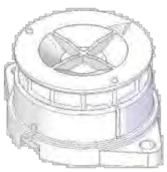
Light Breeze Sensor

MMS002XA
Datasheet

DESCRIPTION



MMS002 provides digital output (I2C) of X- and Y-axis sensor values, which are proportional to the wind velocity, as well as the temperature sensor values. This product uses a highly sensitive unique sensor element and can detect breeze of 0 to 3 m/s. Since wind velocity correction parameters for each sensor are saved in the AFE, performing a simple calculation using the data of this product by the external microcontroller (the host) provides the wind velocity and direction. Only this product and the external microcontroller can achieve a high-performance device, without using an intricate sensor-driven / control circuit.

FEATURES

- Downsized by using a MEMS thermal sensor
- Wind velocity range: 0 to 3 m/s
- Wind direction range: 0 to 360 deg
- Wind velocity error: ±(0.1m/s+5%RD) (@0 to 1m/s)
- Wind direction error: ±15 deg (@0.3 to 3m/s)
- Possible to load wind velocity correction parameters from NVM

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BLOCK DIAGRAM

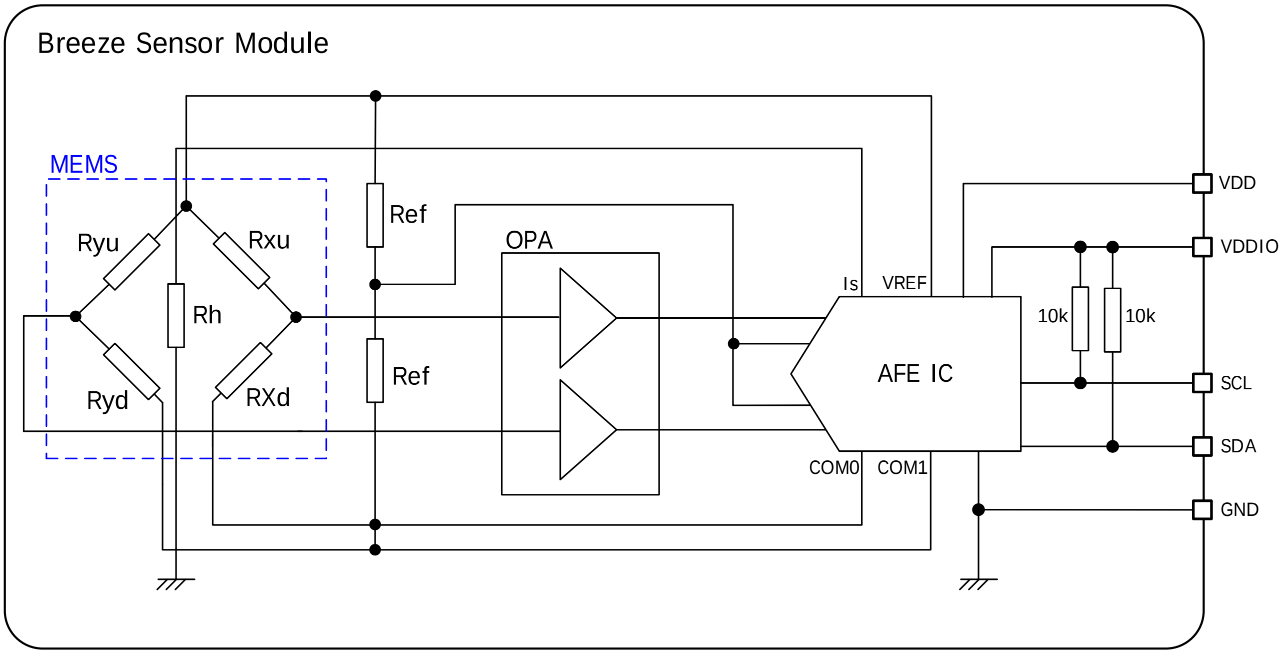


Fig. 1 Block diagram

PIN CONFIGURATION

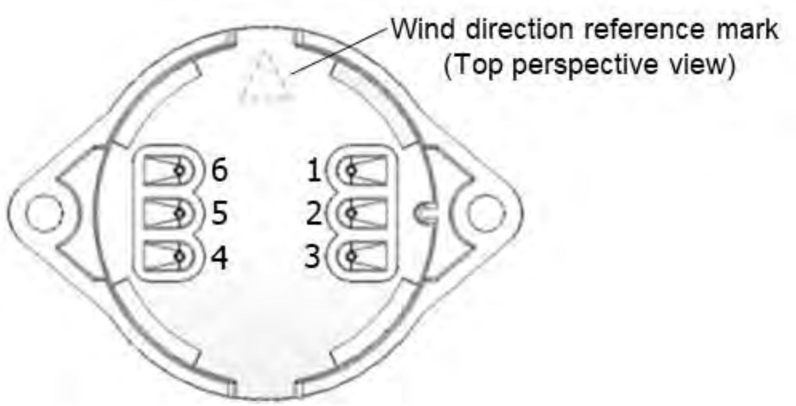


Fig. 2 Pin configuration（Bottom view）

Table 1 Pin configuration table

Pin	Name
1	SCL
2	SDA
3	NC
4	GND
5	VDDIO
6	VDD

TERMINAL EXPLANATIONS

Table 2 Pin table

No.	Pin Name	Type	Function
1	SCL	I/O	Serial clock for I2C communication
2	SDA	I/O	Serial Data (Input and output) for I2C communication
3	NC	-	No connect
4	GND	-	GND
5	VDDIO	I	Power-supply for digital I/O
6	VDD	I	Power-supply for analog circuit

ABSOLUTE MAXIMUM RATINGS

(Unless otherwise specified, Ta=25℃)

Item	Symbol	Min.	Max.	Unit
Storage temperature range	T_{STG}	-25	55	℃
Analog supply voltage	VDD_{MAX}	-0.3	3.6	V
Digital I/O voltage	$VDDIO_{MAX}$	-0.3	3.6	V
Digital input voltage	$VDDIN_{MAX}$	-0.3	VDD+0.3	V

RECOMMENDED OPERATING CONDITIONS

(Unless otherwise specified, Ta=25℃)

Item	Symbol	Min.	Typ.	Max.	Unit
Operating temperature range	T_{OPR}	0	-	40	℃
Analog supply voltage	VDD_{OPR}	2.4	3.3	3.6	V
Digital I/O voltage	$VDDIO_{OPR}$	2.4	3.3	3.6	V
Measurement Media	-	Air (Non-condensing. Restrict to non-corrosive)			V

ELECTRICAL CHARACTERISTICS

Analog characteristics

(Unless otherwise specified, Ta=25°C, VDD=VDDIO=3.3V)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Current consumption	I_{DD}	Average current in one measurement	-	0.7	1.05	mA

Digital I/O

(Unless otherwise specified, Ta=25°C, VDD=VDDIO=3.3V)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Input voltage High level	V_{IH}	SCL、SDA	0.7× VDDIO	-	VDDIO +0.3	V
Input voltage Low level	V_{IL}	SCL、SDA	-0.3	-	0.3× VDDIO	V
Output voltage High level	V_{OH}	SDA I_{OH}=-3mA	0.8× VDDIO	-	-	V
Output voltage Low level	V_{OL}	SCL、SDA I_{OL}=3mA	-	-	0.4	V

Sensor characteristics

(Unless otherwise specified, Ta=25°C, VDD=VDDIO=3.3V)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Wind velocity range	M_{vel}	-	0	-	3	m/s
Wind velocity error	E_{vel}	Wind velocity 0～1.0m/s 4 directions (0,90,180,270deg)	-	±(0.1m/s +5%RD)	-	-
		Wind velocity 1.0～3.0m/s 4 directions (0,90,180,270deg)	-	±25	-	%RD
Wind direction range	M_{dir}		-	-	360	deg
Wind direction error	E_{dir}	Wind velocity 0.3～3m/s 4 directions (0,90,180,270deg)	-	±15	-	deg
Response time	t_{res}	The first time after issuing the Active command	-	3	-	sec
Sampling time	t_s	-	0.5	-	-	sec

FUNCTION EXPLANATION

Function outline

MS002 consists of a MEMS thermal sensor, an operational amplifier, and an analog front-end IC. It converts the analog output voltage from the MEMS thermal sensor to the 24-bit digital value. Reading the correction coefficient, which stored in the sensor, by the user and converting it to the wind velocity value using the 24-bit digital value and the correction coefficient correct can correct variations in sensor characteristics caused by variations in temperature and processes.

State transition table

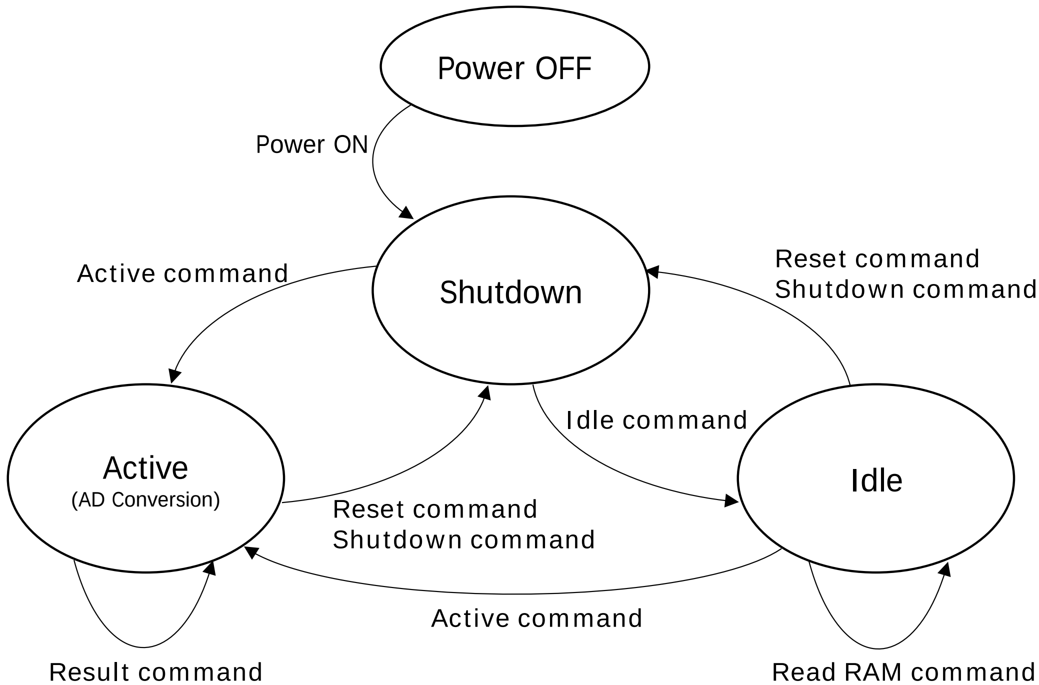


Fig. 3 State transition table

Table 3 State transition table

Command \ State	Shutdown	Active	Idle
Reset	Power on Reset & Initial Boot =>Shutdown state	Power on Reset & Initial Boot =>Shutdown state	Power on Reset & Initial Boot =>Shutdown state
Shutdown	=>Keep state	=>Shutdown state	=>Shutdown state
Active	Reset & Boot Load =>Active state (AD conversion)	Ignore(note[1]) =>Keep state	=>Active state (AD conversion)
Result	Ignore(note[1]) =>Keep state	Output result =>Keep state	Do not issue(note[2]) =>Keep state
Idle	Reset & Boot Load =>Idle state	Do not issue(note[3]) =>Idle state	=>Keep state
Bank SW	Ignore(note[1]) =>Keep state	Change memory Bank =>Keep state	Do not issue(note[4]) =>Keep state
Read RAM	Ignore(note[1]) =>Keep state	Do not issue(note[3]) =>Keep state	Output RAM data =>Keep state

note[1]: NACK is returned to the command.
note[2]: The correct result is not output. Additionally, ACK is returned to the command.
note[3]: Although command is acceptable, it goes unintended behavior since sequence is running.
note[4]: Although command is acceptable, it goes unintended behavior during sequence execution

Command code

Table 4 Command code list

<table>
<tr><th colspan="2" rowspan="3">Command Name</th><th colspan="9">Command Code</th><th rowspan="3">Format</th></tr>
<tr><th rowspan="2">HEX.</th><th colspan="8">BIN.</th></tr>
<tr><th>C7</th><th>C6</th><th>C5</th><th>C4</th><th>C3</th><th>C2</th><th>C1</th><th>C0</th></tr>
<tr><td colspan="2" rowspan="2">Shutdown</td><td>0x90</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>I2C Write format</td></tr>
<tr><td colspan="10">Stop measurement. Change to shutdown status.</td></tr>
<tr><td colspan="2" rowspan="2">Idle</td><td>0x94</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>I2C Write format</td></tr>
<tr><td colspan="10">Start up the internal circuit and put it in the Idle state. Operation only with command code.</td></tr>
<tr><td colspan="2" rowspan="2">Active</td><td>0xA0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>I2C Write format</td></tr>
<tr><td colspan="10">Start AD conversion. Operation only with command code.</td></tr>
<tr><td rowspan="6">Result</td><td rowspan="2">Result0</td><td>0xC0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>Combine format</td></tr>
<tr><td colspan="10">Read result data of X.
ADC data (3 bytes /24 bits) is output MSB first. A negative number is expressed by 2's complement.
For output range, positive output is 000000 h to 7FFFFF h (0 to +8388607 in decimal number), while negative output is FFFFFF h to 800000 h (-1 to -8388608 in decimal number).
However, the measurement data acquired during the usage beyond the recommended operating conditions cannot be guaranteed.</td></tr>
<tr><td rowspan="2">Result1</td><td>0xC2</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>Combine format</td></tr>
<tr><td colspan="10">Read temp coefficient for result data.
ADC data (3 bytes /24 bits) is output MSB first. A negative number is expressed by 2's complement.
For output range, positive output is 000000 h to 7FFFFF h (0 to +8388607 in decimal number), while negative output is FFFFFF h to 800000 h (-1 to -8388608 in decimal number).
However, the measurement data acquired during the usage beyond the recommended operating conditions cannot be guaranteed.</td></tr>
<tr><td rowspan="2">Result2</td><td>0xC4</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>Combine format</td></tr>
<tr><td colspan="10">Read result data of Y.
ADC data (3 bytes /24 bits) is output MSB first. A negative number is expressed by 2's complement.
For output range, positive output is 000000 h to 7FFFFF h (0 to +8388607 in decimal number), while negative output is FFFFFF h to 800000 h (-1 to -8388608 in decimal number).
However, the measurement data acquired during the usage beyond the recommended operating conditions cannot be guaranteed.</td></tr>
<tr><td rowspan="6">BankSW</td><td rowspan="2">BankSW0</td><td>0xB0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>I2C Write format</td></tr>
<tr><td colspan="10">Change memory Bank to Bank0.</td></tr>
<tr><td rowspan="2">BankSW2</td><td>0xB4</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>I2C Write format</td></tr>
<tr><td colspan="10">Change Memory Bank to Bank2</td></tr>
<tr><td rowspan="2">BankSW3</td><td>0xB6</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>I2C Write format</td></tr>
<tr><td colspan="10">Change memory Bank to latest Bank</td></tr>
<tr><td colspan="2" rowspan="2">Read RAM</td><td>0xD4</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>Combine format</td></tr>
<tr><td colspan="10">Read data from RAM. After sending the command code, send 8-bit memory address.
4-byte / 32-bit data is output MSB first.</td></tr>
<tr><td colspan="2" rowspan="2">Reset</td><td>0x72</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>I2C Write format</td></tr>
<tr><td colspan="10">Reset and Return to Shutdown state. It becomes busy for the maximum 1.8msec.
Operation only with command code.</td></tr>
</table>

Sequence

1. Read the correction parameters from the Light breeze sensor after turning on the sensor.
2. The sensor starts to acquire data by issuing Active command (0xA0).
3. Acquire the sensor measurement result (Result 0 to 2) by issuing Result command (0xC0, 0xC2, 0xC4) three seconds after issuing the Active command. After acquiring the result, perform correction calculation of the wind velocity and direction based on the sensor measurement result and correction parameter.
4. The measurement result is subsequently updated every 0.5 seconds. Issuing the Result command every 0.5 seconds allows the user to get the updated measurement result.
5. To end the measurement, issue Shutdown command (0x90).

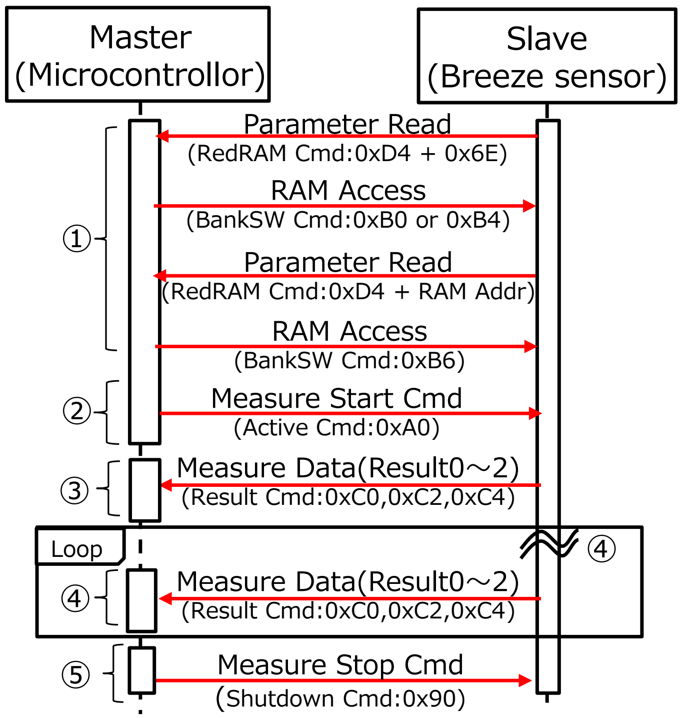


Fig. 4 Sequence

Correction parameter read-out processing

Correction coefficients are saved in the sensor. They are read by the user and converted to the wind velocity value using the sensor output and the coefficient. The correction coefficients are saved in the memory area different from the one at the power-on, and the storage area differs depending on sensors. Therefore, the correction parameters should be read after the sensor is turned on, following to the procedure shown below. After reading, BankSW command must be issued without fail.

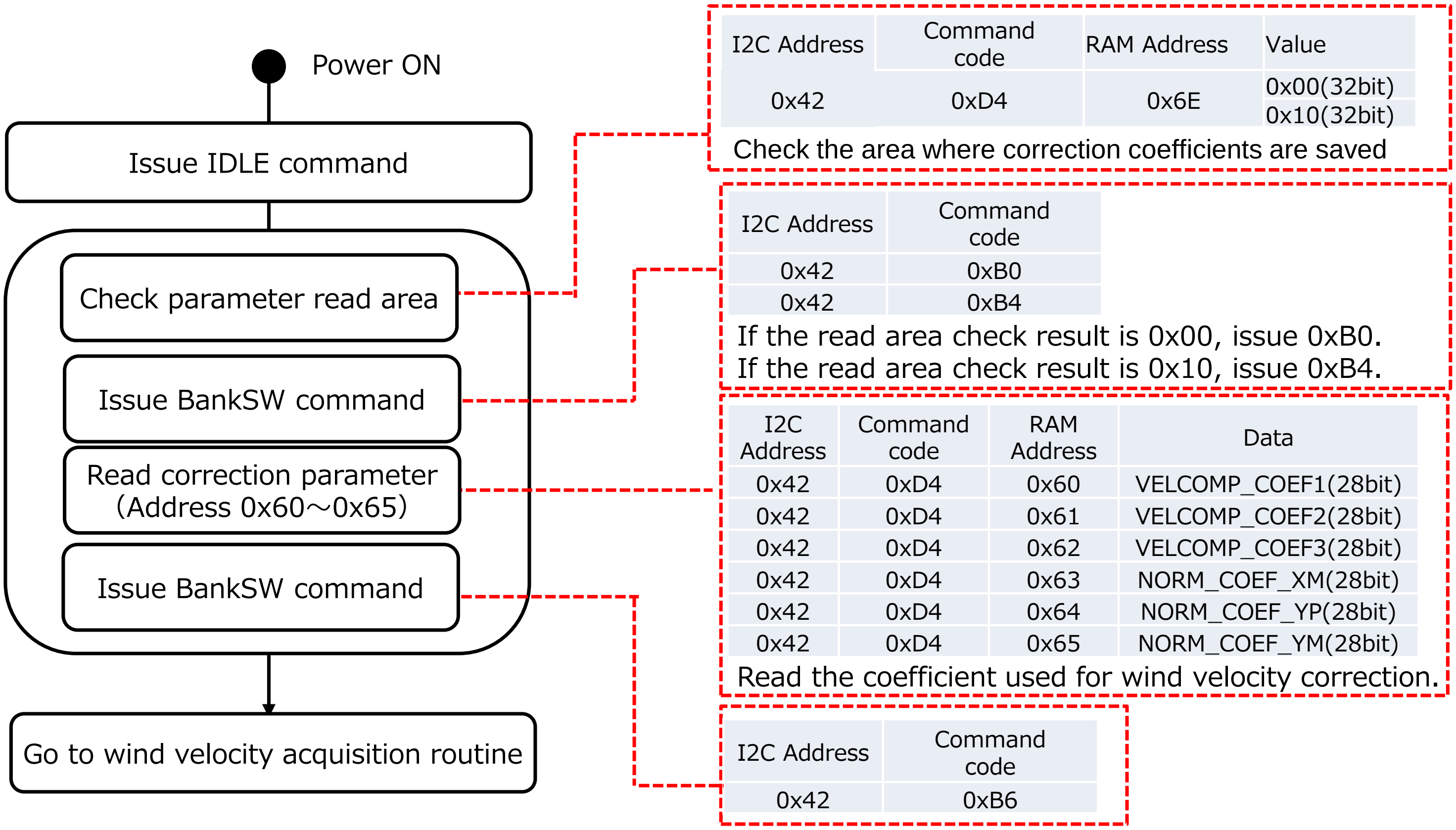


Fig. 5 Correct parameter read-out sequence

Read of correction parameter

Read RAM command reads data with 4 bytes 32bits width of [31:0], but the correction parameter is 28bits of [27:0].

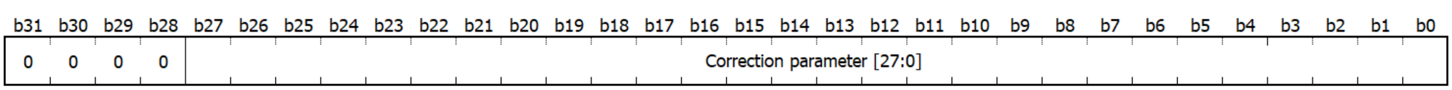


Fig. 6 RAM read data

Wind velocity calculation method

The wind velocity is calculated in the following order: 1. Normalization of sensitivity, 2. Correction of sensitivity temperature characteristics, and 3. Correction of wind velocity.

1. Normalization of sensitivity

The sensor sensitivity varies depending on whether the axis is X or Y, and whether the polarity is + or -. Because of this, the sensitivity needs to be adjusted to + output reference of X axis using the correction parameter.

$$X_{normed} = Result0 * (1 + \mathrm{X_{normcoef}}/2^{27})$$
$$Y_{normed} = Result2 * (1 + \mathrm{Y_{normcoef}}/2^{27})$$

Condition	X_normcoef
Result0>0	1
Result0<0	NORM_COEF_XM(28bit)

Condition	Y_normcoef
Result2>0	NORM_COEF_YP(28bit)
Result2<0	NORM_COEF_YM(28bit)

2. Correction calculation of sensitivity temperature characteristics

The sensitivity is corrected using the temperature correction data (Result1) because the sensitivity characteristics depend on the sensor temperature.

$$X_{tcomp} = X_{normed} * (1 + Result1/1000)$$
$$Y_{tcomp} = Y_{normed} * (1 + Result1/1000)$$

3. Correction calculation of wind velocity

The wind velocity output is calculated by synthesizing output from X and Y axes and multiplying it by the correction coefficient.

$$AD_{temp} = ((X_{tcomp})^2 + (Y_{tcomp})^2) * 2^{-12}$$
$$Vel_{temp} = \alpha * (AD_{temp})^3 + \beta * (AD_{temp})^2 + \gamma * (AD_{temp})^1$$

α	(VELCOMP_COEF_3) * (2^27)^-3
β	(VELCOMP_COEF_2)* (2^27)^-2
γ	(VELCOMP_COEF_1)* (2^27)^-1

$$Vel[m/s] = \left(\sqrt{\sqrt{(Vel_{temp}) * 2}}\right) / 2^5$$

Wind direction calculation method

The upper side of the sensor (with "△" indicated) is defined as 0° . The wind direction is calculated using the data of Result0 and Result2.

$$\theta[°] = arctan(Result0/Result2) \times \frac{180°}{\pi} + b$$

$b = 0$, $Result0 < 0$, $Result2 < 0$
$b = 180$ $Result2 > 0$
$b = 360$, $Result0 > 0$, $Result2 < 0$

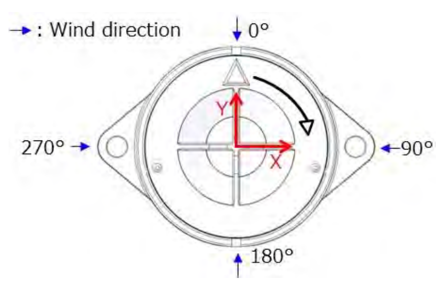


Fig. 7 Definition of angle

Timing chart

TBD

SERIAL COMMUNICATION INTERFACE

It supports I2C as an interface for serial communication.

Baud rate

※This item is not inspected at the time of shipment.
(Unless otherwise specified, Ta=25℃, VDD=3.0~3.6V)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
I2C communication speed	BR_{I2C1}	VDDIO ≧ 2.0V Cb≦100pF	-	-	3.4	Mbps
	BR_{I2C2}	VDDIO < 2.0V Cb≦100pF	-	-	0.4	
	BR_{I2C3}	VDDIO ≧ 2.0V Cb≦400pF	-	-	1.7	
	BR_{I2C4}	VDDIO < 2.0V Cb≦400pF	-	-	0.4	

I2C AC characteristics

※This item is not inspected at the time of shipment

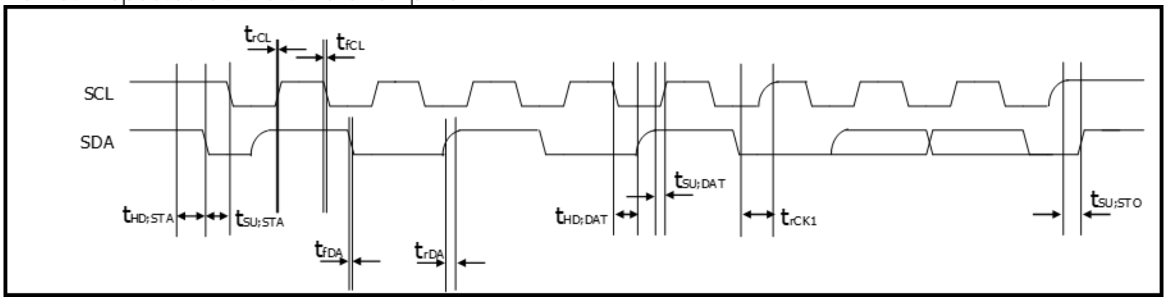


Fig. 8 I2C AC timing chart

Table 5 I2C AC Characteristics

項目	Symbol	VDDIO < 2.0V		VDDIO ≧ 2.0V				Unit
		Fast mode		Hsmode				
				Cb=100pF		Cb=400pF		
		min.	max.	min.	max.	min.	max.	
SCL frequency	f_{SCL}	0	400kHz	0	3.4	0	1.7	MHz
Start condition setup time	$t_{SU;STA}$	600	-	160	-	160	-	ns
Start condition hold time	$t_{HD;STA}$	600	-	160	-	160	-	ns
Stop condition setup time	$t_{SU;STO}$	600	-	160	-	160	-	ns
Data setup time	$t_{SU;DAT}$	100	-	20	-	20	-	ns
Data hold time (note[5])	$t_{HD;DAT}$	20	-	20	70	20	150	ns
SCL rise time	t_{rCL}	-	300	10	40	20	80	ns
Rise time of SCL after ACK (When clock stretch is released.)	t_{rCL1}	-	300	10	80	20	160	ns
SCL fall time	t_{fCL}	10	300	10	-	20	80	ns
SDA rise time	t_{rDA}	-	300	10	80	20	160	ns
SDA fall time	t_{fDA}	10	300	10	80	20	160	ns

note[5]: This product does not have the function to retain data in SDA.
Please ensure the hold of SDA with 20nsec for the area where SCL falling edge is not defined.

I2C format

It conforms to I2C protocol except some special formats. I2C address is the total of 8 bits. The first 7 bits are slave address and the rest of 1 bit is R/W bit. Slave address for MMS002 (7 bits) is 0x42. I2C address (8 bits) will be 0x84 (Write) and 0x85 (Read) by combining with R/W bit.

Table 6 I2C Address

	I2C Address (8 bit)							
	Slave address (7 bit)							R/W bit
HEX.	A6	A5	A4	A3	A2	A1	A0	
0x84	1	0	0	0	0	1	0	0
0x85	1	0	0	0	0	1	0	1

I2C Write format

Please send I2C address of 8 bits (0x84) by Write Mode. Then please send command code.

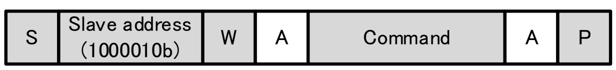
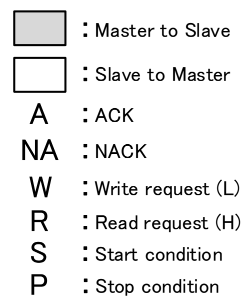


Fig. 9 I2C Write format



Combine format

Please send I2C address (0x84) and the command code by Write Mode. Then please send I2C address (0x85) by Read Mode. It outputs the data MSB first

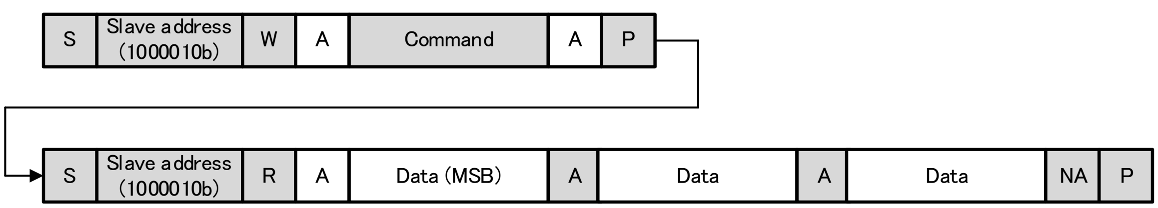


Fig. 10 I2C Combine format

TYPICAL APPLICATION CIRCUIT

TBD

TYPICAL PERFORMANCE CHARACTERISTICS

TBD

PACKAGE STRUCTURE

TBD

DIMENSIONS

UNIT	mm

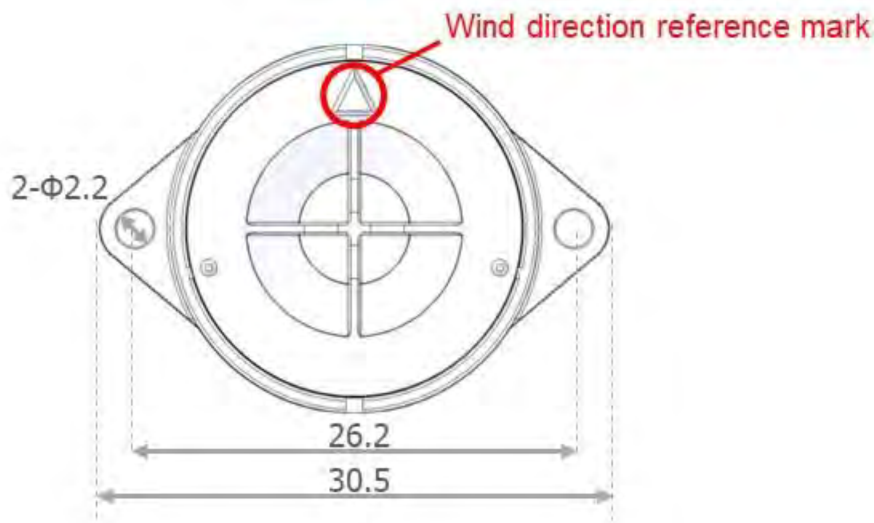


Fig. 11 Top view

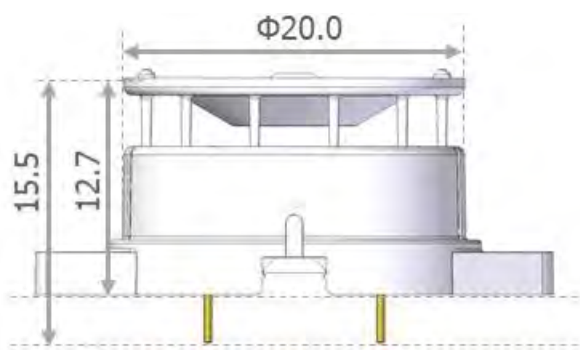


Fig. 12 Side view

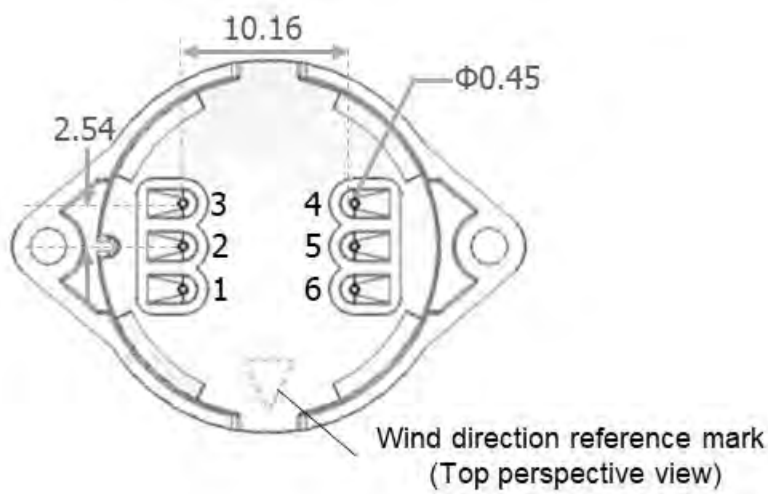


Fig. 13 Bottom view

MARKING CONTENTS

TBD

NOTES

Safety Precautions

- Though Mitsumi Electric Co., Ltd. (hereinafter referred to as "Mitsumi") works continually to improve our product's quality and reliability, semiconductor products may generally malfunction or fail. Customers are responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of this product could cause loss of human life, bodily injury, or damage to property, including data loss or corruption. Before customers use this product, create designs including this product, or incorporate this product into their own applications, customers must also refer to and comply with (a) the latest versions or all of our relevant information, including without limitation, product specifications, data sheets and application notes for this product and (b) the user's manual, handling instructions or all relevant information for any products which is to be used, or combined with this products. Customers are solely responsible for all aspects of their own product design or applications, including but not limited to (a) determining the appropriateness of the use of this product in such design or applications; (b) evaluating and determining the applicability of any information contained in this document, or in charts, diagrams, programs, algorithms, sample application circuits, or any other referenced documents; and (c) validating all operating parameters for such designs and applications. Mitsumi assumes no liability for customers' product design or applications.
- This product is intended for applying to computers, OA units, communication units, instrumentation units, machine tools, industrial robots, AV units, household electrical appliances, and other general electronic units.
- If you have any intentions to apply this product to the units related to the control and safety of transportation units (vehicles, trains, etc.), traffic signaling units, disaster-preventive & burglar-proof units, or the like, contact our sales representatives in advance.
- Don't apply this product to any aeronautical & space systems, submarine repeaters, nuclear power controllers, medical units involving the human life, or the like.
- Before using this product, even when it is not used for the usage written above, notify and present us beforehand if special care and attention are needed for its application, intended purpose, environment of usage, risk, and the design or inspection specification corresponding to them.
- If any damage to our customer is objectively identified to be caused by the defect of this product, Mitsumi is responsible for it. In this case, Mitsumi is liable for the cost limited to the delivery price of this product.

Application considerations during actual circuit design

- The outline of parameters described herein has been chosen as an explanation of the standard parameters and performance of the product. When you actually plan to use the product, please ensure that the outside conditions are reflected in the actual circuit and assembling designs.
- Before using this product, please evaluate and confirm the actual application with this product mounted and embedded.
- To investigate the influence by applied transient load or external noise, It is necessary to evaluate and confirm them with mounting this product to the actual application.
- Any usage above the maximum rating may destroy this product or shorten the lifetime. Be sure to use this product under the maximum rating.
- If you continue to use this product highly-loaded (applying high temperature, large current or high voltage; or variation of temperature) even under the absolute maximum rating and even in the operating range, the reliability of this product may decrease significantly. Please design appropriate reliability in consideration of power dissipation and voltage corresponding to the temperature and designed lifetime after confirming our individual reliability documents (such as reliability test report or estimated failure rate). It is recommended that, before using this product, you appropriately derate the maximum power dissipation (typically, 80% or less of the maximum value) considering parameters including ambient temperature, input voltage, and output current.

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  - Environment with strong static electricity or electromagnetic wave
  - Environment with high temperature or high humidity where dew condensation may occur
- This product is not designed to withstand radioactivity, and must avoid using in a radioactive environment.

PACKING SPECIFICATIONS

TBD

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