R464-0
Rotation sensor integrated circuit

1. General Description

The Rotary Angle Sensor IC is a high-precision magnetic angle detection device integrating AMR sensor bridges, mixed-signal processing circuits, and required capacitors into a single compact package. The device outputs a linear analog voltage proportional to the detected magnetic angle, with programmable reference angle, measurement range, clamp voltages, and output slope. All configuration parameters are stored in non-volatile memory (NVM) with optional write-lock protection.

2. Features

2.1 Functional Features

- Magnetic angle detection using dual MR sensor bridges
- 180° periodic analog output
- Linear output within programmable angle range
- Programmable parameters: Reference angle (αZERO)
  Measurement range (αRANGE)
  Clamp voltages (VHI, VLO)
  Output slope direction (rising/falling)
  Output slope multiplier (SLOPE_MULTI)
- One-wire communication interface
- 44-bit unique identification code

2.2 Diagnostic Features

- ECC-based NVM integrity check
- Register integrity check
- MR sensor wire-open detection
- Magnetic field loss detection
- VCC under-voltage / over-voltage detection
- Power-on reset (POR)
- Ground-open detection
- Diagnostic output override (<4% VCC or >96% VCC)

2.3 Environment & Electrical

- Supply voltage up to 18V
- Operating temperature: −40 to +140°C
- Junction temperature up to 140°C
- NVM retention: 10 years
- NVM endurance: 100 write cycles

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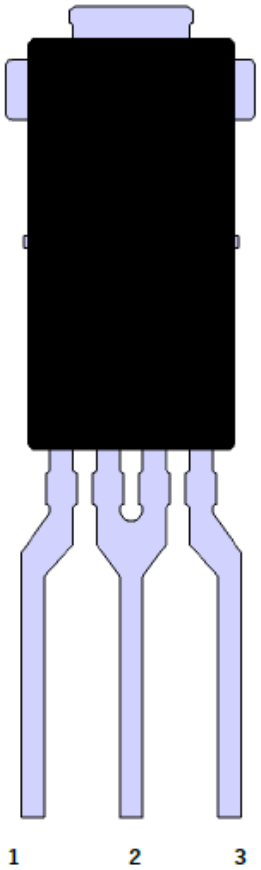
3. Pin Configuration

Pin list and package figure are shown in below table.

Table 1. Pin configuration

Pin #	Pin name	Function	Pin location
1	VCC	Power supply	
2	GND	Ground	
3	OUT	- Analog output - One-wire Communication (For test mode)	

4. Functional Block Diagram

Below figure shows block diagram of the IC. The package includes MR sensor chip, and processing chip and capacitors.

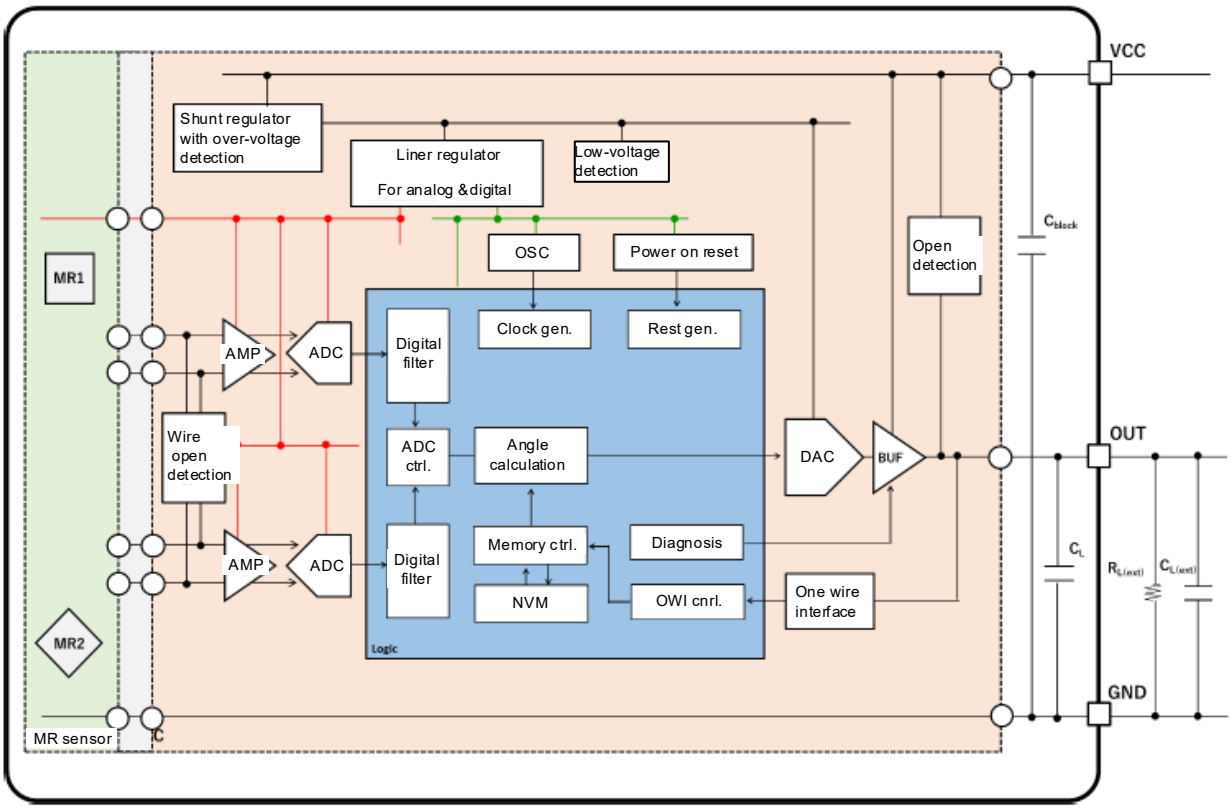


Figure 1. Block diagram

5. Analog Output Characteristics

5.1 Angle Detection Principle

The IC detects the direction of the external magnetic field vector applied parallel to the MR sensor plane. And it outputs voltage as one cycle of 180° . Below angle characteristic shows a behavior with initial configuration.

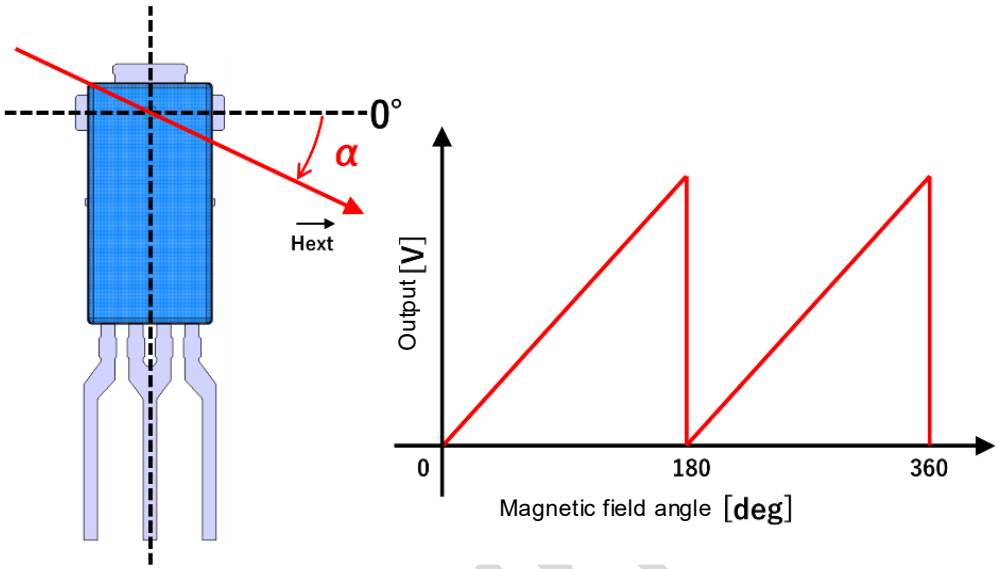


Figure 2. Initial characteristic

5.2 Analog Output Behavior

The IC outputs linear voltage within αRANGE in proportion to VCC as an angle information on OUT terminal. Rising or falling output is selectable by programing. Valid angle range is defined between clamped VLO and VHO. Diagnostic forces output less than 4% VCC or more than 96% VCC. The output angle repeats every 180° as a one cycle.

5.3 Output Transfer Curve

The IC can be configured characteristic to angle detection by programing. The parameters can be programed for are as following;

- Standard angle : αZERO
- Angle range : αRANGE
- Clamp voltage : VHI, VLO
- Slope : SLOPE

The output voltage varies linearly within αRANGE and are clamped to VOL and VHI outside the range. Switch angle α SW which changes clamp voltage is defined by 90° shift from center of α RANGE automatically.

$$\alpha_{sw} = \frac{\alpha_{RANGE}}{2} + \alpha_{ZERO} + 90$$

Next figure shows output characteristic with rising slope. If falling slope is selected, clamp voltage will be revised.

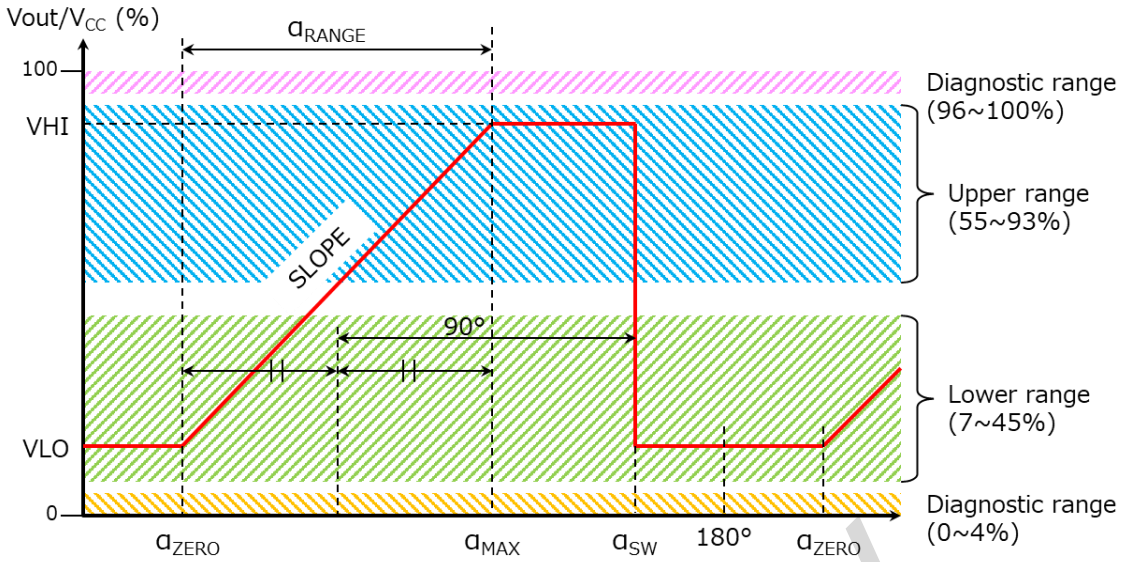


Figure 3. Output characteristic (rising)

Available range of each parameter is described in below table.

Table 2. Range of output characteristics

Parameter	Register name	bit	Range				Initial value
			Min.	Typ.	Max.	Unit	
Standard angle	ANG_ZERO	16	0	-	180	°	0000h (0°)
Angle range	ANG_RANGE	16	10	-	180	°	FFFF (180°)
Clamp voltage LO	CLAMP_LO	16	7	-	45	%VCC	11EBh (7%VCC)
Clamp voltage HI	CLAMP_HI	16	55	-	93	%VCC	EE14h (93%VCC)
Output slope	SLOPE_MULTI	20				-	0DC28h

Note : Value of 180 would be -1LSB, but it is described expediently.
If clamp voltage value is out of range, expected operation is not guarantee.
Slope value should be referred to equation.

Equations of each parameter are described in following.

Table 3. Standard angle (ANG_ZERO)

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
00h	-	-	-	-	-	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
02h	-	-	-	-	-	-	-	-	-	-	-	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}

$$\mathbf{ANG\_ZERO[15:0]} = \frac{\alpha_{ZERO}[deg]}{180} \times 2^{16}$$

Example:

$\alpha_{ZERO} = 0°$ → ANG_ZERO = 0000h

$\alpha_{ZERO} = 45°$ → ANG_ZERO = 4000h

Table 4. Angle range (ANG_RANGE)

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
01h	-	-	-	-	-	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
02h	-	-	-	-	-	-	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	-	-	-	-	-

$$\mathbf{ANG\_RANGE[15:0]} = \frac{\alpha_{RANGE}[deg]}{180} \times 2^{16}$$

Example:

$\alpha_{RANGE} = 10°$ → ANG_RANGE = 0E38h

$\alpha_{RANGE} = 45°$ → ANG_RANGE = 4000h

Table 5. Clamp voltage, LO (CLAMP_LO)

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
03h	-	-	-	-	-	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
05h	-	-	-	-	-	-	-	-	-	-	-	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}

$$\mathbf{CLAMP\_LO[15:0]} = \frac{V_{LO}[\%Vcc]}{100} \times 2^{16}$$

Example:

$V_{LO} = 7\%Vcc$ → CLAMP_LO = 11EBh

$V_{LO} = 45\%Vcc$ → CLAMP_LO = 7332h

Note : CLAMP_LO < 11EBh or 7332h < CLAMP_LO is out of range. Thus, it does not compensate expected operation.

Table 6. Clamp voltage, HI (CLAMP_HI)

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
04h	-	-	-	-	-	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
05h	-	-	-	-	-	-	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	-	-	-	-	-

$$\mathbf{CLAMP\_HI[15:0]} = \frac{V_{HI}[\%Vcc]}{100} \times 2^{16}$$

Example:

$V_{HI} = 55\%Vcc$ → CLAMP_HI = 8CCCh

$V_{HI} = 93\%Vcc$ → CLAMP_HI = EE13h

Note : CLAMP_HI < 8CCCh or EE13h < CLAMP_HI is out of range. Thus, it does not compensate expected operation.

Table 7. Output slope (SLOPE_MULTI)

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
06h	-	-	-	-	-	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
07h	-	-	-	-	-	-	2^{20}	2^{19}	2^{18}	2^{17}	2^{16}	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}

$$\mathrm{SLOPE\_MULTI[19:0]} = \frac{\mathrm{CLAMP\_HI[15:0]} - \mathrm{CLAMP\_LO[15:0]}}{\mathrm{ANG\_RANGE[15:0]}} \times 2^{16}$$

The case of other initial parameters

SLOPE_MULTI = 0DC28h

Table 8. Slope direction

Address	15~1	0	Description
08h	-	SLOPE_DIR	0 : rising, 1 : falling

6. Diagnosis Function

Rotation sensor IC has several diagnosis function. When it detects each of them, output voltage goes to less than 4%VCC or more than 96%VCC. Diagnosis functions except power-on-reset ant ground open are available through programing. But which diagnosis happens is not determined.

Table 9. Diagnosis detection

Address	15~4	3	2	1	0	Description
08h	-	DIAG_OFF	-	-	-	0 : on, 1 : off

6.1 Memory and Register Check

When the IC initializes, the function can detect abnormal in memory of the IC. Memory data of Non-Volatile-Memory (NVM) consists of two bytes. Five MSB bits of the data contributes for ECC parity. ECC function works for below error detect and data correction.

- 1bit error : Correct data automatically (SBC : Single bit error correction)
- 2bit error : Not correct, but detect as error (DBC : Double bit error detection)

Table 10. Memory construction

Byte 2								Byte 1							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ECC parity				Memory data											

When memory check is working, read data is stored in internal register and odd parity check is carried out simultaneously. If reverse bit in the register data is detected, it goes to diagnosis error state. As described before, output voltage of error detection can be selected. Condition to resume register check is only power-on-reset.

6.2 Magnetic Field Loss Detection

When enough magnetic density is not applied to the IC, or magnet is put off, it detects magnetic field loss. The function is available through programing.

Table 11. Magnetic field loss detection

Address	15~2	1	0	Description
08h	-	MAG_LOS	-	0 : off, 1 : on

Note : As far as DIAG_OFF is set to 1 (not available), MAG_LOS data is ignored.

6.3 Wire Open Check between sensor and processing chip

When the IC initializes, wire connection between sensor and processing chip is checked. Diagnosis function is available through programing. The output voltage of diagnosis detection is available through programing. Condition to resume normal operation is only power-on-reset.

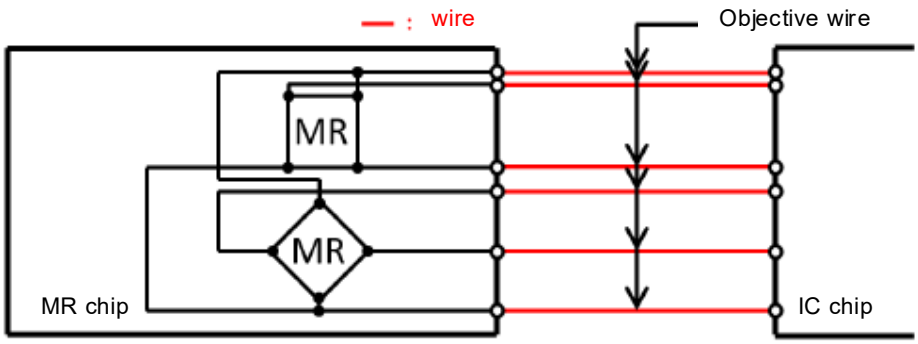


Figure 4. Open check of the wire between sensor and IC

6.4 Over and Under Voltage Detection of VCC

It detects VCC voltage goes down to low voltage (V_{LVDON}) or up to high voltage (V_{OVDON}). Then the output voltage goes to less than 4%VCC. Condition to resume normal operation is that VCC voltage returns more than release low voltage (V_{LVDOFF}) or release over voltage (V_{OVDOFF}).

6.5 Power-on-Reset

It detects less than power-on-reset detection voltage (V_{PORON}) of VCC. During the IC stays on power-on-reset, it suspend all function of the IC, and then output voltage goes to less than 4%VCC. Condition to resume function is VCC voltage resumes more than release power-on-reset voltage (V_{POROFF}). State transition due to VCC voltage is shown in below figure.

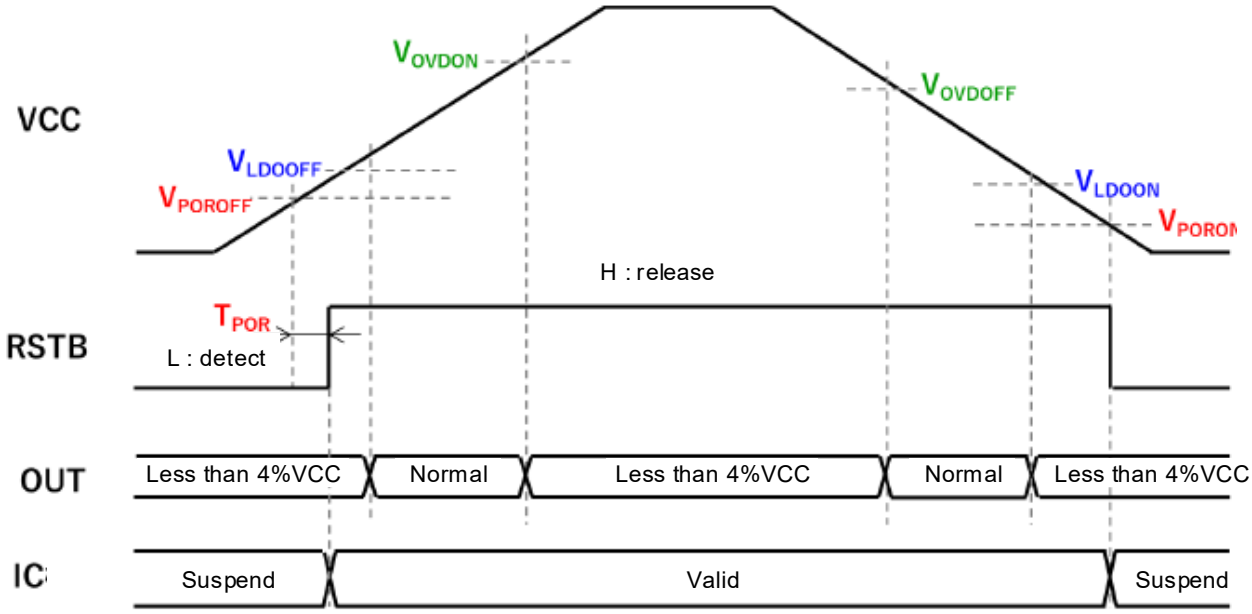


Figure 5. State transition due to VCC voltage

6.6 GND open Detection

It detects GND loss of the IC. In the case that pull-up resister $R_{L(ext)}$, when it detects GND less, then output voltage goes to more than 96%VCC.

6.7 Summary of Diagnosis Dunction

Diagnosis function is listed in below table.

Table 12. Summary of diagnosis function

Diagnosis	Output	When	Resume	ON/OFF
Memory	DIAG_LEVEL	Initializing	Power-on-reset	DIAG_OFF
Register	DIAG_LEVEL	Always	Power-on-reset	
Wire loss	DIAG_LEVEL	Initializing	Power-on-reset	
Over voltage	≦4%VCC	Always	Normal	
Under voltage	≦4%VCC	Always	Normal	
Reset	≦4%VCC	Always	Normal	Always
GND loss	≦4%VCC	Always	Normal	
Mag. loss	DIAG_LEVEL	Always	Normal	MAG_LOS

Table 13. Diagnosis error output voltage

Address	15~3	2	1	0	Description
08h	-	DIAG_LEVEL	-	-	0 : ≦4%VCC 1 : ≧96%VCC

7. Operation

7.1 Timing Chart

When just after the IC is applied supply voltage VCC, the IC stays at power-on-reset. After power-on-reset is released, initial process is carried out. If no abnormal condition is detected it enter normal operation. Or after start operation, it can enter test mode after dedicated test command is transferred on OUT terminal. Below figure shows timing chart under normal operation.

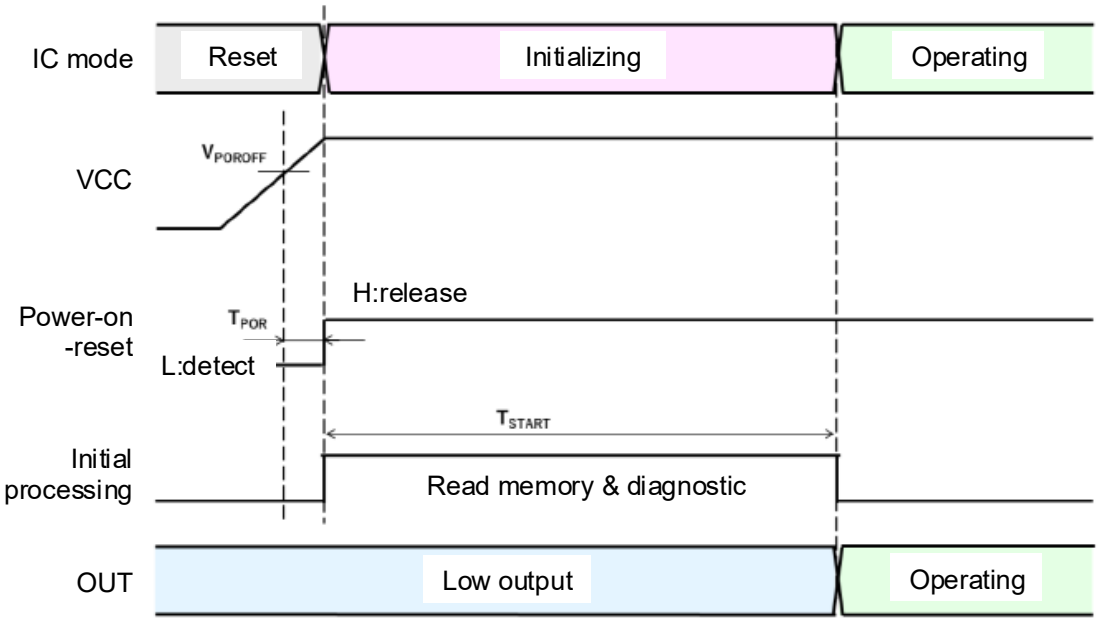


Figure 6. Timing chart (Normal operation)

7.2 State Transition

There are three state, “Reset”, “Initial”, and “Normal”. Explanation of each state is as following in accordance with state transition diagram.

- Reset
  - Applied VCC voltage below V_{POROFF}
  - Suspend function except power supply circuit
  - Enter initial state after power-on-reset release
- Initial
  - Enter power-on-reset release
  - Read data from memory, diagnosis at applied power (memory check, register check, wire check between sensor and IC)
  - Start operation of power and digital circuit
- Normal operation
  - Enter after initial processing completion
  - Perform angle calculation, output analog voltage proportional angle
  - All circuits operate include diagnosis function

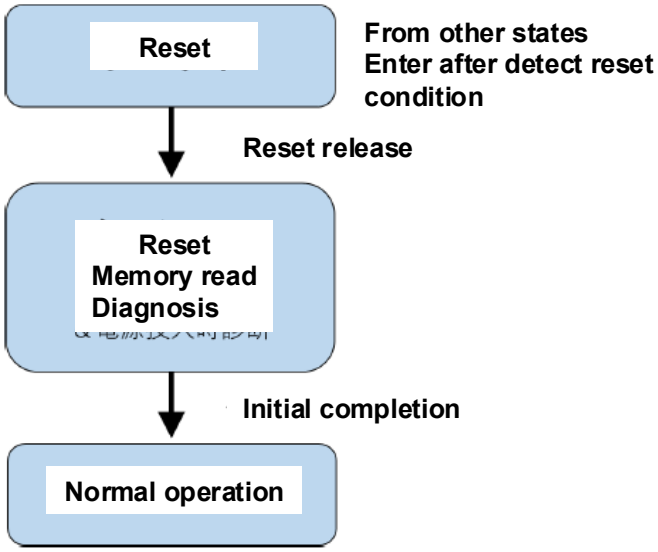


Figure 7. State transition diagram

8. One Wire Interface (For test mode)

The IC has one-wire-interface (OWI) function by bidirectional communication on OUT terminal. It forces to enter test mode. OWI is synchronous digital communication using one wire. It consists of master and slave. The IC performs as slave every time and external test device or program equipment perform as master. Entering test mode makes possibility to access internal memory and registers.

8.1 OWI Protocol

In order to communicate with the IC, three level voltage, VCC, 1/2VCC, and GND voltage should be applied on OUT terminal. Clock and data signal are separated from these three levels internal circuit. Data signal is sampled during clock logic “1”.

Out terminal (Input wave form)	Internal signal	
	Clock	Data
Vcc	1	1
½ Vcc	1	0
GND	0	0

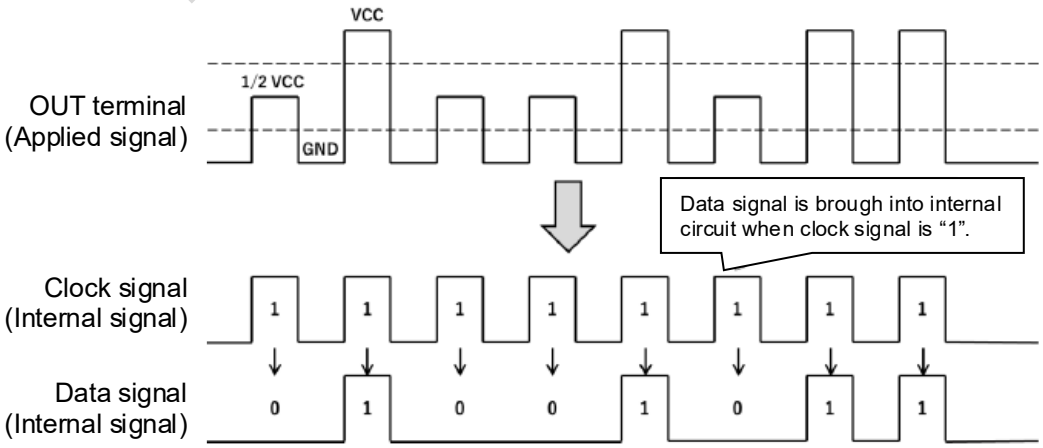


Figure 8. Separation of OWI signal

OWI command composites 25 bits including 8 address bits, 16 data bits, and 1 odd parity bit. Address and data should be transmitted by MSB first, odd parity bit is calculated for 16 data bits. MSB bit of address data indicates to judge write or read.

Table 14. OWI command composition

Address (8 bits)								Data (16 bits)																P
7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	*

↑ Judgement for write or read

↑ Attached for 16 data bits

If the IC receives MSB bit of address data 1, it turns write mode. Thus, 16 data bits and odd parity bit are transmitted from master device. In the case of MSB bit 0, it turns read mode after address data transmission is finished.
After it receives address MSB bit, if there is no command transmission within 100ms(T_{FTO}), it judges to ignore communication. Then, the IC waits for next command.

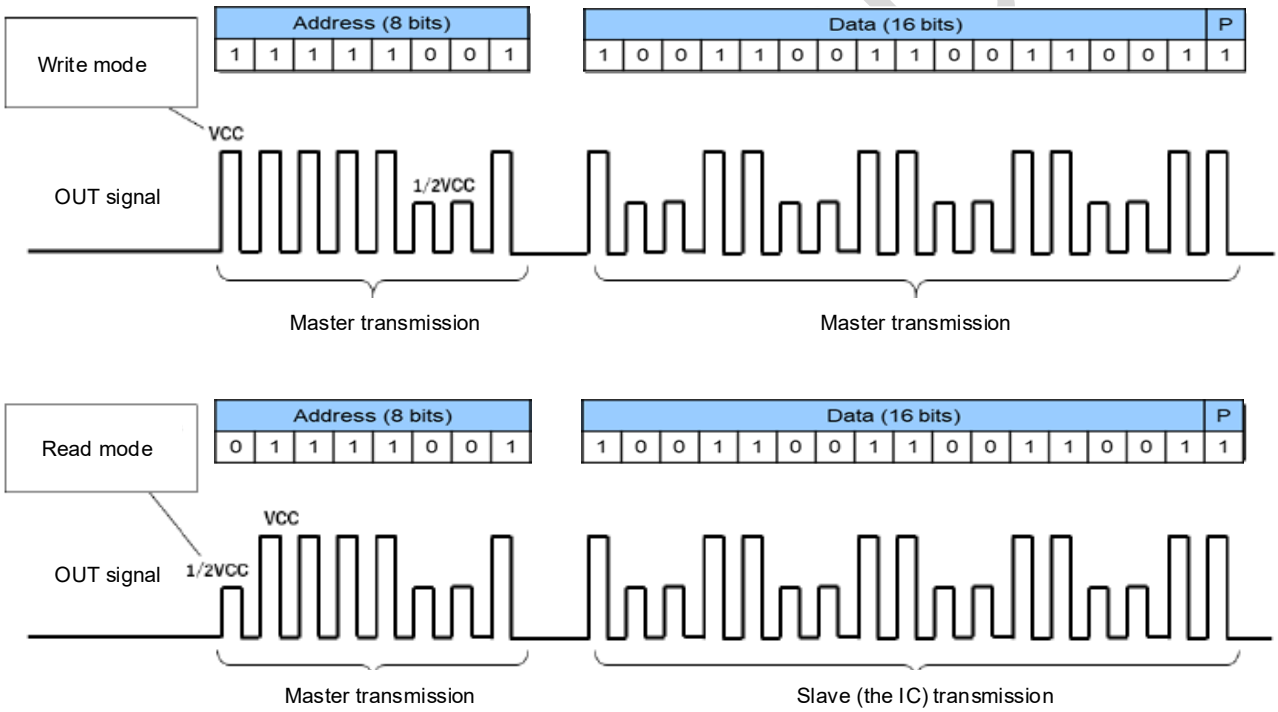


Figure 9. OWI write and read operation

8.2 Entering and Exiting Test Mode

8.2.1 Entering Test Mode

Test mode can be entered after only power supply is provided. Toward entering test mode, user should execute following procedure.

1. Apply power supply (Vcc) to the IC
2. Apply 1/2Vcc voltage for more than 40μs (T_{TMST}) until initial process completion time (T_{START}) on OUT terminal.
3. Transmit test mode command within 1s (T_{TME}) on OUT terminal.

Note : Applying 1/2Vcc leads to state waiting for command. In this state, OUT terminal turns to Hi-Z.
In the case that no test mode commands within 1s (T_{TME}) or difference command, the IC enters normal operation rather than test mode.

Table 15. Entering test mode command

Address (8 bits)								Data (16 bits)															
1	1	1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1

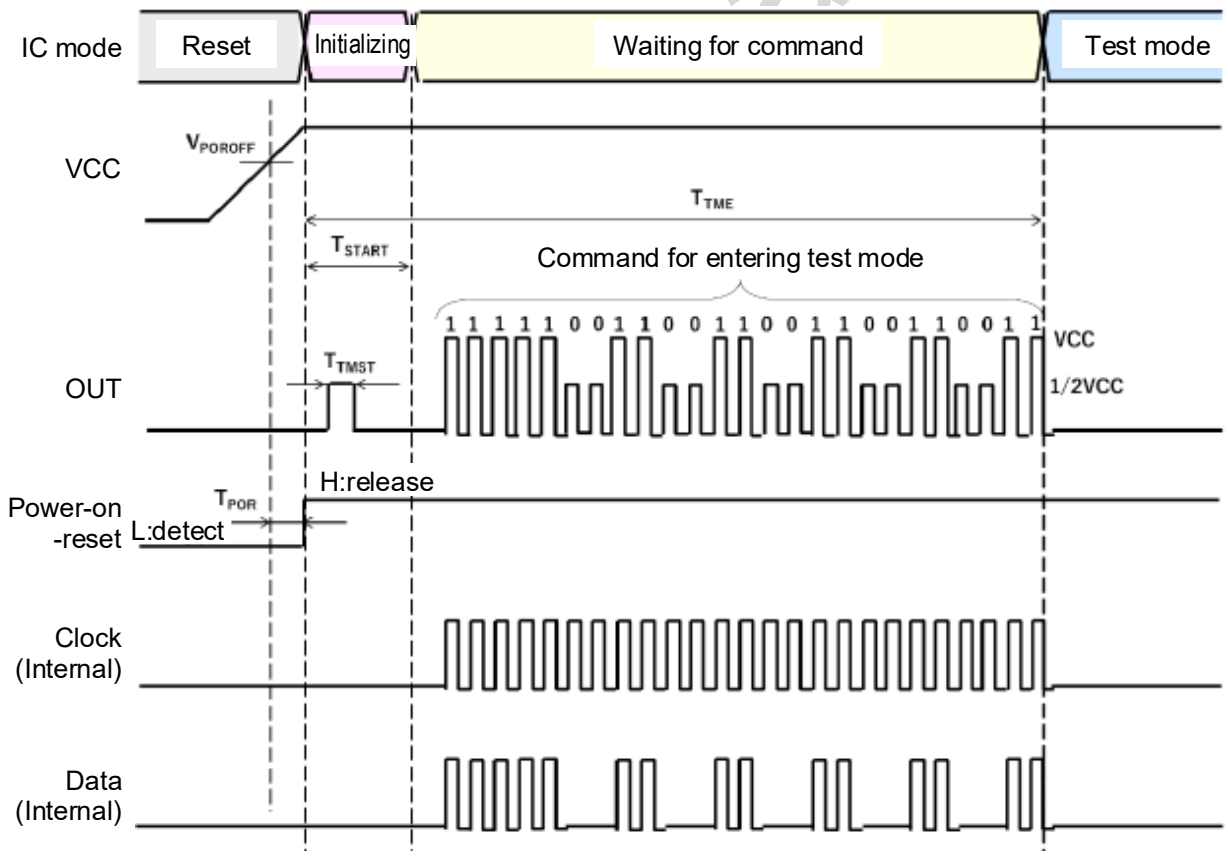


Figure 10. Timing chart of entering test mode

8.2.2 Exiting Test Mode

After the IC transmits or receives command, if there is no command during 10s(T_{TTO}), test mode will be released automatically. After releasing test mode, the IC enters normal operation.

Note : T_{TTO} count starts after receiving last command. As far as new command is transmitted, test mode is maintained.

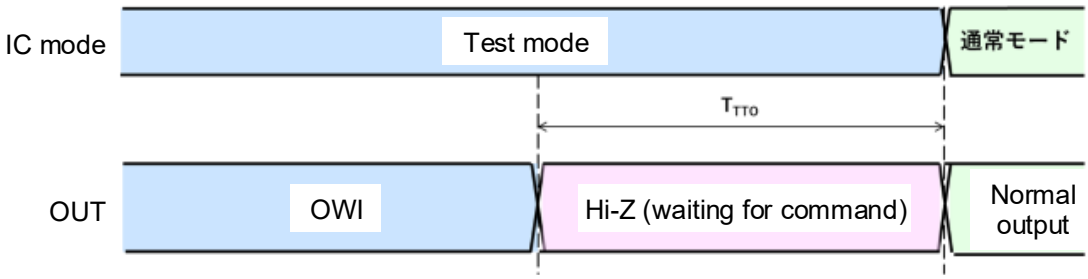


Figure 11. Timing chart of exiting test mode

8.3 Read Mode

In this mode, user can read written data from NVM. Composition of memory data is described as following;

- [15] : DBD (Double-bit Error Detection) flag 0 : No error, 1 : Error detected
- [14] : SBC (Single-bit Error Correction) flag 1 : No error, 1 : Error detected
- [13:11] : 0
- [10:0] : Memory data

Table 16. Composition of read memory

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
00h~0Fh	DBD	SBD	0	0	0	Memory data										

8.4 Write Mode

In this mode, user can write data into NVM or register to change function. It contains command to enter test mode.
In order to write data into memory, dedicated enable command should be transmitted. Write mode can not perform without this command.

- [15:2] : 0
- [1] : Write enable 0 : disable, 1 : enable

Table 17. Write enable command

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0Dh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	WRITE_EN

• [15:11] : 0
• [10:0] : Write data

Table 18. Composition of read memory

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
00h~0Fh	0	0	0	0	0	Memory data										

8.5 Identification Code

The IC has memory which can be defined by user.

Table 19. Identification code

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
09h	0	0	0	0	0	ID_CODE[10:0]										
0Ah	0	0	0	0	0	ID_CODE[21:11]										
0Bh	0	0	0	0	0	ID_CODE[32:22]										
0Ch	0	0	0	0	0	ID_CODE[33:44]										

8.6 Memory Lock

In order to prevent to overwrite unexpected data, the IC has memory lock function. Once this command is executed, the IC prohibits to overwrite data into the memory. Further, user can not cancel memory rock.

• [15:11] : 0
• [10:9] : LOCK[1:0]
• [8:0] : 0

Table 20. Memory lock command

Address	15	14	13~0	Description
0Fh	LOCK[1:0]		0	00b, 01b, 10b : off 11b : lock

8.7 Memory Map

Memory map of NVM is shown in below. The output characteristic parameters need 16 bits, but number of contents is 11 bits. Therefore, parameter data needs two addresses.

Table 21. Memory map

Address	Data 16bit																Description
Write/Read	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
80h/00h	ECC parity					ANG_ZERO [10:0]											Standard angle Angle range
81h/01h	ECC parity					ANG_RANGE [10:0]											
82h/02h	ECC parity					0	ANG_RANGE [15:11]					ANG_ZERO [15:11]					
83h/03h	ECC parity					CLAMP_LO [10:0]											Clamp voltage H Clamp voltage L
84h/04h	ECC parity					CLAMP_HI [10:0]											
85h/05h	ECC parity					0	CLAMP_HI [15:11]					CLAMP_LO [15:11]					
86h/06h	ECC parity					SLOPE_MULTI [10:0]											Output slope
87h/07h	ECC parity					0	0	SLOPE_MULTI [19:11]									
88h/08h	ECC parity					0	0	0	0	0	0	0	DIAG _OFF	DIAG _LEVEL	MAG _LOS	SLOPE _DIR	Diagnosis Polarity
89h/09h	ECC parity					ID_CODE1[10:0]											Identification code
8Ah/0Ah	ECC parity					ID_CODE1[21:11]											
8Bh/0Bh	ECC parity					ID_CODE1[32:22]											
8Ch/0Ch	ECC parity					ID_CODE1[43:33]											
8Dh/D7h	ECC parity					0	0	0	0	0	0	0	0	0	0	0	Reserved
8Eh/0Eh	ECC parity					0	0	0	0	0	0	0	0	0	0	0	
8Fh/0Fh	ECC parity					LOCK1[1:0]		0	0	0	0	0	0	0	0	0	Memory lock
D0h/-	0	0	0	0	0	0	0	0	0	0	0	0	0	WRITE_EN		0	Write enable
F9h/-	TM_KEY[15:0] = 9999h																Test mode enable

9. Electrical Characteristics

9.1 Absolute Maximum Rating

Table 22. Absolute maximum rating

Parameter	Comment	Min.	Typ.	Max.	Unit
Pin voltage (VCC)		-	-	18	V
Pin voltage (OUT)		-	-	VCC+0.3	V
Thermal resistance	Junction to ambient	-	135	-	°C/W
Junction temperature		-	-	150	°C
Storage temperature		-50	-	150	°C
Memory storage lifetime		10	-	-	year
General ESD1	HBM	-	+/-8	-	kV
General ESD2	CDM	-	+/-750	-	V
General ESD3	HMM		+/-8		kV

Warning : Stress beyond those listed under Absolute Maximum Rating may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

9.2 Recommended Operating Condition

Table 23. Recommended operating condition

Parameter	Symbol	Comment	Min.	Typ.	Max.	Unit
Supply voltage	Vcc		4.5	5.0	5.5	V
Temperature range	Ta		-40	25	140	°C
Magnetic density	B		30	-	-	mT
Load resistance	$R_{L(ext)}$	To GND	5	-	-	kΩ
Load capacitance	$C_{L(ext)}$	To GND	-	-	22	nF

9.3 DC Electrical Characteristics

The IC performs under recommended operating condition.

Table 24. DC characteristics

Parameter	Symbol	Comment	Min.	Typ.	Max.	Unit
Current consumption	Icc	Except output current	-	7	10	mA
Start time	T_{START}	From power-on-reset release	-	-	5	ms
POR release voltage	V_{POROFF}		3.1	3.2	3.3	V
POR detect voltage	V_{PORON}		3.0	3.1	3.2	V
POR time	T_{POR}		5	-	50	µs

9.4 Angle Output

Table 25. Angle output characteristics

Parameter	Symbol	Comment	Min.	Typ.	Max.	Unit
Angle resolution	α_{RES}		-	-	0.04	°
Standard angle	α_{ZERO}		0	-	180	°
Angle range	α_{RANGE}		10	-	180	°
Clamp high voltage	V_{HI}		55	-	93	%Vcc
Clamp low voltage	V_{LO}		7	-	45	%Vcc
Clamp voltage deviation	$\Delta V_{HI/LO}$		-0.3	-	0.3	%Vcc
Angle accuracy	ANG_{ERR}		-1.1	-	1.1	°
Angle update cycle	ANG_{REF}		-	250	300	µs
Diagnosis detect high	V_{DH}	Load resistance : 5kΩ	96	-	-	%Vcc
Diagnosis detect high	V_{DH}	Load resistance : 5kΩ	-	-	4	%Vcc
Output resistance when GND open	R_{VCC}	Between VCC and OUT	-	-	210	Ω
VCC capacitance	C_{block}	To GND	100	200	300	nF
OUT capacitance	C_L		1.1	2.2	3.3	nF

9.5 One-Wire-Interface

Table 26. OWI characteristic

Parameter	Symbol	Comment	Min.	Typ.	Max.	Unit
High level input voltage	V_{IH}	$R_{L(ext)}$=5kΩ	80	-	100	%Vcc
Middle level input voltage	V_{IM}	$R_{L(ext)}$=5kΩ	40	-	60	%Vcc
Low level input voltage	V_{IL}	$R_{L(ext)}$=5kΩ	0	-	20	%Vcc
High level output voltage	V_{OH}	$R_{L(ext)}$=5kΩ	80	-	100	%Vcc
Mid level output voltage	V_{OM}	$R_{L(ext)}$=5kΩ	40	-	60	%Vcc
Low level output voltage	V_{OL}	$R_{L(ext)}$=5kΩ	0	-	20	%Vcc
Input pulse width	T_{IW}		0.4	0.5	0.6	T_{IBIT}
High input rise time	T_{IRISE_H}		-	-	5	µs
Middle input rise time	T_{IRISE_M}		-	-	5	µs
High input fall time	T_{IFALL_H}		-	-	5	µs
Middle input fall time	T_{IFALL_M}		-	-	5	µs
Input 1 bit time	T_{IBIT}		210	-	-	µs

Table 25. OWI characteristic (Continue)

Parameter	Symbol	Comment	Min.	Typ.	Max.	Unit
Output pulse width	T_{OW}		0.4	0.5	0.6	T_{IBIT}
High output rise time	T_{ORISE_H}	$R_{L(ext)}$=5kΩ, $C_{L(ext)}$=22nF	-	5	10	μs
Middle output rise time	T_{ORISE_M}	$R_{L(ext)}$=5kΩ, $C_{L(ext)}$=22nF	-	2	10	μs
High output fall time	T_{OFALL_H}	$R_{L(ext)}$=5kΩ, $C_{L(ext)}$=22nF	-	5	10	μs
Middle output fall time	T_{OFALL_M}	$R_{L(ext)}$=5kΩ, $C_{L(ext)}$=22nF	-	2	10	μs
Output 1 bit time	T_{OBITH}		310	480	650	μs
Master-slave handover	T_{TKO_MS}		25	30	35	μs
Slave-master handover	T_{TKO_SM}		25	30	35	μs
Test mode time-out	T_{TTO}	See below of this table	9	10	11	s
One frame time-out	T_{FTO}		90	100	110	ms
Memory write time	T_{PROG}	Per byte	2	-	-	ms
Test mode transition enable time	T_{TME}		0.9	1.0	1.1	s
Test mode transition time	T_{TMST}		40	-	-	μs

Note : Time-out counter starts after completion of command transition. As far as it continues to transmit command, it resets the counter.

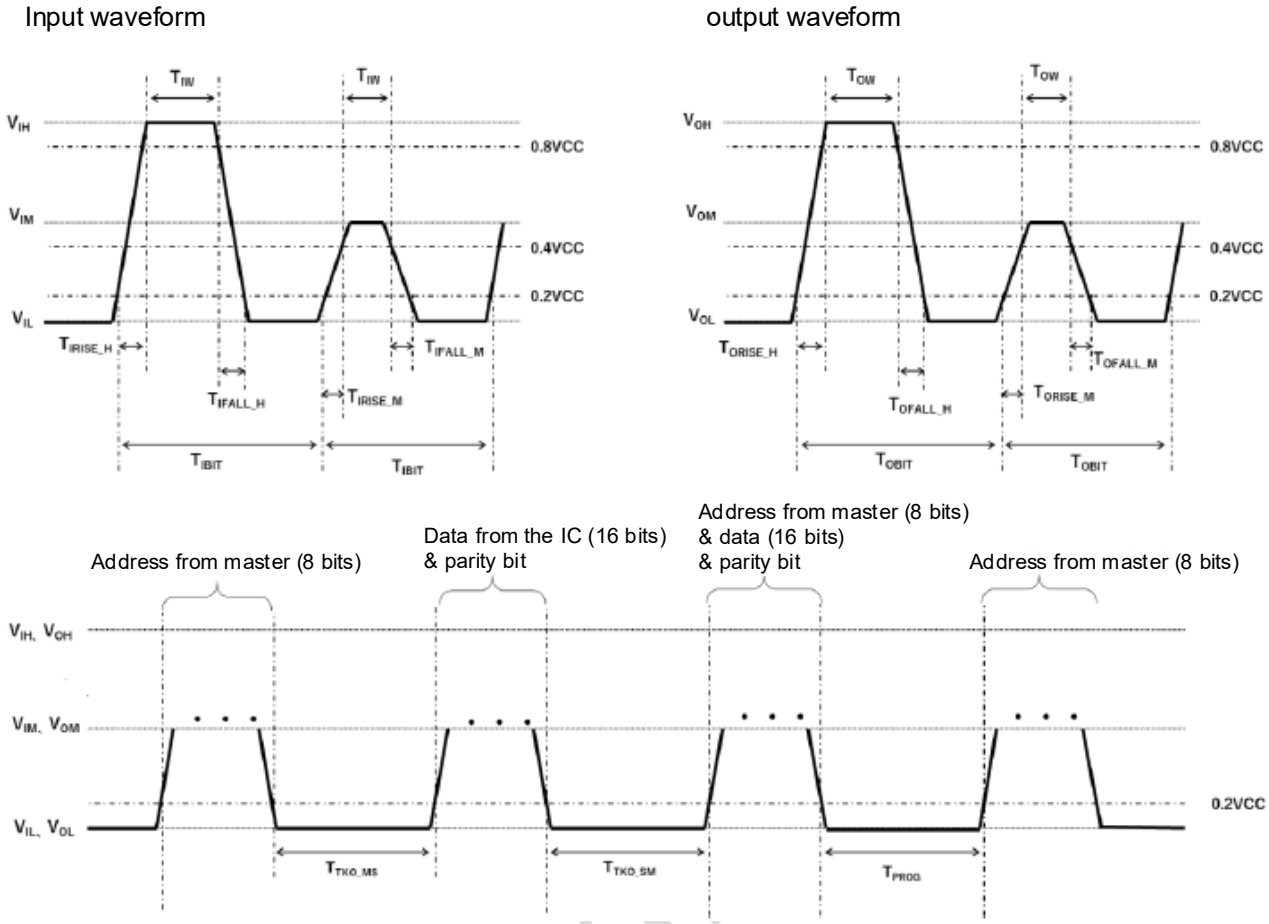


Figure 12. OWI input / output waveform

9.6 Definition of angle accuracy

Angle measurement errors in rotation angle sensor IC are caused by initial deviation from ideal linear line and output fluctuations due to temperature changes. Ideal output of the sensor has a linear relationship with the magnetic angle θ, and this ideal straight line is expressed as $\Phi_{REF}(\theta)$. The measurement angle calculated from the output of the sensor IC is expressed as $\Phi_m(\theta, Ta)$, where Ta means ambient temperature.
To effectively define the error, the angle range and clamp voltage are set as follows;

- Angle range : $\alpha_{RANGE} = 180°$
- Clamp voltage : $V_{LO} = 7\%VCC$, $V_{HI} = 93\%VCC$

9.6.1 Initial Deviation

First, the ideal straight line is expressed as $\Phi_{REF}(\theta)$, and best straight line of measurement is expressed as $\Phi_{BSL}(\theta)$. Initial deviation ANG_{INI} is defined as maximum deviation between measured angular output at Ta=25°C and $\Phi_{BSL}(\theta)$. The expression as equation is shown in below.

$$ANG_{INI} = MAX\{ \Phi_{meas}(\theta n, Ta=25°C)_{ini} - \Phi_{BSL}(\theta n) \}$$

where θn is any angle within angle range, and $\Phi_{meas}(\theta n, Ta=25°C)_{ini}$ is initial measured angle at 25°C.

9.6.2 Temperature Change

Temperature change ANG_{DFT} is defined as maximum value which subtracted ANG_{INI} from

measured deviation entire temperature range.

$$ANG_{DFT} = MAX\{ \Phi_{meas}(\theta n, Ta=-40\sim140°C)_{ini} - ANG_{INI} \}$$

where $\Phi_{meas}(\theta n, Ta=-40\sim140°C)_{ini}$ is measured angle at -40~140°C.

9.6.3 Angle Accuracy

Angle accuracy ANG_{ERR} is sum of initial deviation and temperature change. Below equation represents maximum angular error over the entire temperature range when manufactured based on Ta=25°C.

$$ANG_{ERR} = ANG_{INI} + ANG_{DFT}$$

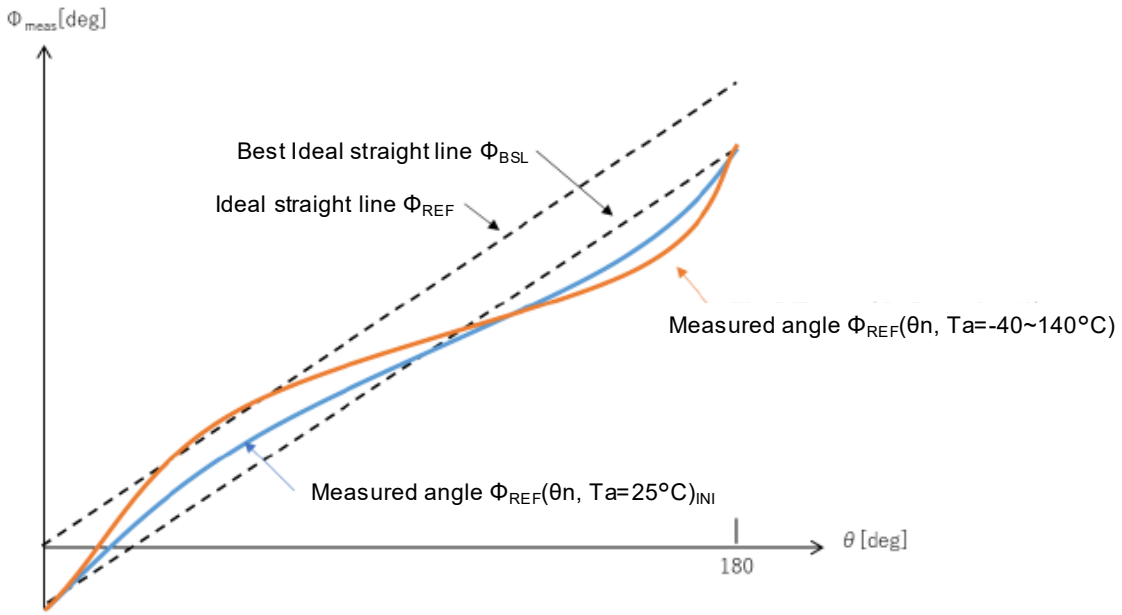


Figure 13. Angle accuracy definition

10. Package Information

10.1 Outline Dimensions

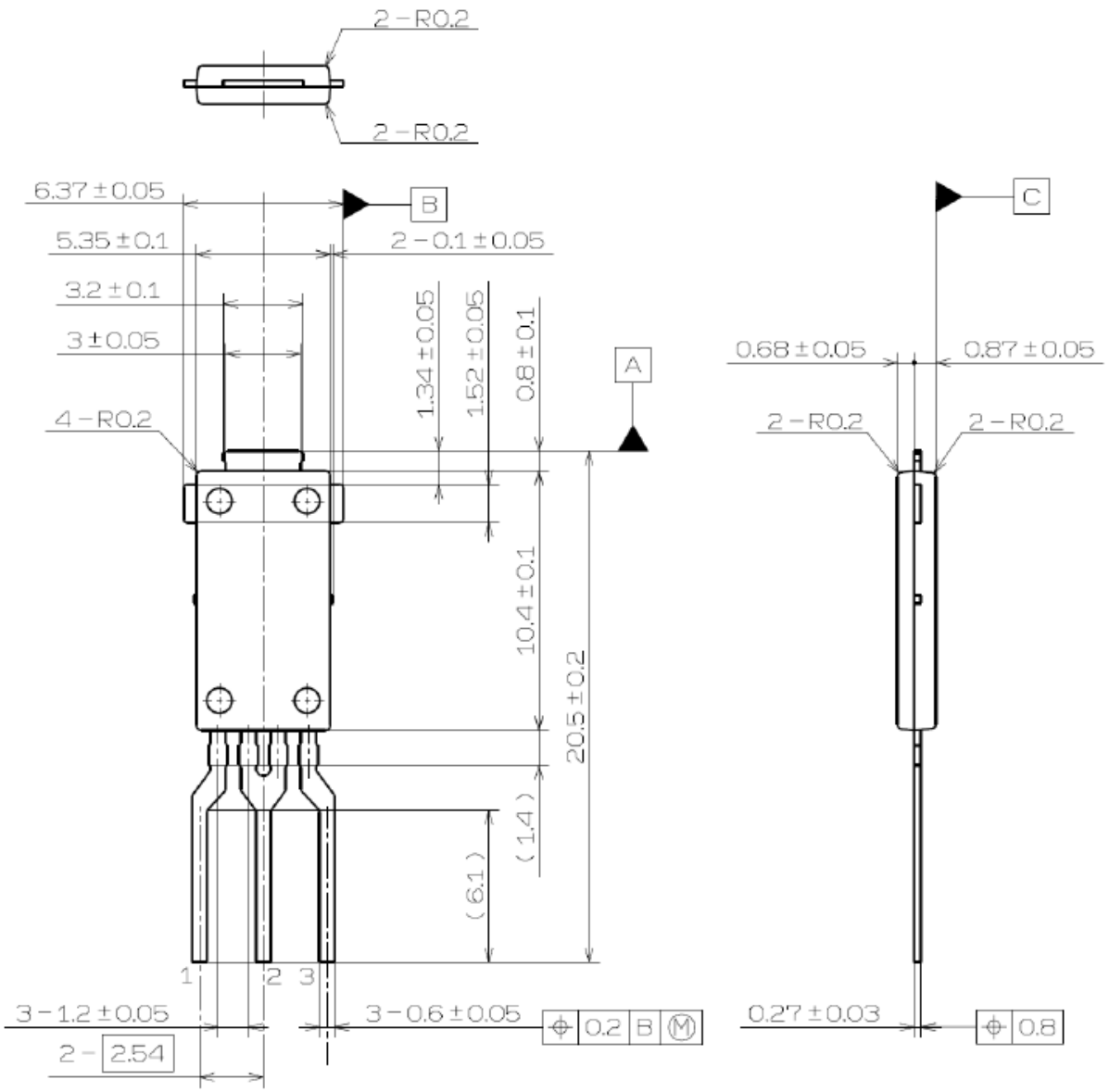


Figure 14. Package outline (Unit : millimeters)

10.2 Marking Specification

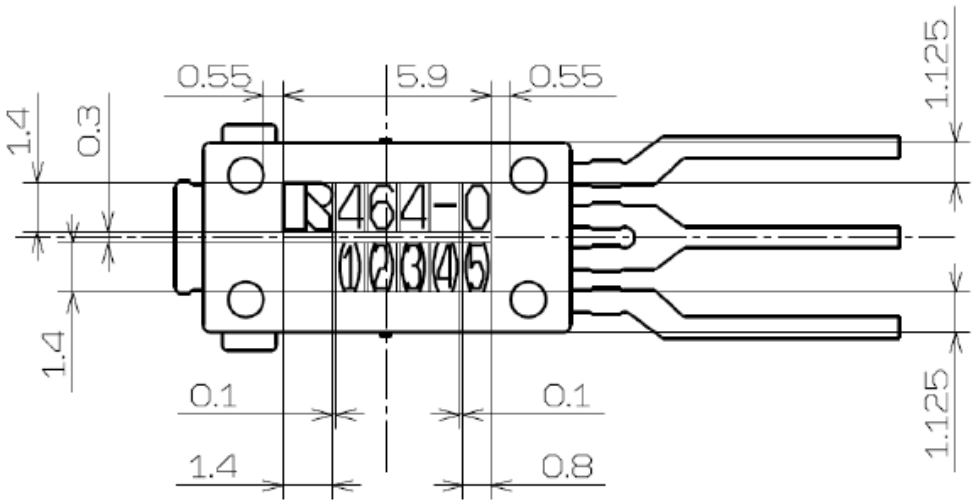


Figure 15. Marking outline (Unit : millimeters)

10.3 Sensor Position

Saying “center of sensing” in below figure means center point of MR sensor chip. Linearity error does not include the error linked to magnet position.

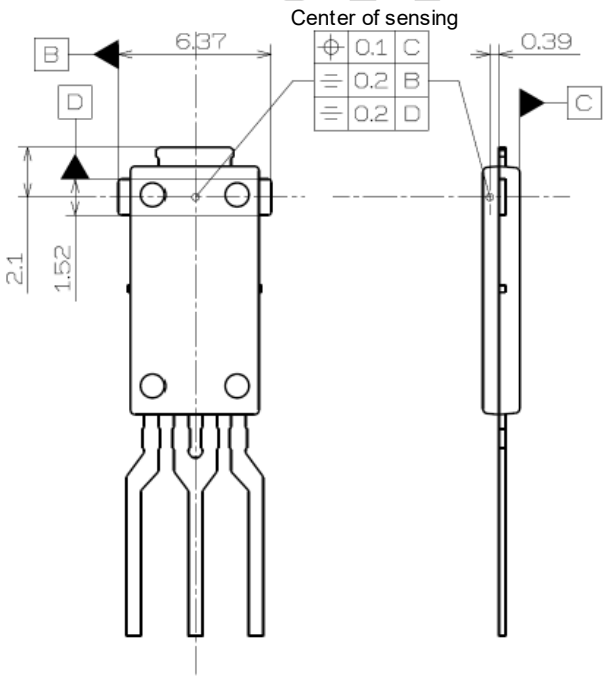


Figure 16. Sensing position (Unit : millimeters)

11. Warranty Condition and Precautions for Use

Absolute Maximum Ratings
If this product is used under conditions exceeding the applied voltage and specified temperature range, damage or degradation may occur. This product should be used within the range specified in this specification

Electrostatic Discharge (ESD)
Semiconductor products, including this product, may be damaged or degraded by the application of static electricity. Please take appropriate electrostatic discharge (ESD) precautions to prevent the application of excessive voltage during manufacturing and handling process.

Radiation-Resistant Design
This product is not designed for radiation resistance.

Restriction on Use
This product is not intended for use in applications requiring a high level of reliability, such as aerospace equipment, unclear power plants, or medical devices for sustaining human life, where failure could result in significant damage. We make no warranties regarding suitability for use in these applications and assumes no liability for any damages resulting from such use. If use in these applications is to be considered, we and user must consult with each other in advance and make a separate written agreement.

Safety Design Precautions
In applications where malfunction or failure of this product could potentially affect life, body, or property, please ensure that the product itself incorporates appropriate safety designs, including redundancy and fail-safe mechanisms. This product alone does not guarantee the safety of the entire system.

Notice Regarding intellectual Property Rights and Licenses
The information contained in this specification is provided for the purpose of understanding the specifications of the product and does not constitute a license to use or implement any intellectual property rights (including third-party intellectual property rights) related to the product, unless otherwise agreed upon under this contract. All matters concerning the ownership, use, handling, and other aspects of intellectual property rights related to the product, as well as the handling of the product including analysis, disassembly, modification, and reverse engineering, shall be governed by the provisions of this contract.

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Trademarks and product names mentioned in this specification belong to their respective owners.

Notes on Using This Document
Before using this product, please ensure you fully understand the contents described in this specification document.

Positioning of this Specification

This specification sets forth the technical conditions and handling precautions for the delivered items based on this contract, and does not change or limit the content of the quality assurance liability, liability for non-conformity, or other rights and obligations stipulated in this contract. In the event of any doubt regarding the interpretation or application of the contents of this specification, the provisions of this contract shall prevail.

12. Environment / Legal Compliance

Environmental Compliance

Regarding compliance with environmental laws and regulations (RoHS, REACH, etc.) for this product, Party A is responsible for confirming and complying with these regulations, including their applicability to the actual product.

Legal and Regulatory Compliance

This product may be subject to export control under Japan's Foreign Exchange and Foreign Trade Act. Please contact us if necessary regarding the applicability of export control list regulations. Please note that this product is not designed for military use, and its use for military purposes is prohibited.