AK09973D

3D Magnetic Smart Switch Sensor

1. General Description

AK09973D is a 3D magnetic smart switch sensor IC with high sensitivity and wide measurement range utilizing our latest Hall sensor technology.
Our ultra-small package of AK09973D incorporates magnetic sensors, chopper stabilized signal amplifier chain, and all necessary interface logic for detecting weak to strong magnetic fields in the X-axis, Y-axis and Z-axis independently. From its compact foot print, thin package, and extremely low power consumption, it is suitable for a smartphone and wearable application.

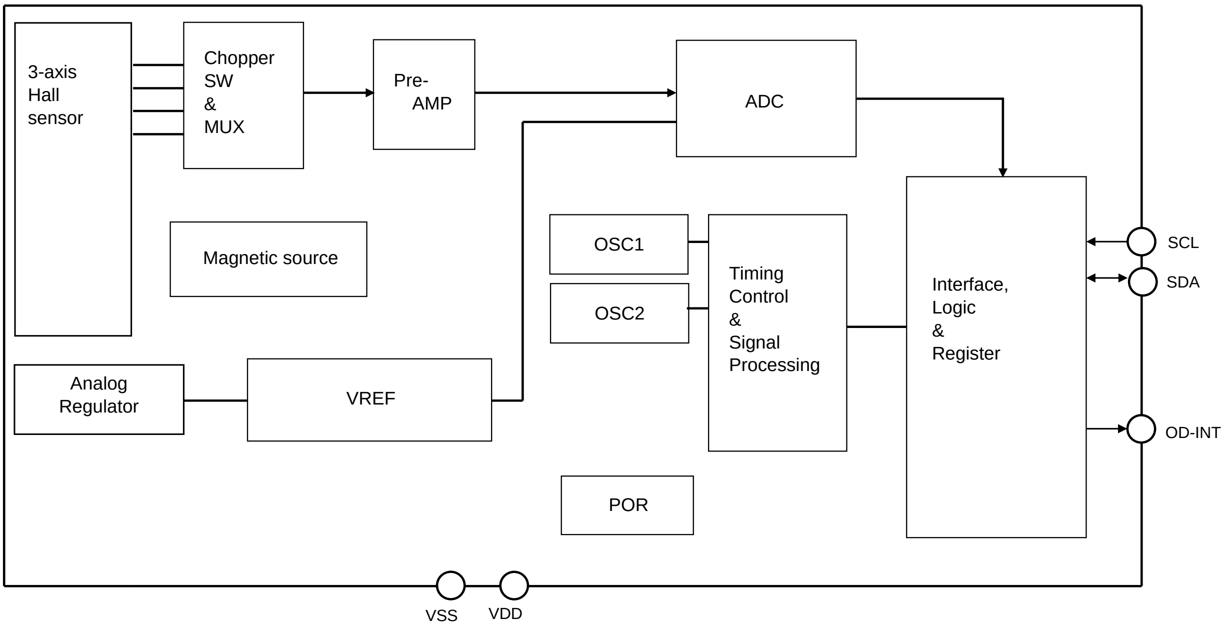
2. Features

- Functions:
  - 16-bit data out for each 3-axis magnetic component
  - Built-in A to D Converter for magnetometer data output
  - Sensor measurement range and sensitivity
    - High sensitivity setting
      - Sensitivity: 1.1 µT/LSB (typ.)
      - Measurement range: ±36 mT
    - Wide range setting
      - Sensitivity: 3.1 µT/LSB (typ.)
      - Measurement range: X and Y-axis → ±34.9 mT, Z-axis → ±101.5 mT
  - Serial interface
    - I^2C bus interface
      Standard mode, Fast mode and Fast mode plus
    - Two selectable slave addresses
  - Operation mode
    - Power-down, Single measurement, Continuous measurement, Self-test
  - 3-axis programmable switch function
  - Output pin for event notification
    - OD-INT pin
  - DRDY function for measurement data ready
  - Magnetic sensor overflow monitor function
  - Built-in power on reset function
  - Built-in oscillator for internal clock source
  - Selectable sensor drive
    - Low power drive / Low noise drive
- Operating temperature:
  - -30˚C to +85˚C
- Operating supply voltage:
  - 1.65 V to 1.95 V
- Current consumption (VDD = 1.8 V, +25˚C):
  - Power-down: 1.0 µA (typ.)
  - Measurement:
    - Average current consumption at 10 Hz / 100 Hz repetition rate
      - Low power drive: 3.5 µA(typ.) at 10 Hz, 22 µA(typ.) at 100 Hz
      - Low noise drive: 11 µA(typ.) at 10 Hz, 101 µA(typ.) at 100 Hz
- Package
  - AK09973D 5-pin WL-CSP (BGA) package: 1.18 mm × 0.78 mm × 0.55 mm

3. Table of Contents

4. Block Diagram and Functions

4.1. Block Diagram



4.2. Functions

Block	Function
3-axis Hall sensor	Monolithic Hall elements.
Chopper SW & MUX	Multiplexer for selecting Hall elements.
Analog Regulator	Internal power supply.
Pre-AMP	Differential amplifier used to amplify the magnetic sensor signal.
ADC	Convert analog output to digital output.
OSC1	Generates an operating clock for sensor measurement.
OSC2	Generates an operating periodic clock for sequencer.
POR	Power On Reset circuit. Generates reset signal on rising edge of VDD.
VREF	Generates temperature independent reference voltage.
Interface Logic & Register	Exchanges data with an external CPU. OD-INT pin indicates some magnetic event (selectable). I^2C bus interface using two pins (SCL and SDA). Standard mode, Fast mode and Fast mode plus are supported.
Timing Control & Signal Processing	Generates a timing signal required for internal operation. Magnetic sensitivity adjustment and switch calculation for switch function.
Magnetic source	Generates magnetic field for Self-test of magnetic sensor.

5. Pin Configurations and Functions

AK09973D has two pin connections shown in the tables below. The slave address can be switched by changing the pin connection.

Connection 1: Slave address = 10h

Pin No.	Pin name	Function name	I/O	Type	Function
B1	IF1	OD-INT	O	Digital	Open-drain interrupt pin "L" active. Refer to section 10.7. Connect this pin to VSS when not using OD-INT.
B3	IF2	SDA	I/O	Digital	Control data input/output pin Input: Schmitt trigger, Output: Open-drain
A1	VDD	VDD	-	Power	Positive power supply pin
A2	VSS	VSS	-	Ground	Ground pin
A3	SCL	SCL	I	Digital	Control clock input pin Input: Schmitt trigger

Connection 2: Slave address = 11h

Pin No.	Pin name	Function name	I/O	Type	Function
B1	IF1	SDA	I/O	Digital	Control data input/output pin Input: Schmitt trigger, Output: Open-drain
B3	IF2	OD-INT	O	Digital	Open-drain interrupt pin "L" active. Refer to section 10.7. Connect this pin to VSS when not using OD-INT.
A1	VDD	VDD	-	Power	Positive power supply pin
A2	VSS	VSS	-	Ground	Ground pin
A3	SCL	SCL	I	Digital	Control clock input pin Input: Schmitt trigger

6. Absolute Maximum Ratings

Vss = 0 V

Parameter	Symbol	Min.	Max.	Unit
Power supply voltage	Vdd	-0.3	+2.5	V
Input voltage	VIN	-0.3	Vdd + 0.3	V
Input current	IIN	-10	+10	mA
Storage temperature	Tst	-40	+125	˚C

Note:
If the device is used in conditions exceeding these values, the device may be destroyed. Normal operations are not guaranteed in such exceeding conditions.

7. Recommended Operating Conditions

Vss = 0 V

Parameter	Symbol	Min.	Typ.	Max.	Unit
Operating temperature	Ta	-30	-	+85	˚C
Power supply voltage	Vdd	1.65	1.8	1.95	V
Input voltage	VIN	1.1	1.8	Vdd	V

8. Electrical Characteristics

The following conditions apply unless otherwise noted:
Vdd = 1.65 V to 1.95 V, VIN = 1.1 V to Vdd, Temperature range = -30˚C to +85˚C
Typical condition: Vdd = 1.8 V, Temperature = +25˚C

8.1. DC Characteristics

Parameter	Symbol	Pin	Condition	Min.	Typ.	Max.	Unit
High level input voltage*[1]	VIH	SCL IF1 IF2	-	1.00	-	Vdd + 0.3	V
Low level input voltage*[1]	VIL	SCL IF1 IF2	-	-0.3	-	0.42	V
Input current*[1]	IIN	SCL IF1 IF2	VIN = Vss or Vdd	-10	-	+10	μA
Hysteresis input voltage*[2]	VHS	SCL IF1 IF2	-	0.15	-	-	V
Low level output voltage	VOL	IF1 IF2	IOL*[3] ≤ +20mA	-	-	0.33	V
Current consumption*[4]	IDD1	VDD	Power-down mode VIN = Vdd	-	1	3	μA
	IDD2		When magnetic sensor is driven	-	1.4	2.2	mA
	IDD3		When self-test is driven	-	5.6	-	mA

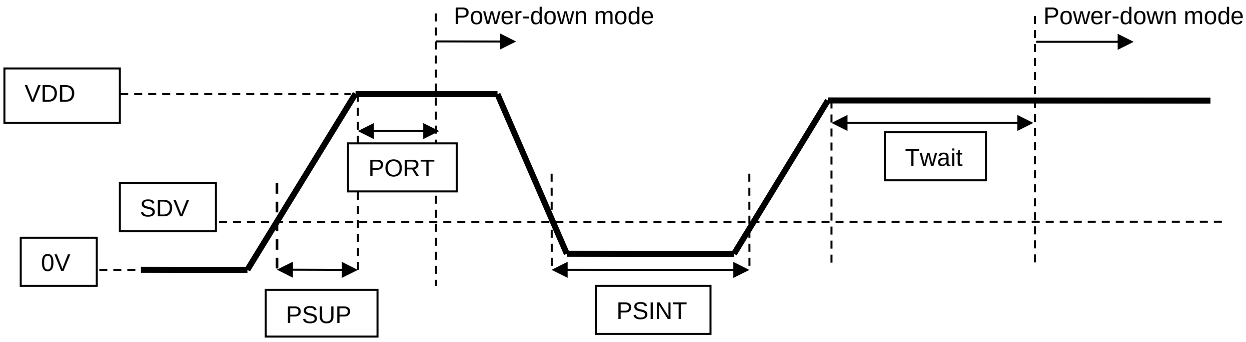
Notes:
* 1. As for IF1 and IF2 pins, the specification is applied when these pins are used for SDA function.
* 2. Schmitt trigger input (reference value for design).
* 3. IOL: Low level output current.
* 4. Without any resistance load.

8.2. AC Characteristics

Parameter	Symbol	Pin	Condition	Min.	Typ.	Max.	Unit
Power supply rise time* 5	PSUP	VDD	Period of time that VDD changes from 0.2 V to Vdd.	-	-	50	ms
POR completion time* 5	PORT		Period of time after PSUP to Power-down mode* 6	-	-	100	µs
Power supply turn off voltage* 5	SDV		Turn off voltage to enable POR to restart* 6	-	-	0.2	V
Power supply turn on interval* 5	PSINT		Period of time that voltage lower than SDV needed to be kept to enable POR to restart	100	-	-	µs
Wait time before mode setting	Twait	-	-	100	-	-	µs

Notes:
* 5. Reference value for design.
* 6. When POR circuit detects the rise of VDD voltage, it resets internal circuits and initializes the registers. After reset, AK09973D transits to Power-down mode.

[Voltage waveform of VDD]



8.3. AC Characteristics of OD-INT

Parameter	Symbol	Pin	Condition	Min.	Typ.	Max.	Unit
Fall time of OD-INT	TfOD	OD-INT	CL = 50 pF RL = 20 kΩ(typ.)	-	-	250	ns

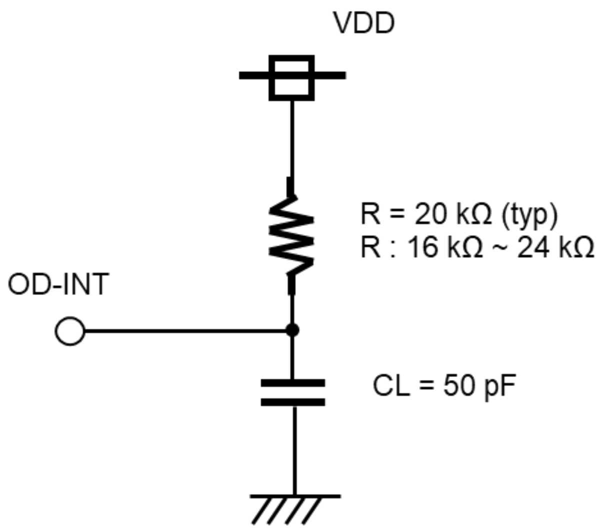
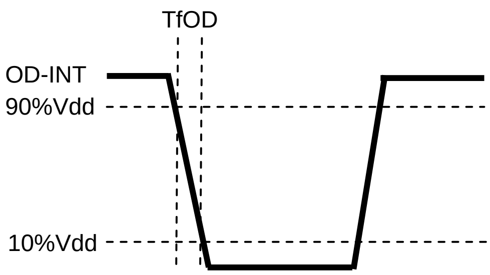


Figure 8.1 Condition of operation verification

[Rise time and fall time]



8.4. Overall Characteristics

Table 8.1 High sensitivity setting

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Measurement data output bit	DBIT	-	-	16	-	Bit
Time for measurement	TSM	SDR bit = “0” (Low noise drive)	-	0.825	0.908	ms
		SDR bit = “1” (Low power drive)	-	0.265	0.292	
Magnetic sensor sensitivity	BSE	Ta = 25˚C, SMR bit = “0”	0.99	1.1	1.21	µT/LSB
Magnetic sensor measurement range* 7	BRG	Ta = 25˚C, SMR bit = “0”	±32.44	±36.04	±39.64	mT
Magnetic sensor initial offset* 8	BOF	Ta = 25˚C	-500	-	+500	LSB
Noise* 7	NIS	SDR bit = “0” (Low noise drive)	-	5.5	-	µTrms
		SDR bit = “1” (Low power drive)	-	15.0	-	

Table 8.2 Wide range setting

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Measurement data output bit	DBIT	-	-	16	-	Bit
Time for measurement	TSM	SDR bit = “0” (Low noise drive)	-	0.825	0.908	ms
		SDR bit = “1” (Low power drive)	-	0.265	0.292	
Magnetic sensor sensitivity	BSE	Ta = 25˚C, SMR bit = “1”	2.79	3.1	3.41	µT/LSB
Magnetic sensor measurement range* 7	BRG	Ta = 25˚C, X and Y-axis, SMR bit = “1”	±31.42	±34.91	±38.4	mT
		Ta = 25˚C, Z-axis, SMR bit = “1”	±91.42	±101.57	±111.73	
Magnetic sensor initial offset* 8	BOF	Ta = 25˚C	-177	-	+177	LSB
Noise* 7	NIS	SDR bit = “0” (Low noise drive)	-	6.8	-	µTrms
		SDR bit = “1” (Low power drive)	-	18.0	-	

Notes:
* 7. Reference value for design. Under steady magnetic field.
* 8. Value of measurement data register on shipment test without applying magnetic field on purpose .

8.5. I²C Bus Interface

I²C bus interface is compliant with Standard mode, Fast mode and Fast mode plus. As for tR and tF, specifications for Fast mode plus are applied.

■ Fast mode plus

Symbol	Parameter	Min.	Typ.	Max.	Unit
fSCL	SCL clock frequency	-	-	1000	kHz
tHIGH	SCL clock “High” time	0.26	-	-	µs
tLOW	SCL clock “Low” time	0.5	-	-	µs
tR	SDA and SCL rise time	-	-	120	ns
tF	SDA and SCL fall time	-	-	120	ns
tHD:STA	Start Condition hold time	0.26	-	-	µs
tSU:STA	Start Condition setup time	0.26	-	-	µs
tHD:DAT	SDA hold time (vs. SCL falling edge)	0	-	-	µs
tSU:DAT	SDA setup time (vs. SCL rising edge)	50	-	-	ns
tSU:STO	Stop Condition setup time	0.26	-	-	µs
tBUF	Bus free time	0.5	-	-	µs
tSP	Noise suppression pulse width	-	-	50	ns

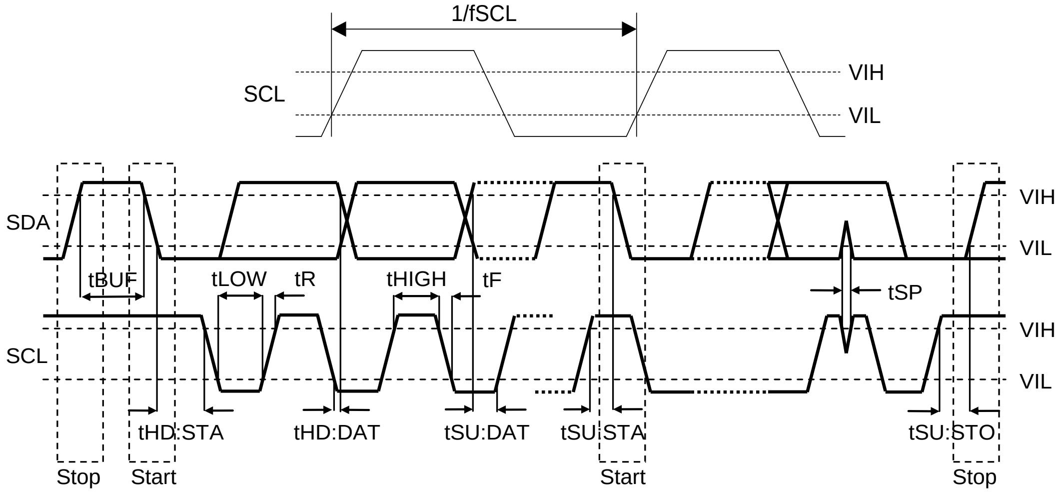
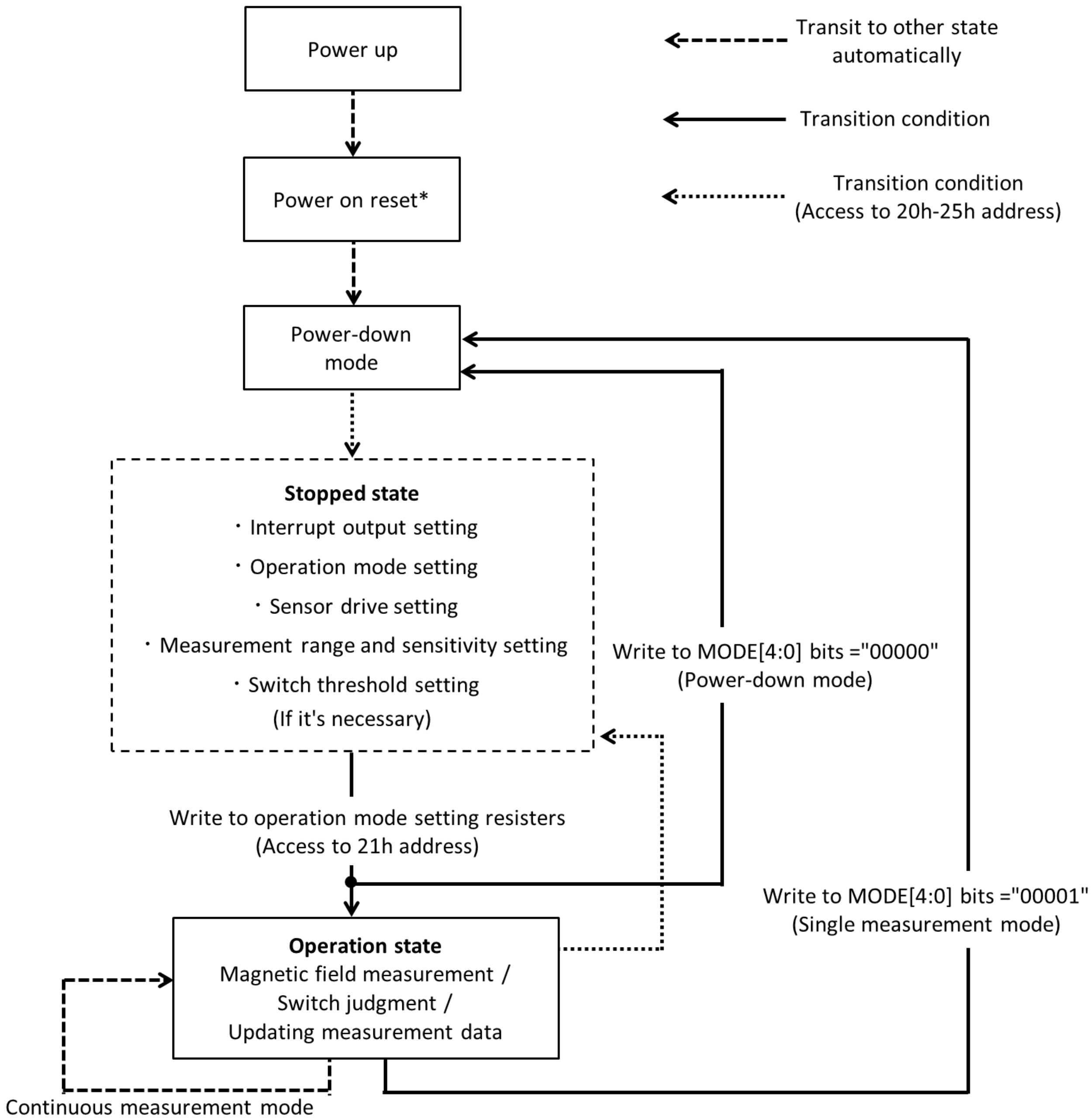


Figure 8.2 I²C bus interface timing

9. Status Description

9.1. State Transition Diagram



*After reset is completed, all resisters are initialized and AK09973D transits to Power-down mode automatically.

Figure 9.1 State transition diagram

9.2. Power States

When VDD is turned on from Vdd = OFF (0 V), all registers in AK09973D are initialized by POR circuit and transit to Power-down mode automatically.

Table 9.1 Power States

State	VDD	Power state
1	OFF (0 V)	OFF (0 V). It does not affect external interface.
2	1.65 V to 1.95 V	ON

10. Functional Descriptions

10.1. Reset Functions

AK09973D has two types of reset;

I. Power on Reset (POR)
When Vdd rise is detected, POR circuit operates, and AK09973D is reset. After reset is completed, all registers are initialized and AK09973D transits to Power-down mode.

II. Soft reset
AK09973D is reset by setting SRST bit = “1”. After reset is completed, all registers are initialized and AK09973D transits to Power-down mode automatically.

10.2. Operation modes

AK09973D has following eleven operation modes:

(1) Power-down mode (MODE[4:0] bits = “00h,03h,05h,07h,09h,0Bh,0Dh,0Fh, ≥ 11h”)

(2) Single measurement mode (MODE[4:0] bits = “01h”)
- Sensor is measured for one time and data is output. Transits to Power-down mode (MODE[4:0] bits = “00h”) automatically after measurement ended.

(3) Continuous measurement mode 1 (MODE[4:0] bits = “02h”)
- Sensor is measured periodically in 5 Hz. Transits to other operation mode by writing MODE[4:0] bits directly.

(4) Continuous measurement mode 2 (MODE[4:0] bits = “04h”)
- Sensor is measured periodically in 10 Hz. Transits to other operation mode by writing MODE[4:0] bits directly.

(5) Continuous measurement mode 3 (MODE[4:0] bits = “06h”)
- Sensor is measured periodically in 20 Hz. Transits to other operation mode by writing MODE[4:0] bits directly.

(6) Continuous measurement mode 4 (MODE[4:0] bits = “08h”)
- Sensor is measured periodically in 50 Hz. Transits to other operation mode by writing MODE[4:0] bits directly.

(7) Continuous measurement mode 5 (MODE[4:0] bits = “0Ah”)
- Sensor is measured periodically in 100 Hz. Transits to other operation mode by writing MODE[4:0] bits directly.

(8) Continuous measurement mode 6 (MODE[4:0] bits = “0Ch”)
- Sensor is measured periodically in 500 Hz. Transits to other operation mode by writing MODE[4:0] bits directly.

(9) Continuous measurement mode 7 (MODE[4:0] bits = “0Eh”)
- Sensor is measured periodically in 1000 Hz. Transits to other operation mode by writing MODE[4:0] bits directly. This mode only enables when AK09973D is set Low power mode (SDR bit = “1”). When set this mode on Low noise mode (SDR bit = “0”), sensor is measured periodically in 500 Hz.

(10) Continuous measurement mode 8 (MODE[4:0] bits = “10h”)
- Sensor is measured periodically in 2000 Hz. Transits to other operation mode by writing MODE[4:0] bits directly. This mode only enables when AK09973D is set Low power mode (SDR bit = “1”). When set this mode on Low noise mode (SDR bit = “0”), sensor is measured periodically in 500 Hz.

(11) Self-test mode (STEST bit = “1”)
- Self-test mode is used to check if the magnetic sensor is working normally. This mode only enables when AK09973D is set Single measurement mode.

10.2.1. Description of Each Operation Mode

10.2.1.1. Power-down Mode

Power to almost all internal circuits is turned off, all registers are accessible in Power-down mode and data stored in read/write registers are remained. They can be reset by reset function.

10.2.1.2. Single Measurement Mode

When Single measurement mode (MODE[4:0] bits = “01h”) is set, magnetic sensor measurement is started. After magnetic sensor measurement and signal processing is finished, measurement magnetic data is stored to measurement data registers (HX, HY, HZ and HV registers), then AK09973D transits to Power-down mode automatically. On transition to Power-down mode, MODE[4:0] bits turns to “0”. At the same time, DRDY bit in ST register turns to “1” and SW bits in ST register turn to another state when measurement magnetic data exceed a setup threshold value.

10.2.1.3. Continuous Measurement Mode 1,2,3,4,5,6,7 and 8

When Continuous measurement modes (1 to 8) are set, magnetic sensor measurement is started periodically at 5 Hz, 10 Hz, 20 Hz, 50 Hz, 100 Hz, 500 Hz, 1000 Hz and 2000 Hz respectively. After magnetic sensor measurement and signal processing is finished, measurement magnetic data is stored to measurement data registers and all circuits except for the minimum circuit required for counting cycle length are turned off (Power Save: PS). When the next measurement timing comes, AK09973D wakes up automatically from PS and starts measurement again.
Continuous measurement mode ends when a different operation mode is set. When user access to Setting Registers (address 20h to 25h), AK09973D stops updating switch states and measurement data registers.

Table 10.1 Continuous measurement modes

Operation mode	Register setting (MODE[4:0] bits)	Measurement frequency [Hz]
Continuous measurement mode 1	0 0010	5
Continuous measurement mode 2	0 0100	10
Continuous measurement mode 3	0 0110	20
Continuous measurement mode 4	0 1000	50
Continuous measurement mode 5	0 1010	100
Continuous measurement mode 6	0 1100	500
Continuous measurement mode 7	0 1110	1000
Continuous measurement mode 8	1 0000	2000

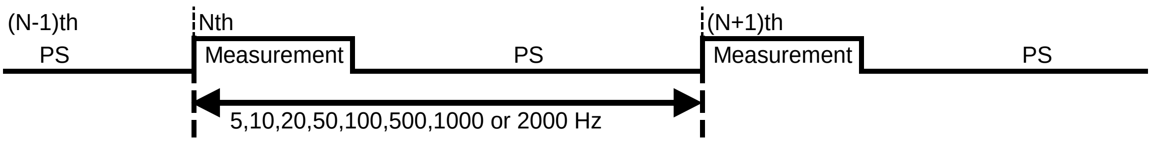


Figure 10.1 Continuous measurement modes

10.3. Data Ready

When measurement data is stored and ready to be read, DRDY bit in ST register turns to “1”. This is called “Data Ready”. When DRDYEN bit in CNTL1 register is “1”, OD-INT pin notify user of the Data Ready state. When any of measurement data register (HX,HY,HZ and HV register) is read all the way through or access to Setting Registers (address 20h to 25h), DRDY bit turns to “0”.

10.3.1. Normal Measurement Data Read Sequence

(1) Check Data Ready or not by any of the following method.
    Monitor OD-INT pin
    Polling DRDY bit of ST register

    When Data Ready, proceed to the next step.

(2) Read ST and measurement data
    When ST register and any of measurement data register (HX, HY, HZ and HV register) is read all the way through, or access to Setting Registers (address 20h to 25h), AK09973D judges that data reading is finished. When data reading is finished, DRDY bit and DOR bit turns to “0”.

    When measurement data register is accessed, AK09973D judges that data reading is started. Stored measurement data is protected during data reading and data is not updated. By reading measurement data register is finished, this protection is released.

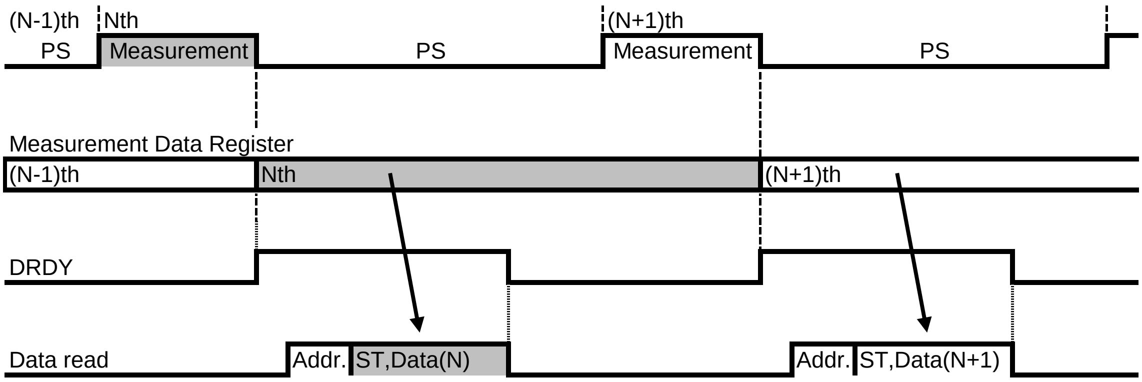


Figure 10.2 Timing chart of Measurement data read

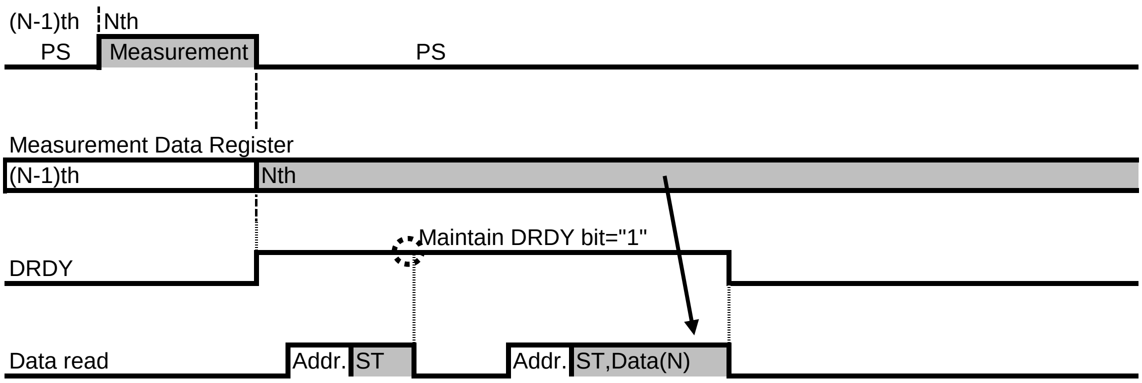


Figure 10.3 Timing chart of ST data read

10.3.2. Data Read Start during Measurement

When the sensor is measuring (Measurement period), measurement data registers (HX, HY, HZ and HV register) keep the previous data. Therefore, it is possible to read out data even during measurement period. If data is started to be read during measurement period, previous data is read.

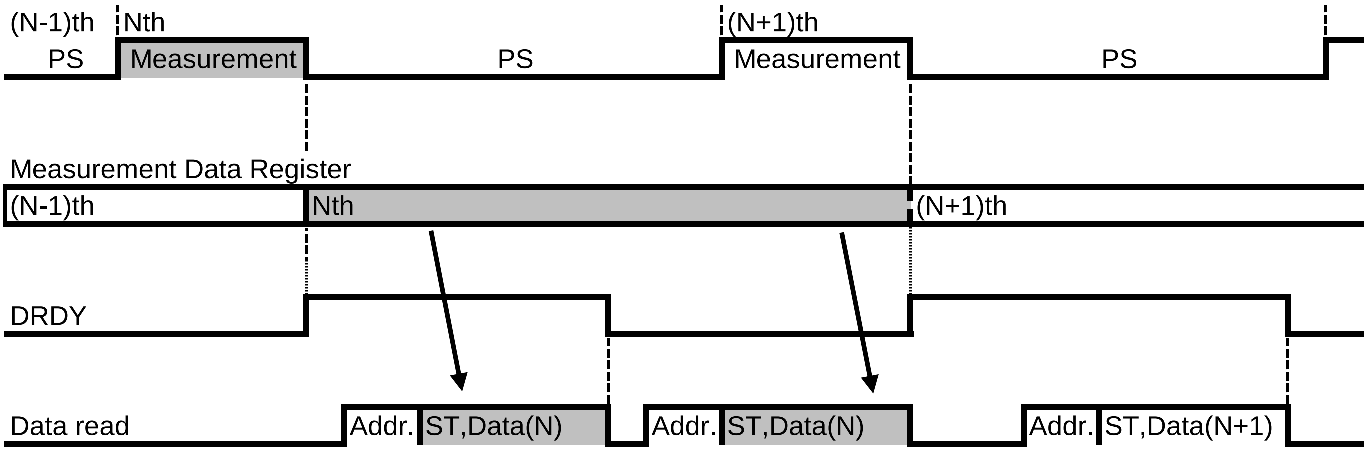


Figure 10.4 Data read start during measuring

10.3.3. Data Skip

When Nth data was not read before (N+1)th measurement ends, Data Ready remains until data is read. In this case, a set of measurement data is skipped so that DOR bit turns to “1”. DOR bit turns to “0” at the (N+2)th measurement ended.

When data reading started after Nth measurement ended and did not finish reading before (N+1)th measurement ended, Nth measurement data is protected to keep correct data. In this case, a set of measurement data is not skipped and stored after finish reading Nth measurement data so that DOR bit = “0”.

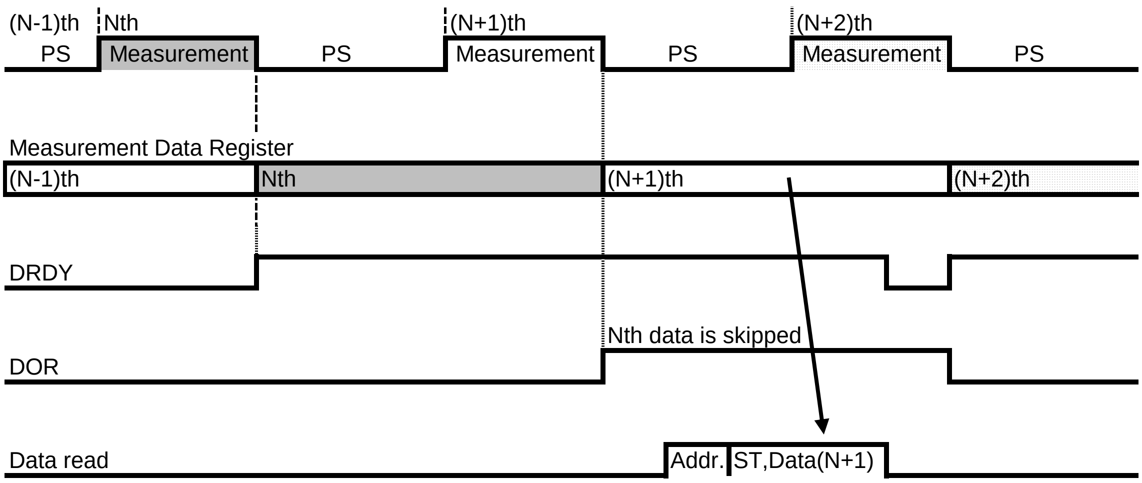


Figure 10.5 Data Skip: When data is not read

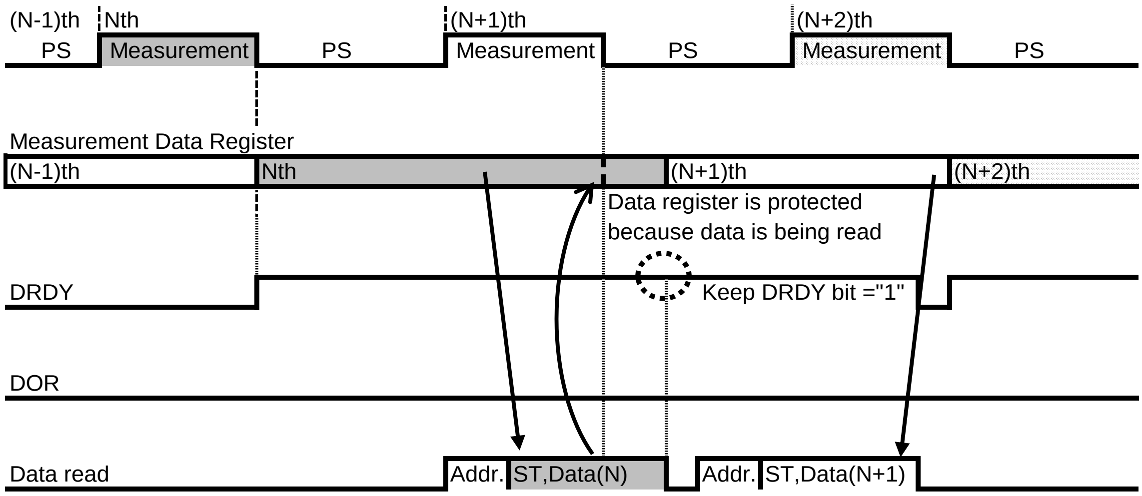


Figure 10.6 Data Not Skip: When data read has not been finished before the next measurement end

10.3.4. End Operation

Set Power-down mode (MODE[4:0] bits = “00h”) to end Continuous measurement mode.

10.4. Programmable Switch Function

AK09973D has a programmable switch function created by setting switch threshold values (operating threshold[* 9] and returning threshold[* 10]) and switch function enable bits (SWEN bits[* 11]). When measurement magnetic data exceeds the operating threshold value, switch event bit (SW bits[* 12]) turns to “1”. When measurement magnetic data is lower than the returning threshold, SW bits turns to “0”. The switch function is used to check the magnitude relation between the measurement data and the switch threshold values. After the magnetic sensor measurement and signal processing has finished, measurement data is stored to the measurement data register. Then AK09973D compares the measurement data with the defined switch threshold values and outputs the comparison results at the SW bits in ST register. Switch thresholds can be free to set (Settable range: same as measurement range. Settable sensitivity: same as measurement sensitivity).

Notes:
* 9. BOPX[15:0], BOPY[15:0], BOPZ[15:0] and BOPV[15:0]
* 10. BRPX[15:0], BRPY[15:0], BRPZ[15:0] and BRPV[15:0]
* 11. SWXEN bit, SWYEN bit, SWZEN bit and SWVEN bit
* 12. SWX bit, SWY bit, SWZ bit and SWV bit

Table 10.2 Relation between threshold values and SW bit of X-axis[* 13]

Relation between BOPX and BRPX	Magnitude relation between measurement data and threshold values	SWX bit result
BOPX ≤ BRPX (Switch function disable)	Don’t care	Don’t care
BOPX > BRPX (Switch function enable)	BOPX < HX	1
	BRPX > HX	0
	BRPX ≤ HX ≤ BOPX	Previous result

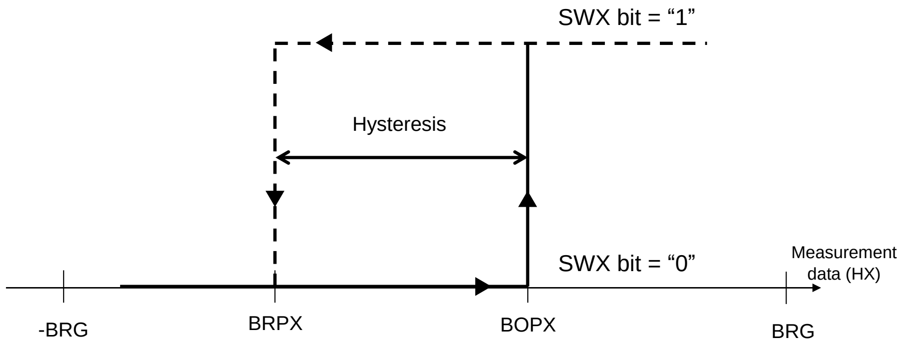


Figure 10.7 Relation between threshold values and SW bit of X-axis*13

Note:

* 13. X-axis, Y-axis, Z-axis and sum of squares of 3-axis exhibits the same relationship

10.5. Self-test Function

Self-test mode is used to check if the magnetic sensor is working normally.
When Self-test mode (STEST bit = “1”) and Single measurement mode (MODE[4:0] bits = “01h”) are set, magnetic field is generated by the internal magnetic source and magnetic sensor is measured. In the Self-test mode, the settings of Sensor drive select (SDR bit) and Sensor measurement range (SMR bit) are invalid and measurement is performed with Low noise (SDR bit = “0”) and High sensitivity (SMR bit = “0”). Measurement data is stored to measurement data registers (HX, HY, HZ), then AK09973D transits to Power-down mode automatically.
Data read sequence and functions of read-only registers in Self-test mode is the same as Single measurement mode.
When measurement data read by the self-test sequence is in the range of following table, AK09973D is working normally.

	HX[15:0] bits	HY[15:0] bits	HZ[15:0] bits
Criteria	$-120 \leq HX \leq 120$	$-120 \leq HY \leq 120$	$60 \leq HZ \leq 400$

10.6. Error Notification Function

AK09973D has a limitation for measurement range, where the absolute value of X-axis and Y-axis should be smaller than 36.04 mT (High sensitivity mode) or 34.91 mT (Wide range mode) and the absolute value of Z-axis should be smaller than 36.04 mT (High sensitivity mode) or 101.57 mT (Wide range mode). When the magnetic field exceeds this limitation, AK09973D outputs limitation value (fixed value: 36.04 mT, 34.91 mT or 101.57 mT) at the X-axis or/and Y-axis or/and Z-axis. This is called magnetic sensor overflow. When magnetic sensor overflow occurs, ERR bit turns to “1”. When the magnetic field less than limitation value, measurement data register and ERR bit are updated.

10.7. Interrupt Function

AK09973D has Open-drain interrupt pin (OD-INT pin). When CNTL1 register is set and interrupt event occurred, AK09973D outputs selected interrupt event at OD-INT pin. AK09973D can output three type of interrupt events (Switch event, Data ready, Error event) to OD-INT pin. Switch event occurs when measurement data is higher than BOP value and POL bit[*14] = “0” or when measurement data is lower than BRP value and POL bit = “1”. When interrupt Switch event or Data ready or Error event occurs, OD-INT pin turns to “L”.

Note:
*14. POLX bit, POLY bit, POLZ bit and POLV bit

Table 10.3 Relation between threshold values of X-axis and OD-INT pin*[15]

Relation between BOPX and BRPX	Magnitude relation between measurement data and threshold values	OD-INT pin	
		POLX = “0”	POLX = “1”
BOPX ≤ BRPX (Switch function disable)	Don’t care	Don’t care	
BOPX > BRPX (Switch function enable)	BOPX < HX	L	H
	BRPX > HX	H	L
	BRPX ≤ HX ≤ BOPX	Previous result	

Note:
* 15. X-axis, Y-axis, Z-axis and sum of squares of 3-axis exhibits the same relationship

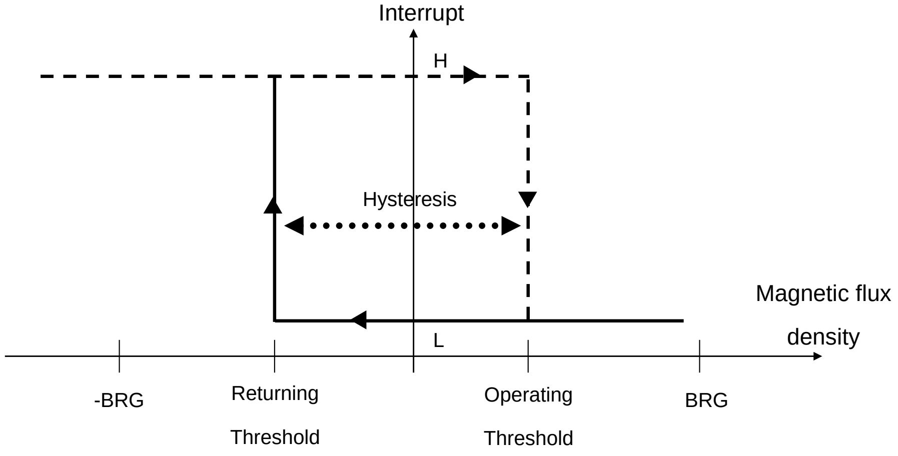


Figure 10.8 Open drain interrupt pin (POL bit = “0”)

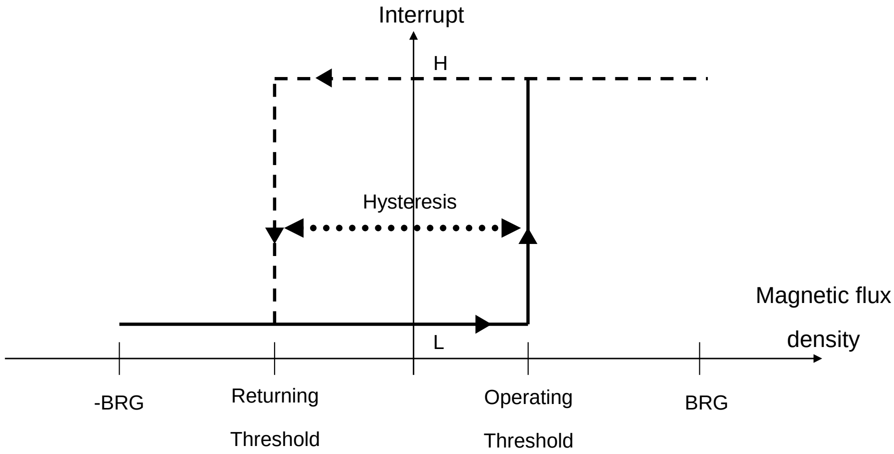


Figure 10.9 Open drain interrupt pin (POL bit = “1”)

10.7.1. Interrupt Event

(1) Switch interrupt event

- When measurement magnetic data exceeds the operating threshold value and POL bit = “0”, SW bit turns to “1” and OD-INT pin turns to “L”. When measurement magnetic data is lower than the returning threshold and POL bit = “0”, SW bit turns to “0” and OD-INT pin turns to “H”. In case of POL bit = “1”, the polarity of OD-INT pin is the reverse of when POL bit = “0”.

(2) Data ready

- OD-INT pin notifies user of the Data Ready state. When Data ready is occurred, DRDY bit turns to “1” and OD-INT pin turns to “L”. When user accesses to register address, OD-INT pin turns to “H”.

(3) Error event (Overflow)

- When magnetic sensor overflow occurs, ERR bit turns to “1” and OD-INT pin turns to “L”. When the magnetic field less than limitation value, ERR bit turns to “0” and OD-INT pin turns to “H”.

10.7.2. Timing of DRDY Interrupt Function Operation

Timing of interrupt function operation is given below.

Table 10.3 Timing of interrupt function operation

Pin name	Output transition	Timing of transition	Remarks
OD-INT pin	H → L	End of measurement	-
	L → H	Read address 10h - 1Fh or Write address 20h - 25h	During access to address, OD-INT pin is always "H" state.

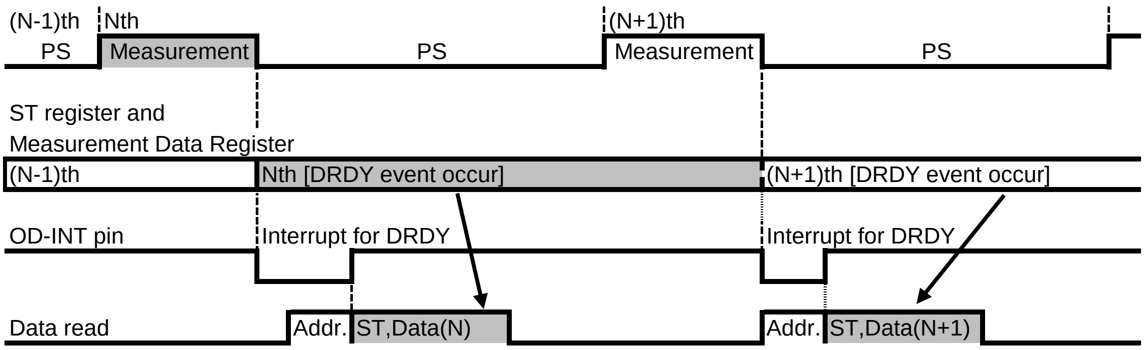


Figure 10.10 Timing chart of DRDY interrupt function (Normal read sequence)

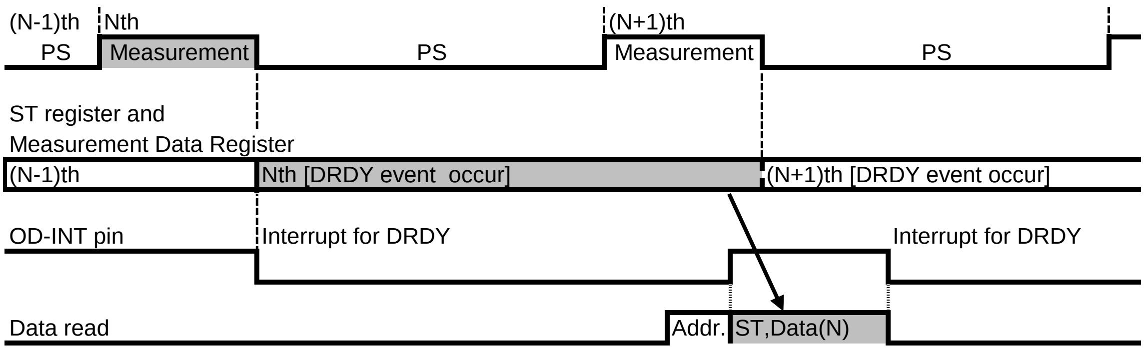


Figure 10.11 Timing chart of DRDY interrupt function
(When Nth data is read start immediately before (N+1)th measurement end)

10.7.3. Timing of Switch/Error Interrupt Function Operation

When user assigns OD-INT pin to SW event output or/and Error event output, OD-INT pin notifies user of these event. Timing of these interrupt function operation is given below.

Table 10.5 Timing of SW/ERROR interrupt function operation (POL bit = “0”)

Pin name	Output transition	Timing of transition
OD-INT pin	H → L	End of measurement(SW/ERROR)
	L → H	End of measurement(SW/ERROR) or Write address 20h - 25h

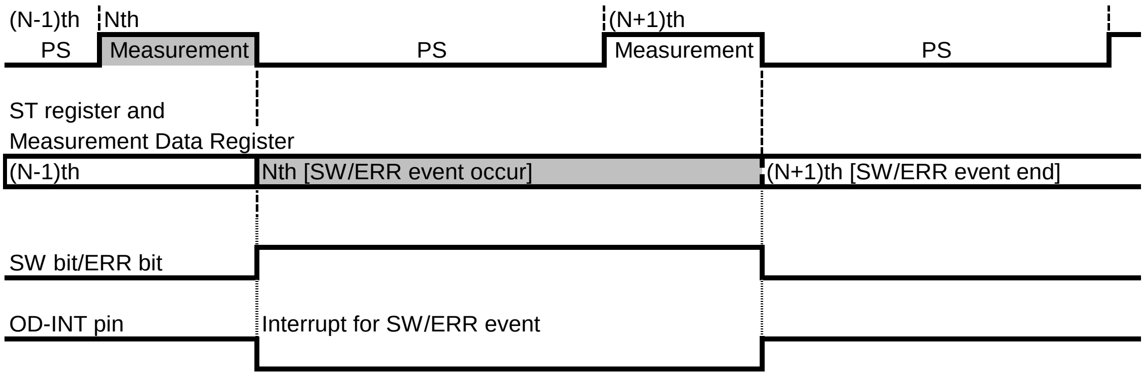


Figure 10.12 Timing chart of SW/ERROR interrupt function

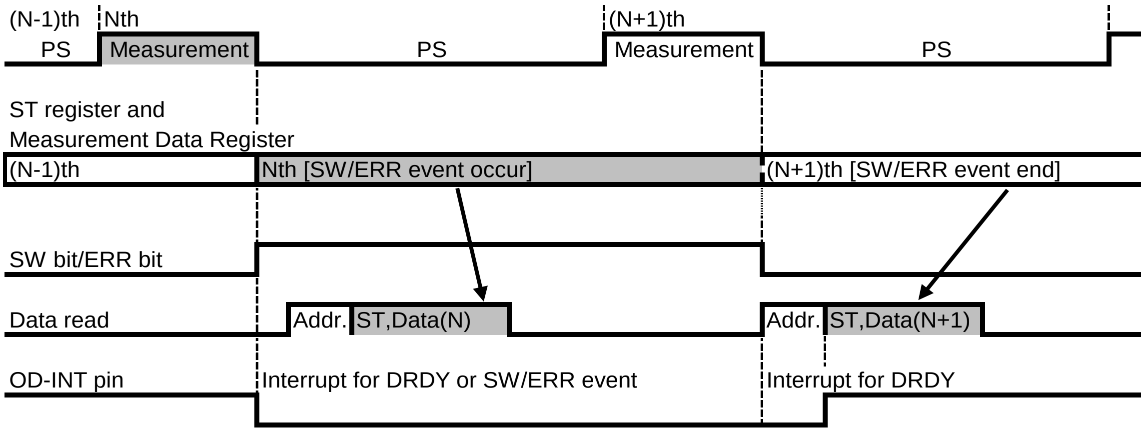


Figure 10.13 Timing chart of DRDY or SW/ERROR interrupt function

10.8. Sensor Drive Select

Users can choose “Low power” or “Low noise” drive by the SDR bit.
“Low power” is used to save the current consumption and “Low noise” is used to reduce the noise of AK09973D. When Low noise (SDR bit = “0”) is set, output magnetic data noise is more reduced than Low power (about 70% of Low power). When Low power (SDR bit = “1”) is set, average current consumption at 10 Hz repetition rate is saved from 11 µA to 3.5 µA (Vdd = 1.8 V, +25˚C). Default SDR bit is Low noise drive (SDR bit = “0”).

10.9. Sensor Measurement Range and Sensitivity Select

Users can choose “High sensitivity (Normal measurement range and high sensitivity)” or “Wide range (Wide measurement range and normal sensitivity)” setting.
“High sensitivity” is used to measure with high magnetic sensitivity and “Wide range” is used to measure strong magnetic field (apply only to Z-axis). When High sensitivity (SMR bit = “0”) is set, magnetic sensor sensitivity is about three times higher than Wide range (3.1 µT/LSB → 1.1 µT/LSB). When Wide range (SMR bit = “1”) is set, Z-axis measurement range is about three times wider than High sensitivity (Z-axis measurement range: ±36.04 mT → ±101.57 mT). Default SMR bit is High sensitivity enable (SMR bit = “0”).

11. Serial Interface

11.1. I²C Bus Interface

The I²C bus interface of AK09973D supports the Standard mode (100 kHz max.), the Fast mode (400 kHz max.) and the Fast mode plus (1000 kHz max.).

11.1.1. Data Transfer

To access AK09973D on the bus, generate a start condition first.
Next, transmit a one-byte slave address including a device address. At this time, AK09973D compares the slave address with its own address. If these addresses match, AK09973D generates an acknowledgement, and then executes READ or WRITE instruction. At the end of instruction execution, generate a stop condition.

11.1.1.1. Change of Data

A change of data on the SDA line must be made during “Low” period of the clock on the SCL line. When the clock signal on the SCL line is “High”, the state of the SDA line must be stable. (Data on the SDA line can be changed only when the clock signal on the SCL line is “Low”.)
During the SCL line is “High”, the state of data on the SDA line is changed only when a start condition or a stop condition is generated.

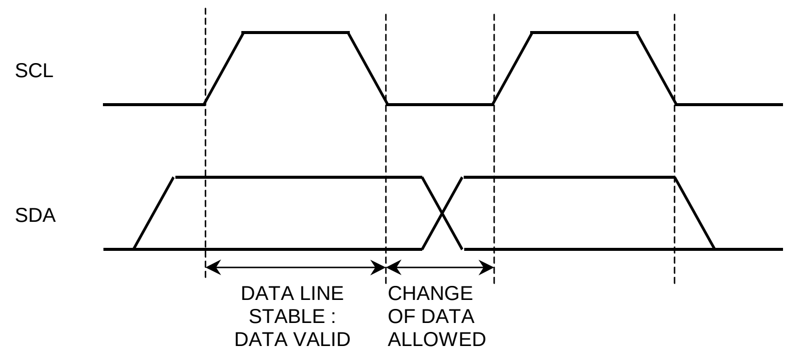


Figure 11.1 Data Change

11.1.1.2. Start/Stop Condition

If the SDA line is driven to “Low” from “High” when the SCL line is “High”, a start condition is generated. Every instruction starts with a start condition.
If the SDA line is driven to “High” from “Low” when the SCL line is “High”, a stop condition is generated. Every instruction stops with a stop condition.

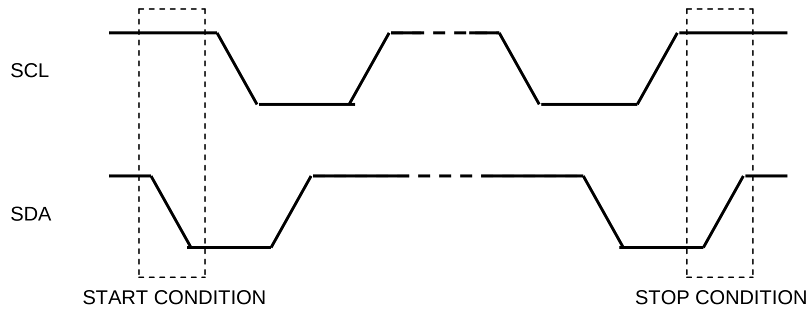


Figure 11.2 Start and stop condition

11.1.1.3. Acknowledge

The IC that is transmitting data releases the SDA line (in the “High” state) after sending 1-byte data. The IC that receives the data drives the SDA line to “Low” on the next clock pulse. This operation is referred as an acknowledge. With this operation, whether data has been transferred successfully can be checked. AK09973D generates an acknowledge after receipt of the start condition and slave address.
When a WRITE instruction is executed, AK09973D generates an acknowledge after every byte that is received.
When a READ instruction is executed, AK09973D generates an acknowledge then transfers the data stored at the specified address. Next, AK09973D releases the SDA line then monitors the SDA line. If a master IC generates an acknowledge instead of a stop condition, AK09973D transmits the 8-bit data stored at the next address. If no acknowledge is generated, AK09973D stops data transmission.

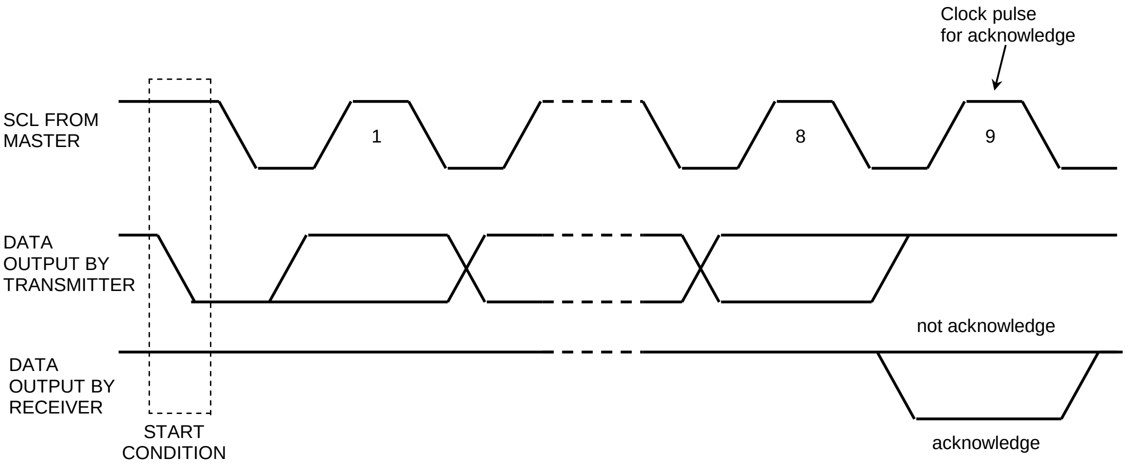


Figure 11.3 Generation of acknowledge

11.1.1.4. Slave Address

The slave address of AK09973D can be selected from the following list by changing pin connections of IF1 and IF2 pin.

	IF1	IF2	Slave address
Connection 1	OD-INT	SDA	10h
Connection 2	SDA	OD-INT	11h

MSB							LSB
0	0	1	0	0	0	0	R/W

Figure 11.4 Slave address of Connection 1

The first byte including a slave address is transmitted after a start condition, and an IC to be accessed is selected from the ICs on the bus according to the slave address.
When a slave address is transferred, the IC whose device address matches the transferred slave address generates an acknowledge then executes an instruction. The 8th bit (least significant bit) of the first byte is a R/W bit.
When the R/W bit is set to “1”, READ instruction is executed. When the R/W bit is set to “0”, WRITE instruction is executed.

11.1.2. WRITE Instruction

When the R/W bit is set to “0”, AK09973D performs write operation.
In write operation, AK09973D generates an acknowledge after receiving a start condition and the first byte (slave address) then receives the second byte. The second byte is used to specify the address of an internal control register and is based on the MSB-first configuration.

MSB LSB

A7	A6	A5	A4	A3	A2	A1	A0

Figure 11.5 Register address

After receiving the second byte (register address), AK09973D generates an acknowledge then receives the third byte.
The third and the following bytes represent control data. Control data consists of 8-bit and is based on the MSB-first configuration. AK09973D generates an acknowledge after every byte is received. Data transfer always stops with a stop condition generated by the master.

MSB LSB

D7	D6	D5	D4	D3	D2	D1	D0

Figure 11.6 Control data

AK09973D can write multiple bytes of data at a time.
After reception of the third byte (control data), AK09973D generates an acknowledge then receives the next data. If additional data is received instead of a stop condition after receiving one byte of data, the address counter inside the LSI chip is automatically incremented and the data is written at the next address.
The address is incremented from 20h to 25h. When the address is between 20h and 25h, the address is incremented 20h → 21h → 22h → 23h → 24h → 25h, and the address goes back to 20h after 25h.
Actual data is written only to Read/Write registers (Table 12.2).

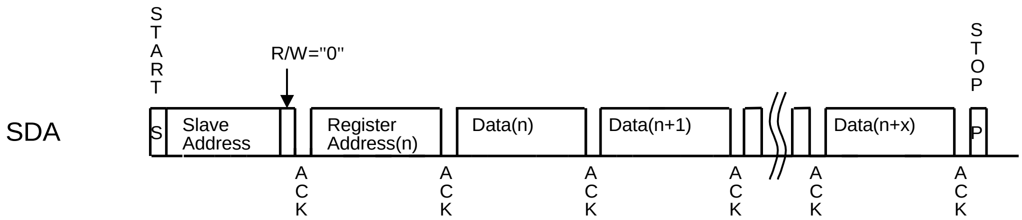


Figure 11.7 WRITE Instruction

11.1.3. READ Instruction

When the R/W bit is set to “1”, AK09973D performs read operation.
If a master IC generates an acknowledge instead of a stop condition after AK09973D transfers the data at a specified address, the data at the next address can be read.
Address can be 20h to 25h. When the address is between 20h and 25h , the address is incremented 20h → 21h → 22h → 23h → 24h → 25h , and the address goes back to 20h after 25h .
AK09973D supports one byte read and multiple byte read.

11.1.3.1. Current Address Read

AK09973D has an address counter inside the LSI chip. In current address read operation, the data at an address specified by this counter is read.
The internal address counter holds the next address of the most recently accessed address.
For example, if the address most recently accessed (for READ instruction) is address “n”, and a current address read operation is attempted, the data at address “n+1” is read.
In current address read operation, AK09973D generates an acknowledge after receiving a slave address for the READ instruction (R/W bit = “1”). Next, AK09973D transfers the data specified by the internal address counter starting with the next clock pulse, then increments the internal counter by one.
If the master IC generates a stop condition instead of an acknowledge after AK09973D transmits one byte of data, the read operation stops.

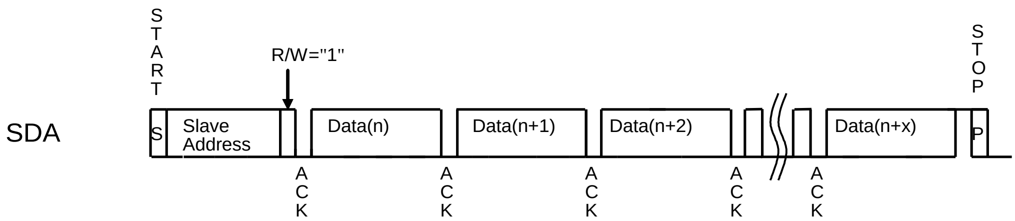


Figure 11.8 Current address read

11.1.3.2. Random Address Read

By random address read operation, data at an arbitrary address can be read.
The random address read operation requires to execute WRITE instruction as dummy before a slave address for the READ instruction (R/W bit = “1”) is transmitted. In random read operation, a start condition is first generated then a slave address for the WRITE instruction (R/W bit = “0”) and a read address are transmitted sequentially.
After AK09973D generates an acknowledge in response to this address transmission, a start condition and a slave address for the READ instruction (R/W bit = “1”) are generated again. AK09973D generates an acknowledge in response to this slave address transmission. Next, AK09973D transfers the data at the specified address then increments the internal address counter by one. If the master IC generates a stop condition instead of an acknowledge after data is transferred, the read operation stops.

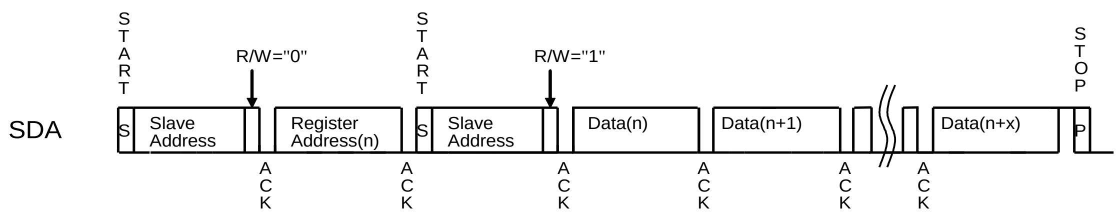


Figure 11.9 Random address read

12. Registers

12.1. Description of Registers

AK09973D has registers of 26 addresses as indicated in Table 12.1. Every address consists of 1-byte to 7-byte data. Data is transferred to or received from the external CPU via the serial interface described previously.

Table 12.1 Register Table

Address	READ/ WRITE	Description	Byte width	Remarks
00h	READ	Company ID, Device ID	4	Device Information
10h		Status	1	ST data
11h		Status and Measurement Magnetic Data	3	ST + X-axis data
12h			3	ST + Y-axis data
13h			5	ST + X and Y-axis data
14h			3	ST + Z-axis data
15h			5	ST + X and Z-axis data
16h			5	ST + Y and Z-axis data
17h			7	ST + X, Y and Z-axis data
18h			5	ST + Sum of squares of 3-axis data
19h		Status and Measurement Magnetic Data (upper 8 bits of measurement data register)	2	ST + X-axis data
1Ah			2	ST + Y-axis data
1Bh			3	ST + X and Y-axis data
1Ch			2	ST + Z-axis data
1Dh			3	ST + X and Z-axis data
1Eh			3	ST + Y and Z-axis data
1Fh			4	ST + X, Y and Z-axis data
20h	READ/ WRITE	Control 1	2	Interrupt function settings
21h		Control 2	1	Operation Mode, Sensor Drive, Measurement Range and Sensitivity
22h		Control 3 (Switch threshold value)	4	X-axis threshold settings
23h			4	Y-axis threshold settings
24h			4	Z-axis threshold settings
25h			4	Sum of squares of 3-axis threshold settings
30h		Reset	1	Soft reset
40h		Test	2	DO NOT ACCESS
41h	READ		1	DO NOT ACCESS

Addresses 20h to 25h are compliant with automatic increment function of serial interface respectively. When the address is in 20h to 25h , the address is incremented 20h → 21h → 22h → 23h → 24h → 25h, and the address goes back to 20h after 25h .

12.2. Register Map

Table 12.2 Register Map

Addr.	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
Read only register							
00h	WIA[15:8]	WIA[7:0]	RSV[15:8]	RSV[7:0]	-	-	-
10h	ST[7:0]	-	-	-	-	-	-
11h	ST[7:0]	HX[15:8]	HX[7:0]	-	-	-	-
12h	ST[7:0]	HY[15:8]	HY[7:0]	-	-	-	-
13h	ST[7:0]	HY[15:8]	HY[7:0]	HX[15:8]	HX[7:0]	-	-
14h	ST[7:0]	HZ[15:8]	HZ[7:0]	-	-	-	-
15h	ST[7:0]	HZ[15:8]	HZ[7:0]	HX[15:8]	HX[7:0]	-	-
16h	ST[7:0]	HZ[15:8]	HZ[7:0]	HY[15:8]	HY[7:0]	-	-
17h	ST[7:0]	HZ[15:8]	HZ[7:0]	HY[15:8]	HY[7:0]	HX[15:8]	HX[7:0]
18h	ST[7:0]	HV[31:24]	HV[23:16]	HV[15:8]	HV[7:0]	-	-
19h	ST[7:0]	HX[15:8]	-	-	-	-	-
1Ah	ST[7:0]	HY[15:8]	-	-	-	-	-
1Bh	ST[7:0]	HY[15:8]	HX[15:8]	-	-	-	-
1Ch	ST[7:0]	HZ[15:8]	-	-	-	-	-
1Dh	ST[7:0]	HZ[15:8]	HX[15:8]	-	-	-	-
1Eh	ST[7:0]	HZ[15:8]	HY[15:8]	-	-	-	-
1Fh	ST[7:0]	HZ[15:8]	HY[15:8]	HX[15:8]	-	-	-
Read/Write register							
20h	CNTL1[15:8]	CNTL1[7:0]		-	-	-	-
21h	CNTL2[7:0]	-	-	-	-	-	-
22h	BOPX[15:8]	BOPX[7:0]	BRPX[15:8]	BRPX[7:0]	-	-	-
23h	BOPY[15:8]	BOPY[7:0]	BRPY[15:8]	BRPY[7:0]	-	-	-
24h	BOPZ[15:8]	BOPZ[7:0]	BRPZ[15:8]	BRPZ[7:0]	-	-	-
25h	BOPV[15:8]	BOPV[7:0]	BRPV[15:8]	BRPV[7:0]	-	-	-
30h	SRST[7:0]	-	-	-	-	-	-
40h	TEST1[15:8]	TEST1[7:0]	-	-	-	-	-
41h	TEST2[7:0]	-	-	-	-	-	-

Table 12.3 Further details about Register Map (D[7:0])

Register name	Bit number (D[7:0])							
	7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
WIA[7:0]	1	1	0	0	0	0	0	1
RSV[7:0]	RSV7	RSV6	RSV5	RSV4	RSV3	RSV2	RSV1	RSV0
ST[7:0]	1	DOR	ERR	SWV	SWZ	SWY	SWX	DRDY
HX[7:0]	HX7	HX6	HX5	HX4	HX3	HX2	HX1	HX0
HY[7:0]	HY7	HY6	HY5	HY4	HY3	HY2	HY1	HY0
HZ[7:0]	HZ7	HZ6	HZ5	HZ4	HZ3	HZ2	HZ1	HZ0
HV[7:0]	HV7	HV6	HV5	HV4	HV3	HV2	HV1	HV0
CNTL1[7:0]	0	0	ERROREN	SWVEN	SWZEN	SWYEN	SWXEN	DRDYEN
CNTL2[7:0]	SELFT	SMR	SDR	MODE4	MODE3	MODE2	MODE1	MODE0
BOPX[7:0]	BOPX7	BOPX6	BOPX5	BOPX4	BOPX3	BOPX2	BOPX1	BOPX0
BRPX[7:0]	BRPX7	BRPX6	BRPX5	BRPX4	BRPX3	BRPX2	BRPX1	BRPX0
BOPY[7:0]	BOPY7	BOPY6	BOPY5	BOPY4	BOPY3	BOPY2	BOPY1	BOPY0
BRPY[7:0]	BRPY7	BRPY6	BRPY5	BRPY4	BRPY3	BRPY2	BRPY1	BRPY0
BOPZ[7:0]	BOPZ7	BOPZ6	BOPZ5	BOPZ4	BOPZ3	BOPZ2	BOPZ1	BOPZ0
BRPZ[7:0]	BRPZ7	BRPZ6	BRPZ5	BRPZ4	BRPZ3	BRPZ2	BRPZ1	BRPZ0
BOPV[7:0]	BOPV7	BOPV6	BOPV5	BOPV4	BOPV3	BOPV2	BOPV1	BOPV0
BRPV[7:0]	BRPV7	BRPV6	BRPV5	BRPV4	BRPV3	BRPV2	BRPV1	BRPV0
SRST[7:0]	0	0	0	0	0	0	0	SRST
TEST1[7:0]	-	-	-	-	-	-	-	-
TEST2[7:0]	-	-	-	-	-	-	-	-

Table 12.4 Further details about Register Map (D[15:8])

Register name	Bit number (D[15:8])							
	15	**14**	**13**	**12**	**11**	**10**	**9**	**8**
WIA[15:8]	0	1	0	0	1	0	0	0
RSV[15:8]	RSV15	RSV14	RSV13	RSV12	RSV11	RSV10	RSV9	RSV8
HX[15:8]	HX15	HX14	HX13	HX12	HX11	HX10	HX9	HX8
HY[15:8]	HY15	HY14	HY13	HY12	HY11	HY10	HY9	HY8
HZ[15:8]	HZ15	HZ14	HZ13	HZ12	HZ11	HZ10	HZ9	HZ8
HV[15:8]	HV15	HV14	HV13	HV12	HV11	HV10	HV9	HV8
CNTL1[15:8]	0	0	0	0	POLV	POLZ	POLY	POLX
BOPX[15:8]	BOPX15	BOPX14	BOPX13	BOPX12	BOPX11	BOPX10	BOPX9	BOPX8
BRPX[15:8]	BRPX15	BRPX14	BRPX13	BRPX12	BRPX11	BRPX10	BRPX9	BRPX8
BOPY[15:8]	BOPY15	BOPY14	BOPY13	BOPY12	BOPY11	BOPY10	BOPY9	BOPY8
BRPY[15:8]	BRPY15	BRPY14	BRPY13	BRPY12	BRPY11	BRPY10	BRPY9	BRPY8
BOPZ[15:8]	BOPZ15	BOPZ14	BOPZ13	BOPZ12	BOPZ11	BOPZ10	BOPZ9	BOPZ8
BRPZ[15:8]	BRPZ15	BRPZ14	BRPZ13	BRPZ12	BRPZ11	BRPZ10	BRPZ9	BRPZ8
BOPV[15:8]	BOPV15	BOPV14	BOPV13	BOPV12	BOPV11	BOPV10	BOPV9	BOPV8
BRPV[15:8]	BRPV15	BRPV14	BRPV13	BRPV12	BRPV11	BRPV10	BRPV9	BRPV8
TEST1[15:8]	-	-	-	-	-	-	-	-

Table 12.5 Further details about Register Map (D[23:16])

Register name	Bit number (D[23:16])							
	23	**22**	**21**	**20**	**19**	**18**	**17**	**16**
HV[23:16]	HV23	HV22	HV21	HV20	HV19	HV18	HV17	HV16

Table 12.6 Further details about Register Map (D[31:24])

Register name	Bit number (D[31:24])							
	31	**30**	**29**	**28**	**27**	**26**	**25**	**24**
HV[31:24]	HV31	HV30	HV29	HV28	HV27	HV26	HV25	HV24

TEST1 and TEST2 are test registers for shipment test. Do not access these registers.

12.3. Detailed Description of Registers

12.3.1 WIA[15:0]: Company ID and Device ID

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read-only register									
00h	WIA[7:0]	1	1	0	0	0	0	0	1
Addr.	**Register name**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**
Read-only register									
00h	WIA[15:8]	0	1	0	0	1	0	0	0

WIA[7:0] bits: Device ID of AK09973D. It is described in one byte and fixed value.
C1h: fixed
WIA[15:8] bits: Company ID of AKM. It is described in one byte and fixed value.
48h: fixed

12.3.2 RSV[15:0]: Reserved Register

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read-only register									
00h	RSV[7:0]	RSV7	RSV6	RSV5	RSV4	RSV3	RSV2	RSV1	RSV0
Addr.	**Register name**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**
Read-only register									
00h	RSV[15:8]	RSV15	RSV14	RSV13	RSV12	RSV11	RSV10	RSV9	RSV8

RSV[7:0] bits/ RSV[15:8] bits: Reserved register for AKM.

12.3.3 ST[7:0]: Status

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read-only register									
10h-1fh	ST[7:0]	1	DOR	ERR	SWV	SWZ	SWY	SWX	DRDY
Reset		1	0	0	0	0	0	0	0

DRDY bit: Data Ready
“0”: Normal
“1”: Data is ready

DRDY bit turns to “1” when data is ready in Single measurement mode and Continuous measurement mode. It returns to “0” when any one of measurement data register (HX, HY, HZ or/and HV register) is read all the way through or access to Setting Registers (address 20h to 25h).

DOR bit: Data Overrun
“0”: Normal
“1”: Data overrun
DOR bit turns to “1” when data has been skipped in Continuous measurement mode. DOR bit turns to “0” at the after both of reading measurement data and the next measurement ended.

SWX bit, SWY bit, SWZ bit, SWV bit
“0”: Measurement data of X, Y, Z-axis and vector sum of 3-axis data is lower than returning threshold
“1”: Measurement data of X, Y, Z-axis and vector sum of 3-axis data is higher than operating threshold

ERR bit: Magnetic sensor overflow
“0”: Normal
“1”: Magnetic sensor overflow occurred

12.3.4 HX[15:0]/HY[15:0]/HZ[15:0]: Measurement Data

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read-only register									
11h | 1fh	HX[7:0]	HX7	HX6	HX5	HX4	HX3	HX2	HX1	HX0
	HY[7:0]	HY7	HY6	HY5	HY4	HY3	HY2	HY1	HY0
	HZ[7:0]	HZ7	HZ6	HZ5	HZ4	HZ3	HZ2	HZ1	HZ0
Reset		0	0	0	0	0	0	0	0
Addr.	**Register name**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**
Read-only register									
11h | 1fh	HX[15:8]	HX15	HX14	HX13	HX12	HX11	HX10	HX9	HX8
	HY[15:8]	HY15	HY14	HY13	HY12	HY11	HY10	HY9	HY8
	HZ[15:8]	HZ15	HZ14	HZ13	HZ12	HZ11	HZ10	HZ9	HZ8
Reset		0	0	0	0	0	0	0	0

Measurement data of magnetic sensor X-axis/Y-axis/Z-axis
HX[7:0] bits: X-axis measurement data lower 8-bit
HX[15:8] bits: X-axis measurement data higher 8-bit
HY[7:0] bits: Y-axis measurement data lower 8-bit
HY[15:8] bits: Y-axis measurement data higher 8-bit
HZ[7:0] bits: Z-axis measurement data lower 8-bit
HZ[15:8] bits: Z-axis measurement data higher 8-bit

Measurement data is stored in two’s complement. Measurement range of each axis is -32768 to 32767 in 16-bit output (High sensitivity setting). Measurement range of X and Y-axis are -11264 to 11264 in 16-bit output, Z-axis is -32768 to 32767 in 16-bit output (Wide range setting).

Table 12.7 Measurement magnetic data format (High sensitivity setting)

Measurement data (each axis) [15:0] bits			Magnetic flux density [mT]	ERR bit
Two’s complement	Hex	Decimal		
0111 1111 1111 1111	7FFF	32767	>36.0437	1
0111 1111 1111 1111	7FFF	32767	36.0437	0
|	|	|	|	|
0000 0000 0000 0001	0001	1	0.0011	0
0000 0000 0000 0000	0000	0	0	0
1111 1111 1111 1111	FFFF	-1	-0.0011	0
|	|	|	|	|
1000 0000 0000 0000	8000	-32768	-36.0448	0
1000 0000 0000 0000	8000	-32768	<-36.0448	1

Table 12.8 Measurement magnetic data format (Wide range setting, X and Y-axis)

Measurement data (X and Y axis) [15:0] bits			Magnetic flux density [mT]	ERR bit
Two's complement	Hex	Decimal		
0010 1100 0000 0000	2C00	11264	>34.9184	1
0010 1100 0000 0000	2C00	11264	34.9184	0
|	|	|	|	|
0000 0000 0000 0001	0001	1	0.0031	0
0000 0000 0000 0000	0000	0	0	0
1111 1111 1111 1111	FFFF	-1	-0.0031	0
|	|	|	|	|
1101 0100 0000 0000	D400	-11264	-34.9184	0
1101 0100 0000 0000	D400	-11264	<-34.9184	1

Table 12.9 Measurement magnetic data format (Wide range setting, Z-axis)

Measurement data (Z axis) [15:0] bits			Magnetic flux density [mT]	ERR bit
Two's complement	Hex	Decimal		
0111 1111 1111 1111	7FFF	32767	>101.5777	1
0111 1111 1111 1111	7FFF	32767	101.5777	0
|	|	|	|	|
0000 0000 0000 0001	0001	1	0.0031	0
0000 0000 0000 0000	0000	0	0	0
1111 1111 1111 1111	FFFF	-1	-0.0031	0
|	|	|	|	|
1000 0000 0000 0000	8000	-32768	-101.5808	0
1000 0000 0000 0000	8000	-32768	<-101.5808	1

12.3.5 HV[23:0]: Sum of Squares of 3-axis Measurement Data

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read-only register									
18h	HV[7:0]	HX7	HX6	HX5	HX4	HX3	HX2	HX1	HX0
Reset		0	0	0	0	0	0	0	0
Addr.	**Register name**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**
Read-only register									
18h	HV[15:8]	HX15	HX14	HX13	HX12	HX11	HX10	HX9	HX8
Reset		0	0	0	0	0	0	0	0
Addr.	**Register name**	**D23**	**D22**	**D21**	**D20**	**D19**	**D18**	**D17**	**D16**
Read-only register									
18h	HV[23:16]	HX23	HX22	HX21	HX20	HX19	HX18	HX17	HX16
Reset		0	0	0	0	0	0	0	0
Addr.	**Register name**	**D31**	**D30**	**D29**	**D28**	**D27**	**D26**	**D25**	**D24**
18h	HV[31:24]	HX31	HX30	HX29	HX28	HX27	HX26	HX25	HX24
Reset		0	0	0	0	0	0	0	0

Sum of squares of 3-axis measurement data.
HV[31:0] = (HX[15:0])^2+ (HY[15:0])^2+ (HZ[15:0])^2
HV[7:0] bits: 3-axis measurement data lower 8-bit
HV[15:8] bits: 3-axis measurement data middle 8-bit
HV[23:16] bits: 3-axis measurement data middle 8-bit
HV[31:24] bits: 3-axis measurement data higher 8-bit

12.3.6 CNTL1[15:0]: Interrupt Output Setting

Addr.	**Register name**	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
Read/Write register									
20h	CNTL1[7:0]	0	0	ERREN	SWVEN	SWZEN	SWYEN	SWXEN	DRDYEN
Reset		0	0	0	0	0	0	0	0
Addr.	**Register name**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**
Read/Write register									
20h	CNTL1[15:8]	0	0	RSV* 16	0	POLV	POLZ	POLY	POLX
Reset		0	0	0	0	0	0	0	0

DRDYEN bit: DRDY event output
“0”: DRDY event outputs disable
“1”: DRDY event outputs enable

SWXEN bit to SWVEN bit: Switch event output
“0”: Switch event outputs disable
“1”: Switch event outputs enable

ERREN bit: ERR event output
“0”: ERR event outputs disable
“1”: ERR event outputs enable

POLX, POLY, POLZ and POLV bit: Polarity of interrupt event signal of OD-INT pin setting
“0”: Negative logic output
“1”: Positive logic output

Note:
* 16 Please write “0” on RSV bit when you write on address 20h.

12.3.7 CNTL2[7:0]: Operation Mode, Sensor Drive and Self-test Setting

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read/Write register									
21h	CNTL2[7:0]	STEST	SMR	SDR	MODE4	MODE3	MODE2	MODE1	MODE0
Reset		0	0	0	0	0	0	0	0

MODE[4:0] bits: Operation mode setting
"01h": Single measurement mode
"02h": Continuous measurement mode 1
"04h": Continuous measurement mode 2
"06h": Continuous measurement mode 3
"08h": Continuous measurement mode 4
"0Ah": Continuous measurement mode 5
"0Ch": Continuous measurement mode 6
"0Eh": Continuous measurement mode 7
"10h": Continuous measurement mode 8
"otherwise": Power-down mode

SDR bit: Sensor drive setting
"0": Low noise drive
"1": Low power drive

SMR bit: Measurement range and sensitivity setting
"0": High sensitivity setting
"1": Wide measurement range setting

STEST bit: Self-test setting
"0": Self-test disable
"1": Self-test enable

12.3.8 BOP and BRP registers: Operating Threshold and Returning Threshold Setting of Programmable Switch Function

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read/Write register									
22h - 25h	BOPX[7:0]	BOPX7	BOPX6	BOPX5	BOPX4	BOPX3	BOPX2	BOPX1	BOPX0
	BRPX[7:0]	BRPX7	BRPX6	BRPX5	BRX4	BRP1X3	BRPX2	BRPX1	BRPX0
	BOPY[7:0]	BOPY7	BOPY6	BOPY5	BOPY4	BOPY3	BOPY2	BOPY1	BOPY0
	BRPY[7:0]	BRPY7	BRPY6	BRPY5	BRPY4	BRPY3	BRPY2	BRPY1	BRPY0
	BOPZ[7:0]	BOPZ7	BOPZ6	BOPZ5	BOPZ4	BOPZ3	BOPZ2	BOPZ1	BOPZ0
	BRPZ[7:0]	BRPZ7	BRPZ6	BRPZ5	BRPZ4	BRPZ3	BRPZ2	BRPZ1	BRPZ0
	BOPV[7:0]	BOPV7	BOPV6	BOPV5	BOPV4	BOPV3	BOPV2	BOPV1	BOPV0
	BRPV[7:0]	BRPV7	BRPV6	BRPV5	BRPV4	BRPV3	BRPV2	BRPV1	BRPV0
Reset		0	0	0	0	0	0	0	0
Addr.	**Register name**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**
Read/Write register									
22h - 25h	BOPX[15:8]	BOPX15	BOPX14	BOPX13	BOPX12	BOPX11	BOPX10	BOPX9	BOPX8
	BRPX[15:8]	BRPX15	BRPX14	BRPX13	BRPX12	BRPX11	BRPX10	BRPX9	BRPX8
	BOPY[15:8]	BOPY15	BOPY14	BOPY13	BOPY12	BOPY11	BOPY10	BOPY9	BOPY8
	BRPY[15:8]	BRPY15	BRPY14	BRPY13	BRPY12	BRPY11	BRPY10	BRPY9	BRPY8
	BOPZ[15:8]	BOPZ15	BOPZ14	BOPZ13	BOPZ12	BOPZ11	BOPZ10	BOPZ9	BOPZ8
	BRPZ[15:8]	BRPZ15	BRPZ14	BRPZ13	BRPZ12	BRPZ11	BRPZ10	BRPZ9	BRPZ8
	BOPV[15:8]	BOPV15	BOPV14	BOPV13	BOPV12	BOPV11	BOPV10	BOPV9	BOPV8
	BRPV[15:8]	BRPV15	BRPV14	BRPV13	BRPV12	BRPV11	BRPV10	BRPV9	BRPV8
Reset		0	0	0	0	0	0	0	0

Operating threshold data of magnetic sensor X-axis/Y-axis/Z-axis
BOPX[7:0] bits: X-axis operating threshold data lower 8-bit
BOPX[15:8] bits: X-axis operating threshold data higher 8-bit
BOPY[7:0] bits: Y-axis operating threshold data lower 8-bit
BOPY[15:8] bits: Y-axis operating threshold data higher 8-bit
BOPZ[7:0] bits: Z-axis operating threshold data lower 8-bit
BOPZ[15:8] bits: Z-axis operating threshold data higher 8-bit
BOPV[7:0] bits: Vector sum of 3-axis operating threshold data lower 8-bit
BOPV[15:8] bits: Vector sum of 3-axis operating threshold data higher 8-bit

Returning threshold data of magnetic sensor X-axis/Y-axis/Z-axis
BRPX[7:0] bits: X-axis returning threshold data lower 8-bit
BRPX[15:8] bits: X-axis returning threshold data higher 8-bit
BRPY[7:0] bits: Y-axis returning threshold data lower 8-bit
BRPY[15:8] bits: Y-axis returning threshold data higher 8-bit
BRPZ[7:0] bits: Z-axis returning threshold data lower 8-bit
BRPZ[15:8] bits: Z-axis returning threshold data higher 8-bit
BRPV[7:0] bits: Vector sum of 3-axis returning threshold data lower 8-bit
BRPV[15:8] bits: Vector sum of 3-axis returning threshold data higher 8-bit

AK09973D can set Operating and Returning threshold (X, Y, Z-axis) in two’s complement. It follows the same format as Measurement data. Switch thresholds can be free to set.

Table 12.10 Vector sum of 3-axis data format

Vector sum of 3-axis [15:0] bits			Magnetic flux density [mT]	
Two's complement	**Hex**	**Decimal**	**SMR bit = "0"**	**SMR bit = "1"**
1111 1111 1111 1111	FFFF	65536	72.09	203.16
|	|	|	|	|
0000 0000 0000 0001	0001	1	0.0011	0.0031
0000 0000 0000 0000	0000	0	0	0

12.3.9 SRST[7:0]: Soft Reset

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read/Write register									
30h	SRST[7:0]	0	0	0	0	0	0	0	SRST
Reset		0	0	0	0	0	0	0	0

SRST bit: Soft reset
"0": Normal
"1": Reset

When "1" is set, all registers are initialized. After reset, SRST bit turns to "0" automatically.

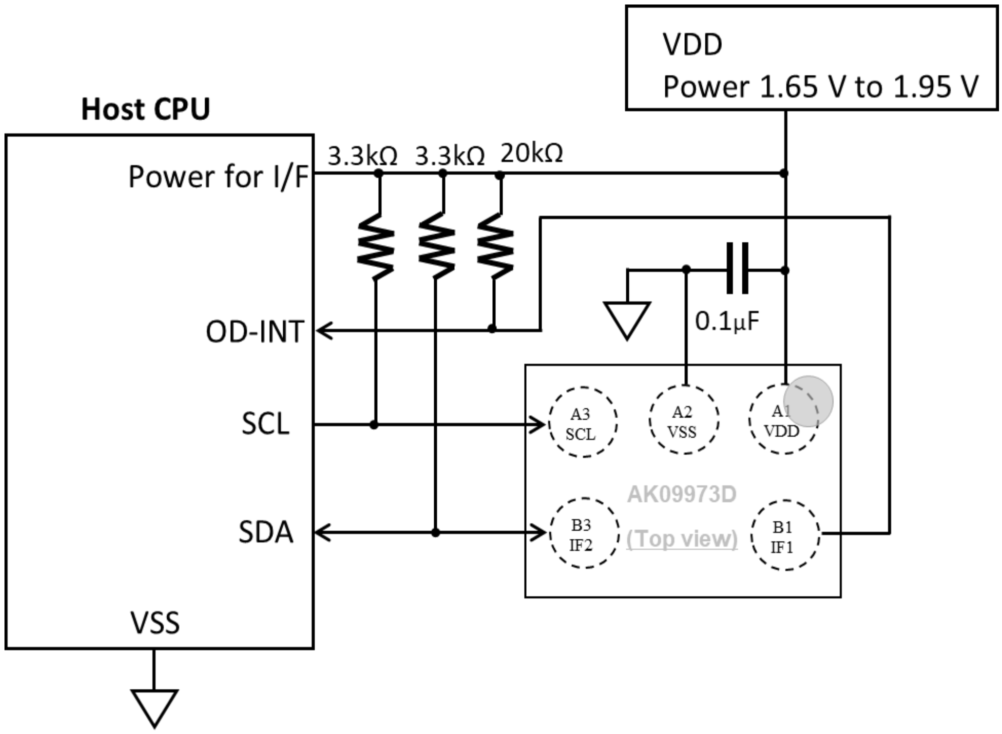
12.3.10 TEST1[15:0]/TEST2[7:0]: Test register

Addr.	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read/Write register									
40h	TEST1	-	-	-	-	-	-	-	-
41h	TEST2	-	-	-	-	-	-	-	-
Reset		0	0	0	0	0	0	0	0
Addr.	**Register name**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**
Read/Write register									
40h	TEST1	-	-	-	-	-	-	-	-
Reset		0	0	0	0	0	0	0	0

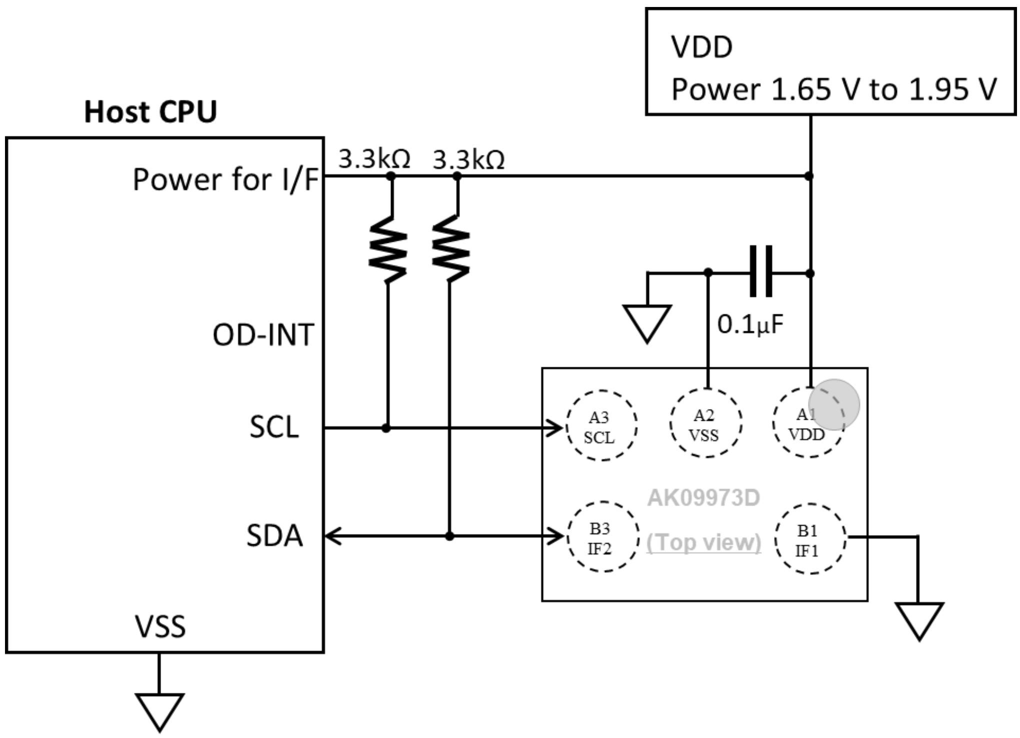
TEST1 and TEST2 register are test register for shipment test. Do not access these registers.

13. Recommended External Circuits

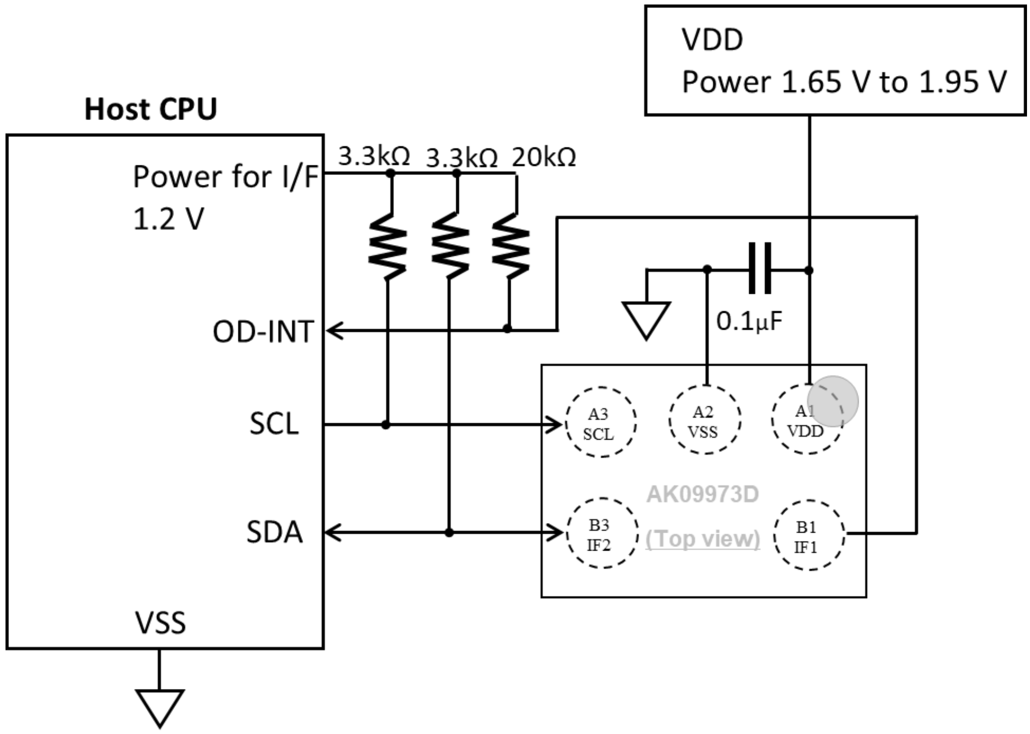
Connection1　Slave address: 10h



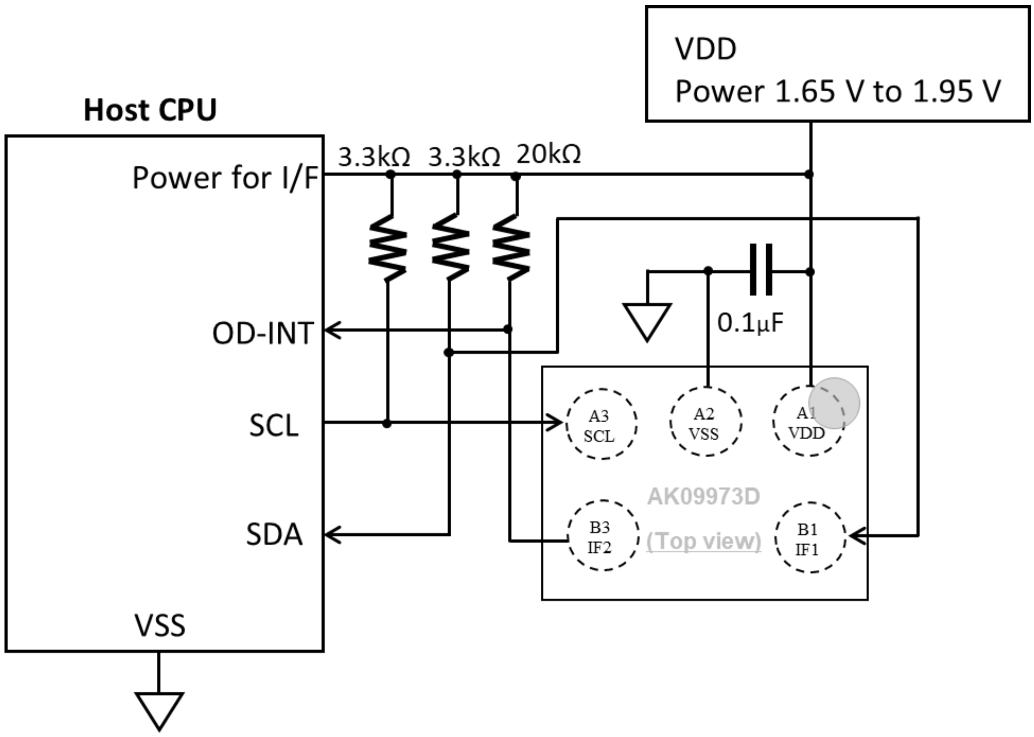
Connection1 when not using OD-INT



Connection1 when power for I/F is 1.2 V

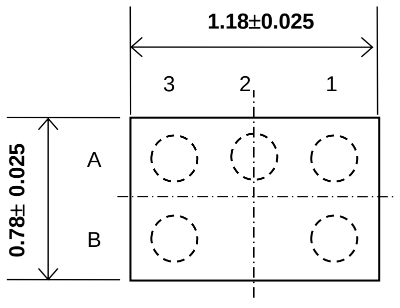


Connection2　Slave address: 11h

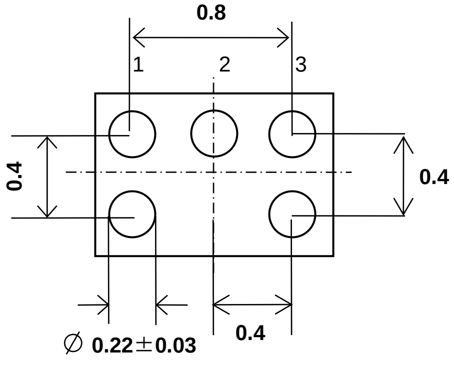


14. **Package**

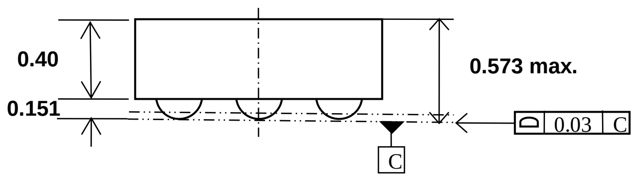
14.1. Outline Dimensions



<Top view>



<Bottom view>

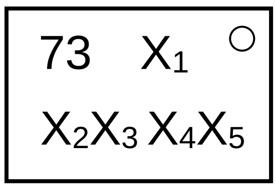


<Side view>

14.2. Marking

Product name: 73
Date code: $X_1X_2X_3X_4X_5$

- X1 = ID
- X2 = Year code
- X3 = Month code
- X4X5= Lot

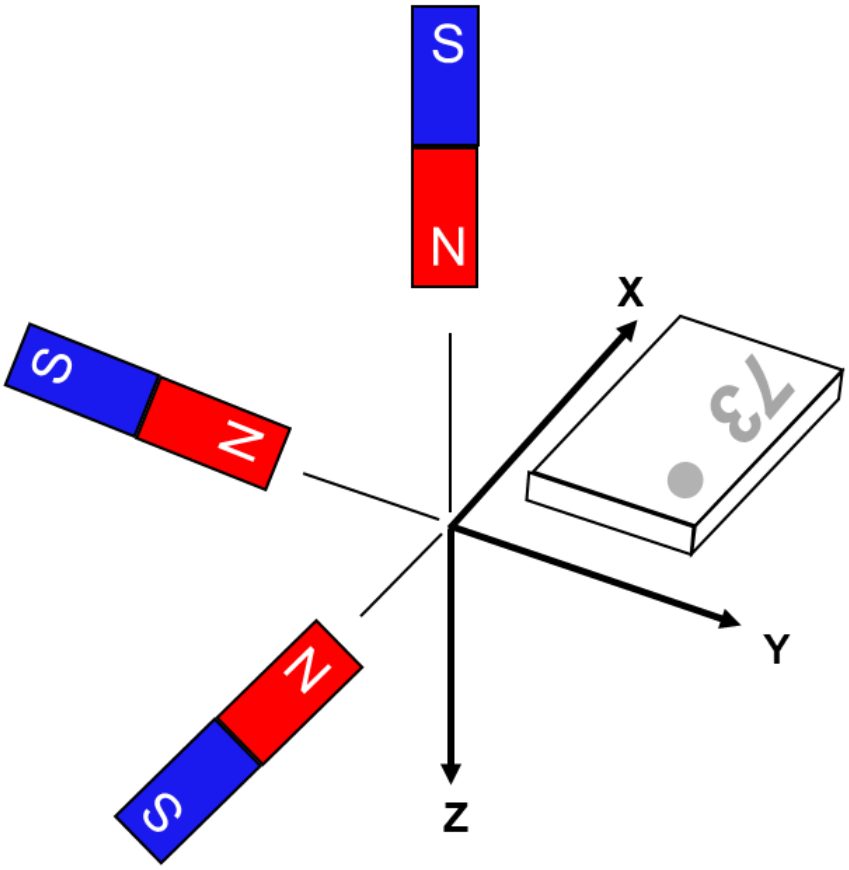


<Top view>

14.3. Pin Assignment

	3	2	1
A	SCL	VSS	VDD
B	IF2		IF1

15. **Magnetic Orientation**



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