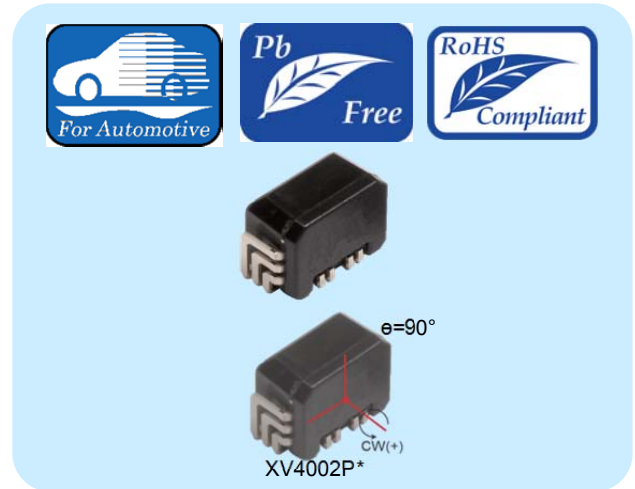# High-Performance Gyro Sensor :XV4002P*

Under Development

Features

- SPI or I^{2}C 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 90°
- 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 gyro sensor.

Using EPSON's proprietary quartz-based MEMS

(QMEMS) process, the XV4000 series delivers superior

stability in a small package.

SPI or I^{2}C serial interface is available.

It also has self-testing function and sends the response

data of DIAG to the Master.[1]

The XV4002PC/PD supports 90° tilted sensing from

the PCB mounting plane and reduced detection error.

Product Name

Product name	Inclination angle	Serial Interface
XV4002PC	90°	I^{2}C
XV4002PD	90°	SPI

*1 When using the I^{2}C interface, command is needed for the acquisition of DIAG signal.

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

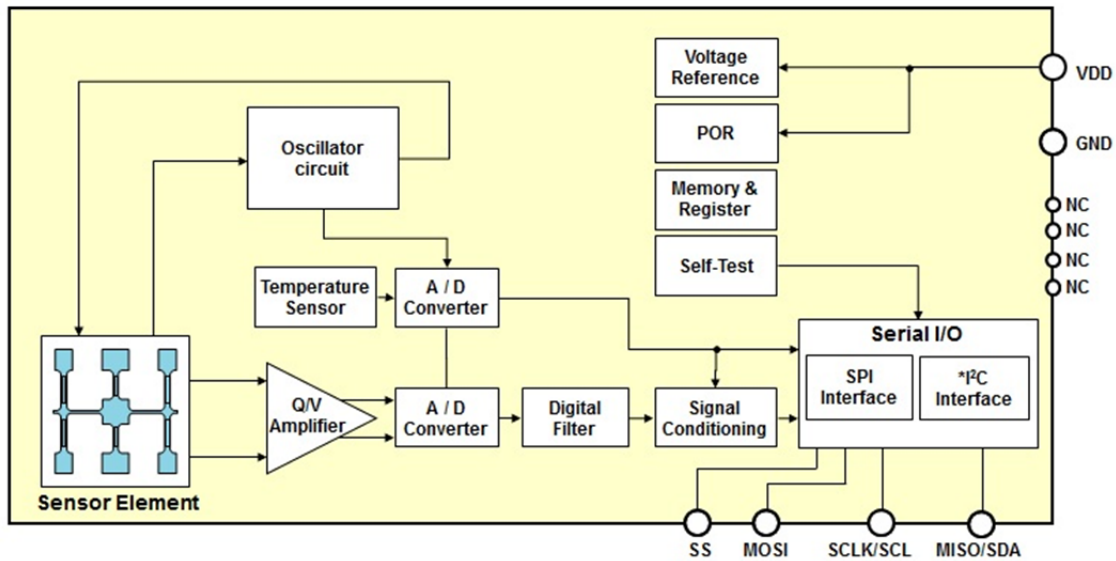|	
Pb Free	►Pb free.

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	►Designed for automotive applications such as Car Multimedia, Body Electronics, Remote Keyless Entry etc.
Automotive Safety	►Designed for automotive applications related to driving safety (Engine Control Unit, Air Bag, ESC etc).

Notice

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  /Space equipment (artificial satellites, rockets, etc.)
  /Medical instruments to sustain life
  /Submarine transmitters
  /Power stations and related
  /Fire work equipment and security equipment
  /Traffic control equipment /and others requiring equivalent reliability.

- The manual does not guarantee the specification of product.

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Contents

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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 low pass 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.

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Specifications are subject to change.

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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
Input voltage	V	-0.3		VDD+0.3	V_{SS}=GND=0V
Storage temperature	°C	-40		+85	

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	°C	-40		+85	
Supply voltage start up time	ms	0.2		100	0%→90% V_{DD}
SPI Clock frequency	MHz	0.08		10	
I^2C Clock frequency	kHz	80		400	
Refresh rate of angular rate data *2	Hz		100	300	

*1 Analog power supply and Digital power supply are in common.
*2 We recommend acquiring angular rate output at less than 100Hz.

2-1) Operating sequence

＜Notice＞
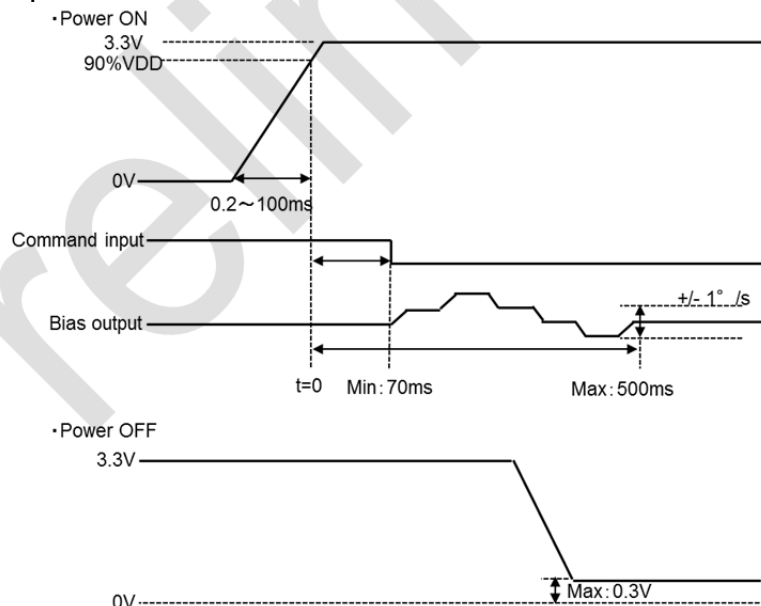
The gyro sensor is inserted POR circuit. Please use the part in the voltage start up time of 0.2ms～100ms to avoid the operation error of POR circuit.

Please input the communication command taking more than 70ms after 90%VDD.

As the operation error may occur with voltage supply from the middle electrical potential, please set the electrical potential of voltage shutdown in lower than 0.3V

3) DC Characteristics

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

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

4) Characteristics

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

Parameter	unit	Specifications			condition
		Min.	Typ.	Max.	
Drive frequency	kHz	49.0	50.3	51.6	
Detuning frequency	Hz	500	800	1100	
Scale factor	LSB/(°/s)		370		
Scale factor tolerance	%	-1.5		+1.5	Ta=+25 °C
Scale factor variation with temp.	%	-2.5		+2.5	Ta=+25 °C reference
Bias	LSB		0		Ta=+25 °C
Bias tolerance	°/s	-2.0		+2.0	Ta=+25 °C
Bias variation with temp.	°/s	-3.0		+3.0	Ta=+25 °C reference
Bias stability 1	°/s	-0.6		+0.6	1s～5min after start-up Bias at 1s reference Temperature is constant
Bias stability 2	°/s	-0.4		+0.4	5min～15min after start-up Bias at 5min reference Temperature is constant

Bias drift gradient	°/s/(7.5℃)	-0.8		+0.8	-40℃→+85℃ Temperature change is only rise direction. Calculate at 7.5℃ step
Rate range	°/s	-70		+70	
Non linearity	%FS	-0.5		+0.5	Ta=+25 °C FS=±70°/s
Frequency characteristic	Hz	9	10	11	LPF Gain -3dB bandwidth
Cross axis sensitivity	%	-5		+5	Ta=+25 °C
Start up time (Tsta)	ms			500	Ta=+25 °C
Current consumption	mA		3.5	4	not rotation and not communicating
Output noise	°/s RMS		0.05		Ta=+25 °C VDD=3.3V Calculated value from the data in 500 measuring points on communication rate of 100Hz

5) Temperature sensor

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

Parameter	unit	Specifications			condition
		Min.	Typ.	Max.	
Output code	LSB	-25	0	+25	Ta=+25 °C
Temperature output accuracy	°C	-5		+5	
Temperature coefficient	LSB/°C	4.9	5.1	5.5	

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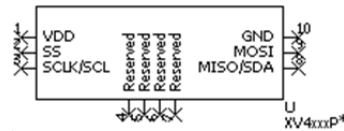**Date: January .23 2014**

6) Serial Interface

Serial I/F can be selected from 4-wire SPI, 3-wire SPI or I²C.

(*Data is transferred with the MSB first.)
I²C is available non-volatile memory set at factory.
The function and terminal processing in Serial Interface terminal and each communication method are as below.
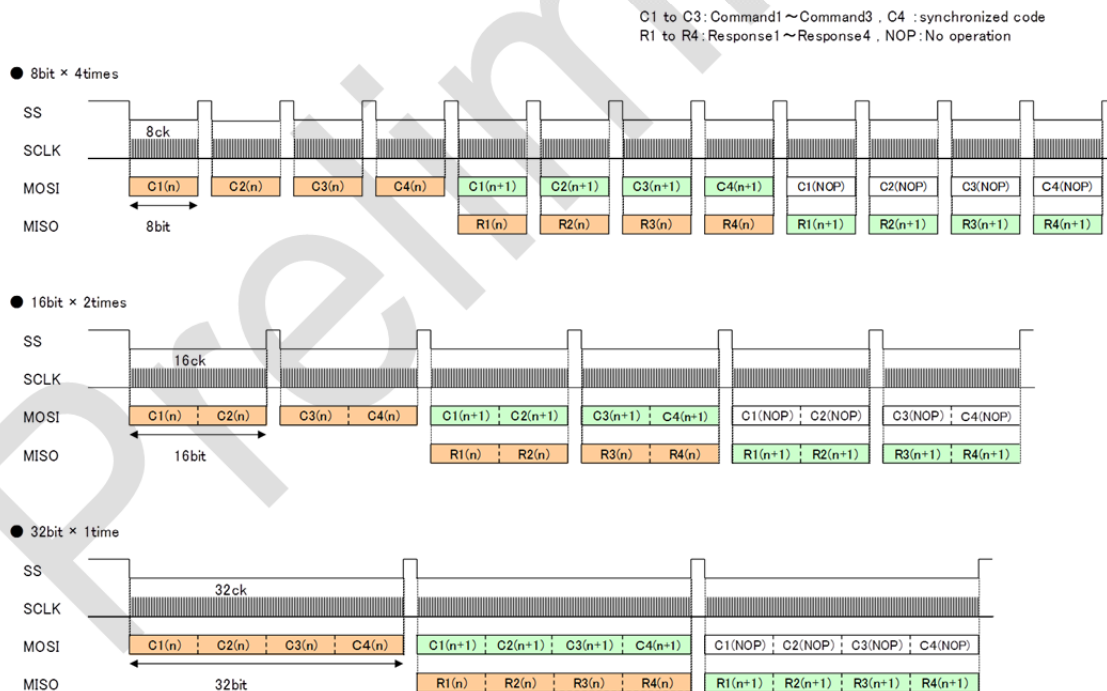

Pin name	4-Wire SPI	3-Wire SPI	I²C
SCLK/SCL	Clock input pin	Clock input pin	Clock input pin
SS	Chip select input pin	Lo fixed	Hi fixed
MISO/SDA	Data output pin	Data output pin	Data input/output pin
MOSI	Data Input pin.	Data Input pin.	Do not connect

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;

C1 to C3 : Command1～Command3 , C4 : synchronized code
R1 to R4 : Response1～Response4 , NOP : No operation

SS=L area becomes effective. Please do not input the clock and data when SS=H area.

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(6-1-2) Timing Chart

According to following condition Max. 10MHz SPI I/F is available.
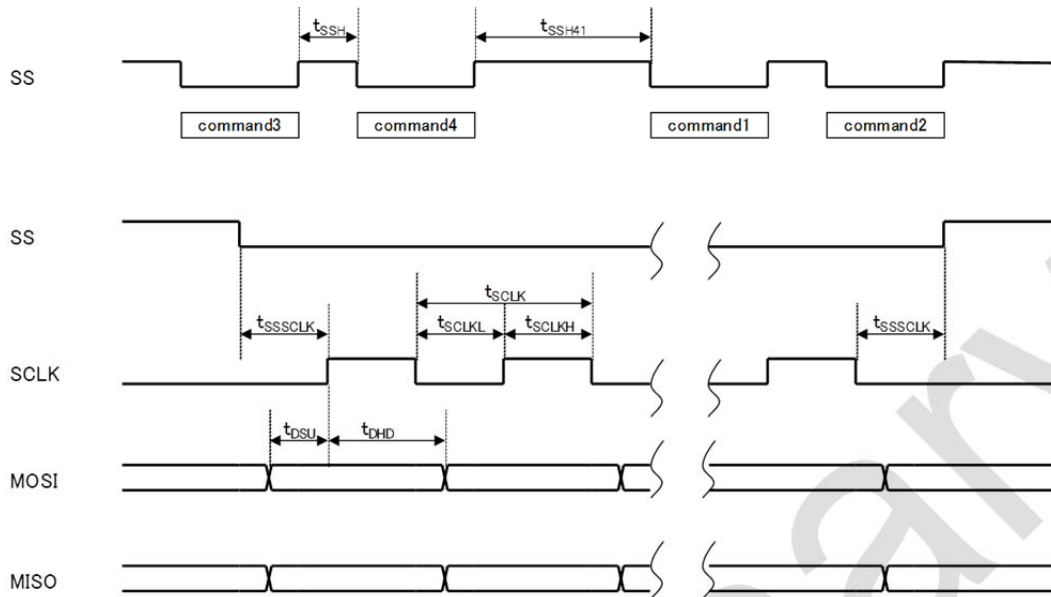
Symbol	Parameter	Specifications			unit
		Min.	Typ.	Max.	
tSSH	SS H width(command-command)	100			ns
tSSH41	SS H width(command4-command1)	25			µs
tSSSCLK	SCLK before and after SS edge：(between L)	45			ns
tSCLKH	SCLK H width	45			ns
tSCLKL	SCLK L width	45			ns
tSCLK	SCLK cycle	100			ns
tDSU	Input data setup time	25			ns
tDHD	Input data hold time	25			ns

(6-1-3) Command/response list

Command /response list is as below. Command4 is stable by synchronous discernment code. Command parameter as below (6-1-4).

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	(58)h
Software reset start 1	(1C)h	(4E)h	(67)h	(58)h
Software reset start 2	(5C)h	(6E)h	(77)h	(58)h
Software reset cancel	(04)h	(42)h	(23)h	(58)h
NOP(No Operation)	(30)h	(1A)h	(0F)h	(58)h

Parameter	CEF	DIAG	0	0	ARU	Response1 (bit31~bit24) low bits	Response2 (bit23~bit16) CS4-0	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	CEF	DIAG	0	0	ARU	0 1 0 1 0 0	CS4-0	0 0 0 0 0 D10 D9 D8	D7 D6 D5 D4 D3 D2 D1 D0
Software reset start 1	CEF	DIAG	0	0	ARU	0 0 0 1 1 1	CS4-0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Software reset start 2	CEF	DIAG	0	0	ARU	0 1 0 1 1 1	CS4-0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Software reset cancel	CEF	DIAG	0	0	ARU	0 0 0 0 0 1	CS4-0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
NOP(No Operation)	CEF	DIAG	0	0	ARU	0 0 0 0 0 0	CS4-0	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.
　　　When the DIAG flag is "1", please do not use the value of the angular rate and temperature sensor output because the value might be abnormal.
　　　When the DIAG flag change into "0" from "1", please send a Software reset command.

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 bit23-21, 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.(*Responce3 D15)

(2) Temperature sensor output
Output data are 2's complements. It becomes the 11bit output of mark bit* +10bit. (*Responce3 D10)
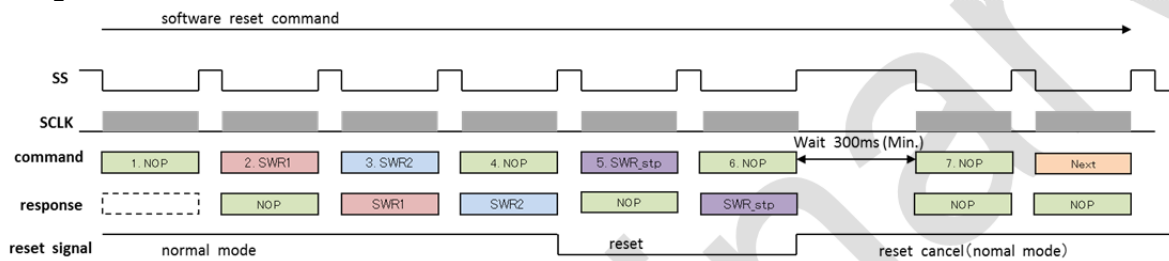
(3) Software reset
It reset a logic circuit by command.
The sequence of the reset is follows. Please send seven commands with the following turns.

1. "NOP" 2. "Software reset start1" 3. "Software reset start2" 4. "NOP"
5. "Software reset cancel" 6. "NOP" wait 300ms(Min.) 7. "NOP"

Waiting time of 300ms(Min.) is necessary between command 6 and command 7.
Timing chart is shown below.

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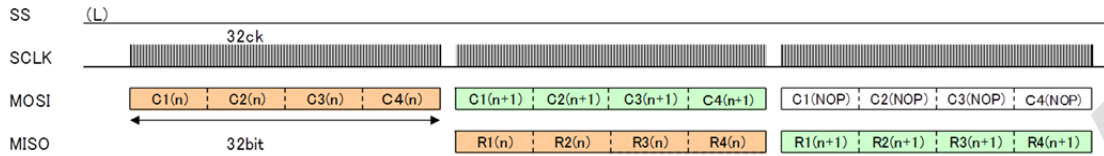
6-2) 3-Wire SPI

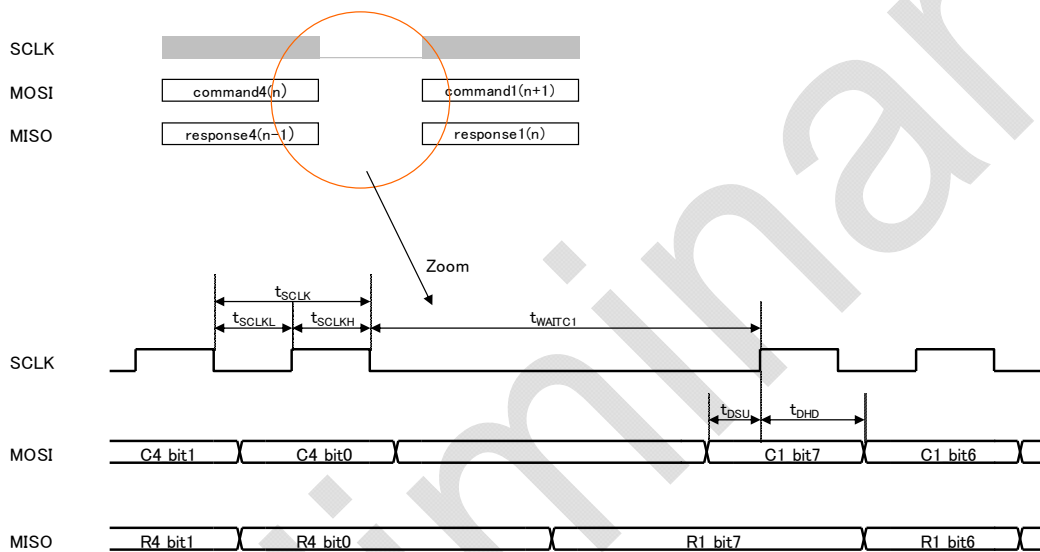### (6-2-1) Correspondence frame

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;

C1 to C3：Command1～Command3，C4：synchronized code
R1 to R4：Response1～Response4，NOP：No operation

(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
tWAITC1	SCLK wait time(command4-command1)	25			µs

(6-2-3) Command/response list

The command/response is the same as 4-Wire SPI. Please refer to (6-1-3)

(6-2-4) Command details

The command/response is the same as 4-Wire SPI. Please refer to (6-1-4)

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6-3) I²C

In I²C, SCLK terminal are used as SCL (clock terminal) and MISO terminal are used as SDA (data input/output terminal).
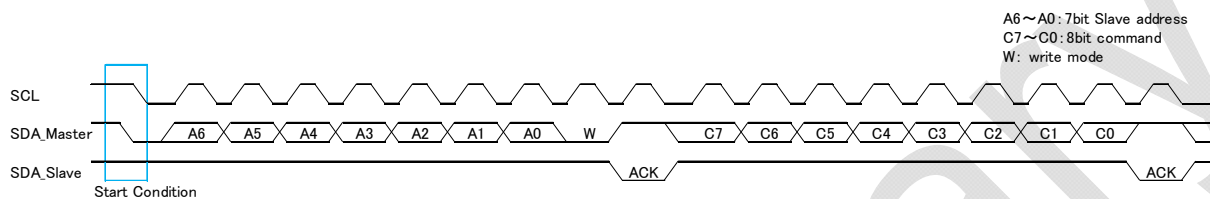SS terminal is fixed to high level. MOSI terminal should not carry out external connection.
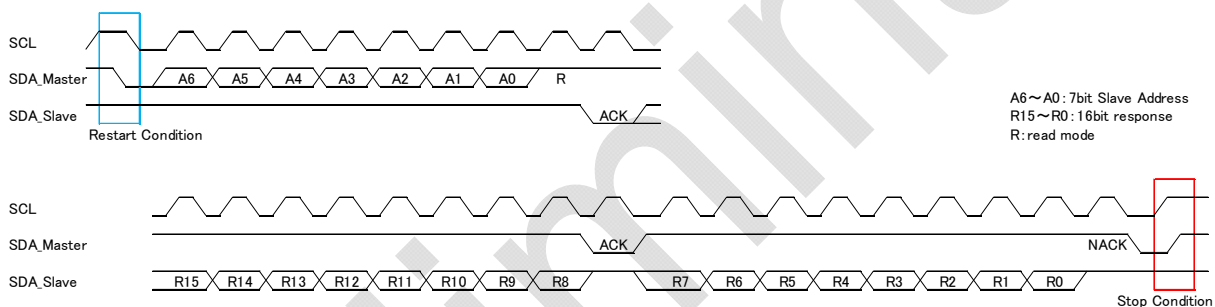
(6-3-1) Correspondence frame

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)

A6～A0：7bit Slave address
C7～C0：8bit command
W: write mode

```
SCL
SDA_Master   A6 A5 A4 A3 A2 A1 A0 W   C7 C6 C5 C4 C3 C2 C1 C0
SDA_Slave                          ACK                        ACK
            Start Condition
```

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

```
SCL
SDA_Master   A6 A5 A4 A3 A2 A1 A0 R
SDA_Slave                        ACK
            Restart Condition
```

A6～A0：7bit Slave Address
R15～R0：16bit response
R：read mode

```
SCL
SDA_Master                  ACK                              NACK
SDA_Slave   R15 R14 R13 R12 R11 R10 R9 R8   R7 R6 R5 R4 R3 R2 R1 R0
                                                        Stop Condition
```

・A slave address (A6:A0) is (1101000)b. When the address overlaps, it can change the preliminary three addresses {(1101001)b , (1011000)b or (1011001)b}. 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.
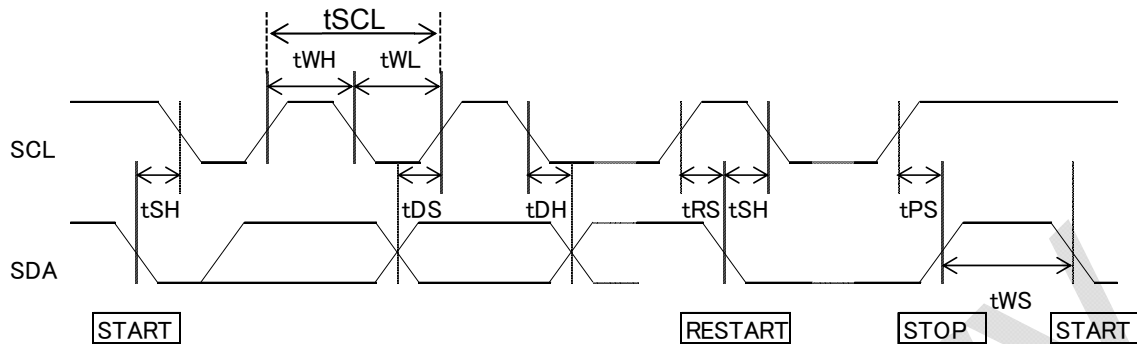
Symbol	Parameter	Fast Mode 400kbit/s		unit
		Min.	Max.	
tSCL	SCL Clock Period	2.5	-	µs
tWH	SCL Clock High Time	1.3	-	µs
tWL	SCL Clock Low Time	0.6	-	µs
tDS	SDA Setup Time	100	-	ns
tDH	SDA Hold Time	0	-	µs
tSH	START condition hold time	0.6	-	µs
tRS	Repeated START setup time	0.6	-	µs
tPS	STOP condition setup time	0.6	-	µs
tWS	Between STOP and START condition	1.3	-	µs

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(6-3-3) Command/response list

The command / response list of I²C 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	DIAG	*1	*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.
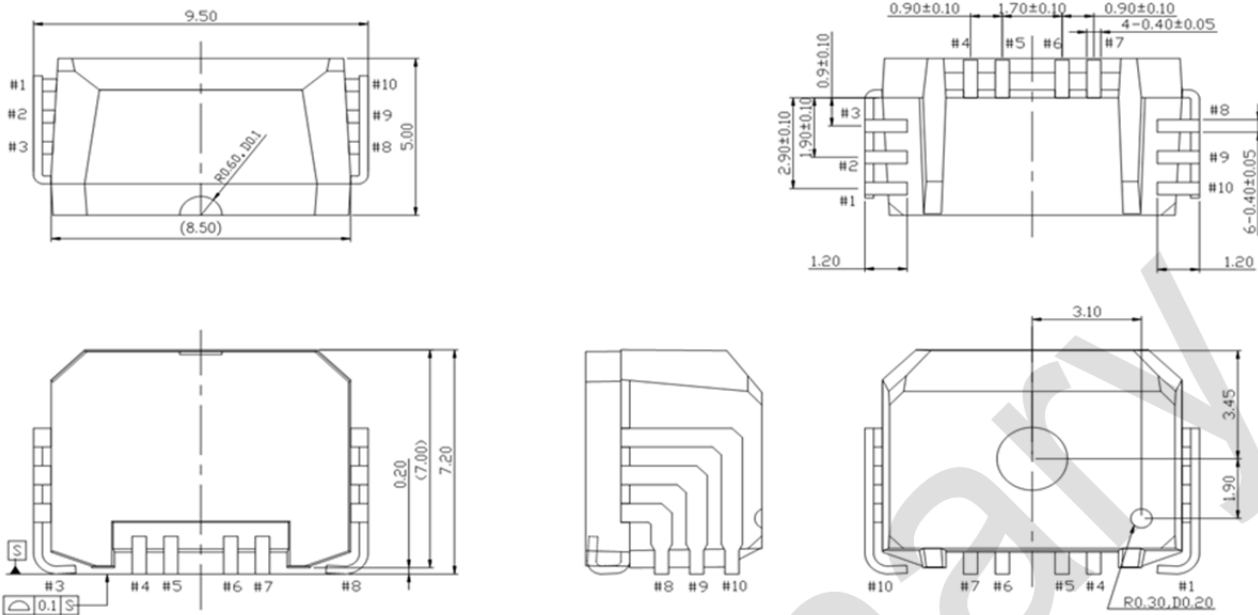
(3)Self test judging result output

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.

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Specifications are subject to change.

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3. Outline

3-1) Outline dimensions and Pin information

Material of terminals: Cu Alloy

Process of terminals: Ni-Pd-Au plating

Dimensional tolerance: +/-0.2mm

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

Pin number XV4002P*	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

This manual is preliminary.
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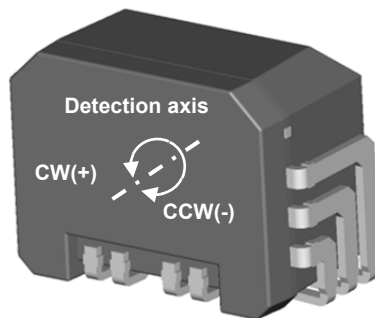**Date: January .23 2014**

3-3) 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.
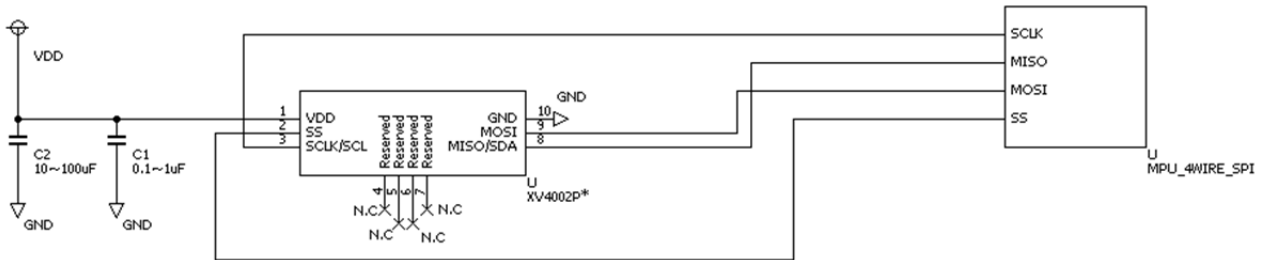
Unit : mm
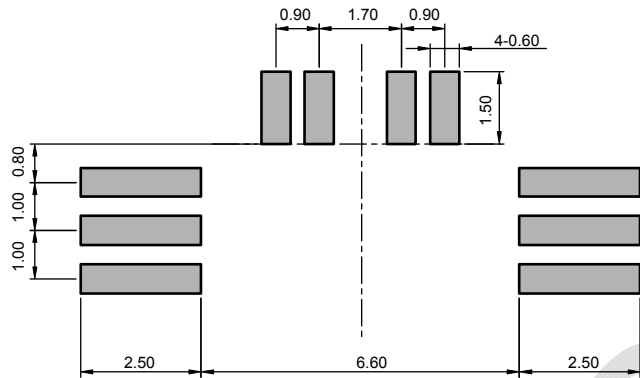
4. Detection direction

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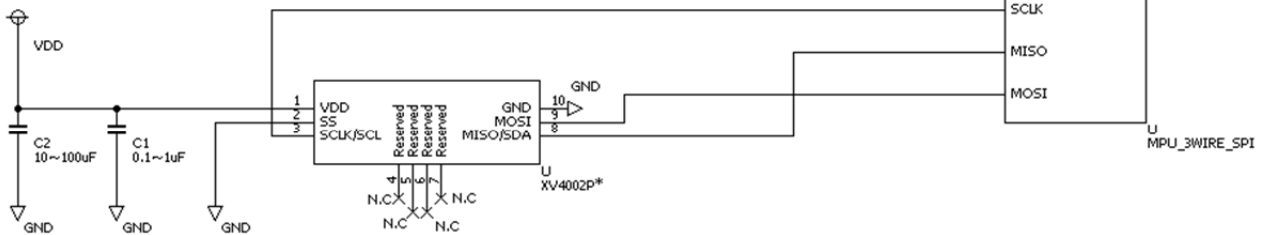
requirement for detect direction

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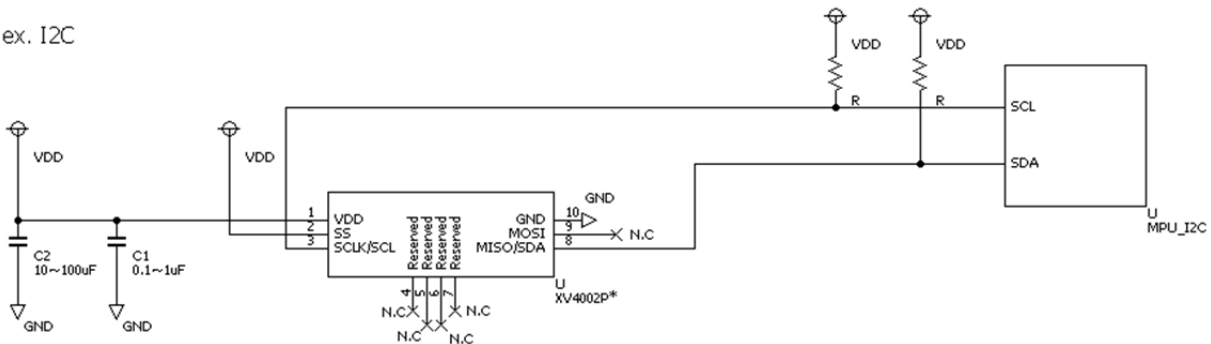**Date: January .23 2014**

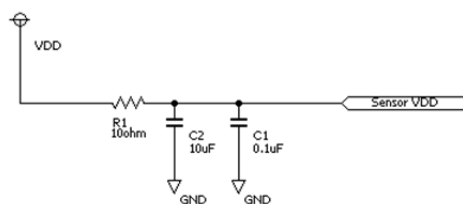## 5. Reference circuit

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)

If you can not remove the noise on voltage line only with bypass condenser, we recommend making Low Pass Filter (referring to below) to avoid inputting noise in sensor voltage.

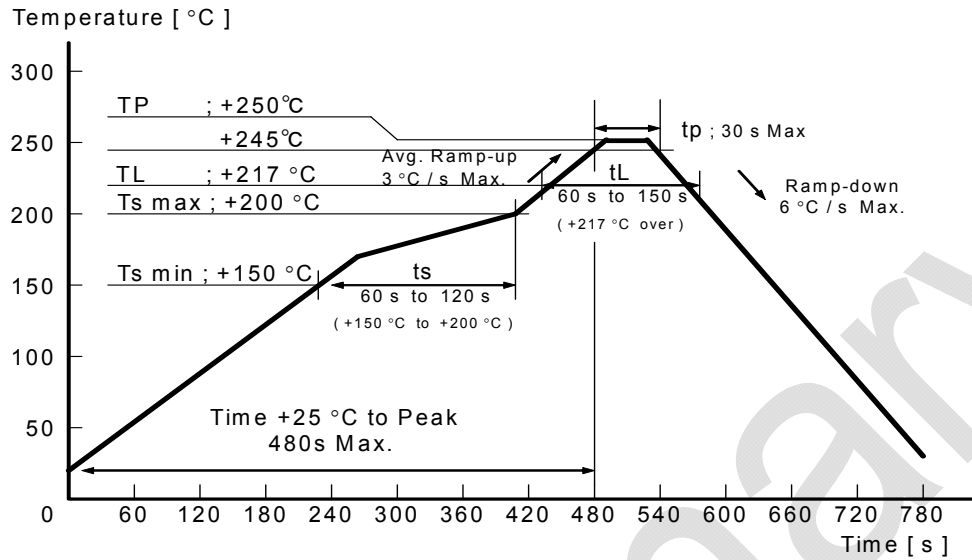Please select the resistance value as the supply voltage will not be below 3.0V.

ex. Power Line Filter

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6. Solder heatproof

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

Temperature [°C]

- TP ; +250℃
- +245℃
- TL ; +217 °C
- Ts max ; +200 °C
- Ts min ; +150 °C

Avg. Ramp-up
3 °C / s Max.

tp ; 30 s Max

tL
60 s to 150 s
(+217 °C over)

Ramp-down
6 °C / s Max.

ts
60 s to 120 s
(+150 °C to +200 °C)

Time +25 °C to Peak
480s Max.

Time [s]

7. Terminology

1. Method for startup time measurement

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
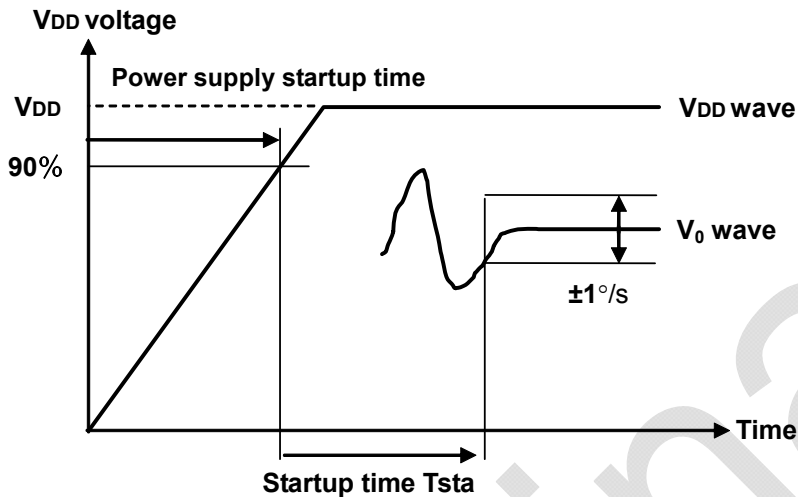
2. Cross axis

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

The X, Y, Z directions are as follows.
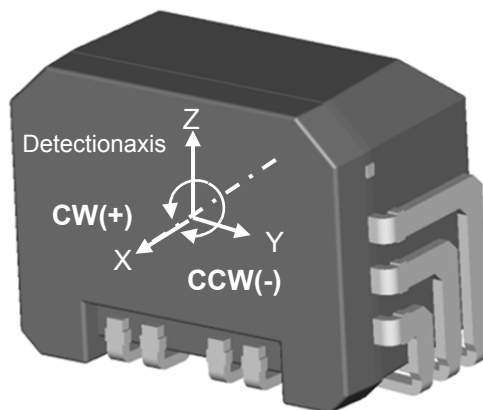
3. Drive frequency and detuning frequency

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

Detuning frequency is the characteristic frequency to convert the Coriolis force into electric signal and is the frequency distance from drive frequency.

Precaution for your design

- The detuned frequency is 800Hz±300Hz. Please make your board design to avoid putting the resonance frequency of the board in the detuned frequency. Please also put our part on fixed area of board which is less influence from vibration

- As you mount our part (vacuum-chucking, mechanical chucking, mounting on the circuit board), the excessive shock may make the characteristics of quartz products change or deteriorate. Therefore please set up the condition so that the shock becomes as small as possible. Please be sure to test in your site before use and confirm that there is no influence on the characteristics.

- The sensor element drive in 50.3kHz(Typ.) to detect the angular rate. If closer frequency to drive frequency and signal having frequency factor of high-order harmonic are inputted to the sensor, the angular rate signal output of sensor may be influenced. Please carefully consider the prevention for decoupling of voltage and the setting for communication frequency in serial interface

- Please do not draw other signal lines on near sensor and backside area of package to avoid the operation error with electromagnetic induction and electrostatic induction from other signal lines. Please also do not draw other signal lines in cross.

- Please check the vibration, shock, noise and take your prevention. If we can get your board design information, we give our advice for your design.

8. Handling precaution

★★ Crystal device is accurate instrument. Please pay attention to below issues ★★

1. This crystal product is designed in consideration of shock resistance. However it may be de stroyed depending on the condition of dropping and impact.
   If you mistakenly drop the part, do not use it because we can not guarantee the characteristic.

2. If you apply ultrasonic oscillation (ex.ultrasonic washing, Printed circuit board cutting) to our product, the crystal may be cause resonant destruction under some use conditions.
   Since we can not specify your use conditions (type of washing machine・Power・Time・posi tion of machine), we can not guarantee the operation of our product after you apply ultraso nic oscillation. If you have no choice but to apply it, please be sure to examine and set up the conditions beforehand.

3. Please surely implement the mounting test at your side before using our part to confirm no influence to the characteristic. Please also confirm it when the condition is changed.
   Be careful not to collide the gyrosensor with the machinery or with other circuit board when/after mounting.

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4. Anti-static protection circuit is contained in this product. However, when the excessive static electricity is charged, IC may break. So please use conductive ones for packing and carrying containers. And use the soldering iron and the measurement instrument that don't have high-voltage leakage and take anti-static measures such as grounding when handling.

5. The limitation of your reflow is up to 3 times. If you find the soldering fail, please fix them with soldering iron.In the case, please use the iron with lower temperature than $+350°C$ and within 3 seconds (You should not use blower) .

6. We recommend our land size when you make the circuit board.

7. This product has a noise which frequency is same as that of drive frequency. It's necessary to remove it by proper filter circuit.

8. This sensor is designed not to interfere easily even if you operate several sensors closely. However, in some cases, the sensors may interfere by vibration of circuit board or common impedance of power supply. Please check them before use at your side.

9. This sensor is inserted POR circuit. Please use the part in the voltage start up time of 0.2 ms～100ms to avoid the operation error of POR circuit. As the operation error may occur with voltage input from the middle electrical potential, please set the electrical potential of voltage shutdown in lower than 0.3V

10. Please keep the ceramic package within normal operating temperature and normal moisture. The mold Package of moisture sensitivity level is 3(MSL3).

    MSL3: The storage term after packing opening will be 168 hours (<=30°C / 60%). Refer to the packing standard document for the management method of proper packing state.

11. Please do not use the part under the condition which may occur short between terminals with dewfall etc.

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