Contents

[1] Scope of Application

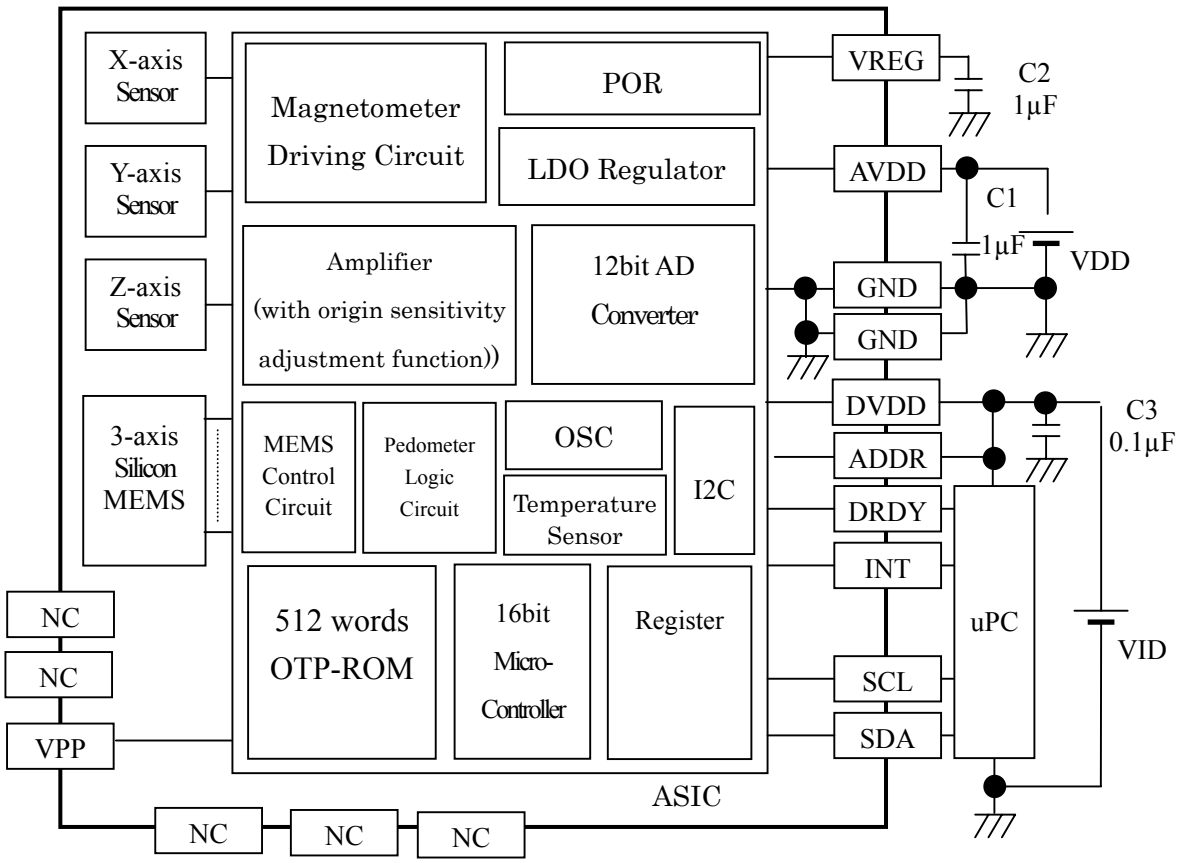
This specification applies to the 6-axis motion sensor AMI603 provided to ＊＊＊ by Aichi Steel Corporation.

[2] General Description

AMI603 is a motion sensor that integrates a 3-axis MI sensor and a 3-axis silicon MEMS accelerometer with their controller ASIC in a single small package.

The controller ASIC of AMI603 consists of a circuit for detecting the magnetic signals from the 3 MI-sensor elements, an amplifier capable of compensating each sensors offset and setting appropriate sensitivity values, a temperature sensor for measuring the ambient temperature, a 12bitAD converter, an I2C serial output circuit, a constant voltage circuit for power control and a 16bit micro-processor controlling each circuit. AMI603 has integrated hard-wired based pedometer function.

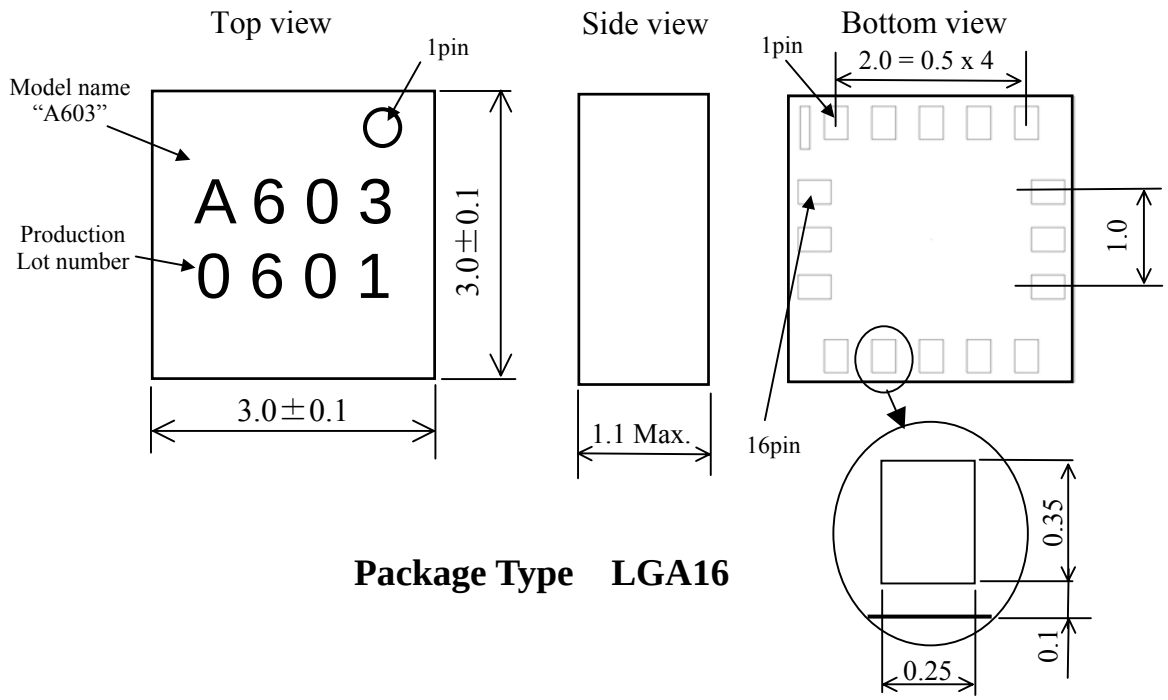
[3] Block Diagram



Note1) Please mount the 1μF capacitor connected with VREG and GND on neighborhood soon.

Note2) Please mount the 1μF capacitor connected with AVDD and GND on neighborhood soon.

[4] Dimensions and marking Layout



Package Type LGA16

[5] Terminal Description

Name	Pin No	I/O	Description	Reference
DVDD	1	Power	Digital Circuit Power Input	Please mount a 0.1μF bypass capacitor between DVDD and GND, in the proximity of terminals.
VREG	2	Output	Constant Voltage Output	Please mount a 1.0μF bypass capacitor between VREG and GND, in the proximity of terminals.
VPP	3	—	Testing Terminal	Use as Non-Connection (NC) or connect to GND.
SCL	4	Input	I2C communication Clock Input	—
GND	5	Power	Ground	—
SDA	6	Input & Output	I2C communication Data I/O	—
ADDR	7	Input	I2C programmable address bit	Please connect to DVDD or GND.
NC	8	—	—	—
INT	9	Output	Interrupt output of the sensor status is seen	—
NC	10	—	—	—
DRDY	11	Output	Completion of Measurement Output	—
GND	12	Power	Ground	—
NC	13	—	—	—
AVDD	14	Power	Analog Circuit Power	Please mount a 1.0μF bypass capacitor between AVDD and GND, in the proximity of terminals.
NC	15	—	—	—
NC	16	—	—	—

[6] Absolute Maximum Ratings

Parameter	Symbol	Ratings	Unit
Supply Voltage	AVDD	-0.3 to +5.0	V
	DVDD	-0.3 to +4.0	V
Storage Temperature	TSTG	-40 to + 125	°C
Input Voltage	VIN	-0.3 to DVDD+0.3	V
Mechanical Shock	Ashk	5000 for 0.5ms 10000 for 0.2ms	g

[7] Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit
Supply Voltage	AVDD	2.40	2.50	3.60	V
	DVDD	1.65	1.80	AVDD	V
Operating Temperature	TOPR	-40	—	+85	°C

[8] Magnetometer

(AVDD= +2.50V 、DVDD= +1.80V 、1.0μF ceramic capacitor between AVDD－GND)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Moving Range (*1)	Rm	Ta= +25 °C	—	±0.3	—	mT
Measurable Range (*2)	Ra	Adjust the offset with OFFX, OFFY, OFFZ to prevent from the saturation of output	—	±1.2	—	mT
Linearity	Lin	Rm=±0.3 mT、Ta= +25 °C	—	0.5	2	%FS
Output Offset Voltage at Zero Gauss	Vofs	Ta= +25 °C	—	0	—	LSB
		Change rate by temperature（Ta=0～+60℃, as 25℃ standard））	—	0±0.3	—	μT/℃
Magnetic Sensitivity	deltaV	Ta= +25 °C	—	6	—	LSB/μT
		Change rate by temperature（Ta=0～+60℃, as 25℃ standard）	—	-2±5	—	%
Resolution	—	Ta= +25 °C , Rm= ± 30μT at Horizontal plane	—	±0.9	—	degree
Accuracy (*3) (*4)	—	Ta= +25 °C , Rm= ± 30μT at Horizontal plane	—	±0.6	±1.0	degree
Measurement Time	Fr	Ta= 0～+60 °C , Force state	—	—	1000	SPS

*1: Moving range: preset operating range

*2: Measurable range: overall measurable range within which preset operating range can be fit in by adjusting appropriate offsets.

*3: After executing an initial calibration after AMI603 is mounted by the customer .

*4: The Cross axial interference correction is done by using "Axis interference" Registers.

[9] Accelerometer

(AVDD= +2.50V 、DVDD= +1.80V 、1.0μF ceramic capacitor between AVDD－GND)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Moving Range	Rm	Ta= +25 °C	—	±2	—	g
Linearity	Lin	Rm=±1g、Ta= +25 °C	—	0.5	4	%FS
Output Offset Voltage at Zero g	Vofs	Ta= +25 °C	—	0	—	LSB
		Change rate by temperature（Ta=0～+60℃, as 25℃ standard	—	0±3	—	mg/℃
Acceleration Sensitivity	deltaV	Ta= +25 °C	—	1000	—	LSB /g
		Change rate by temperature（Ta=0～+60℃, as 25℃ standard	—	0±5	—	%
Measurement Time	Fr	Ta= 0～+60 °C , Force state, A_ALWAYS_ON=1	—	—	1000	SPS

Note1) The manufacturer assures above properties in condition of lead-free solder at +380±5℃, for 5±0.5sec by human operator.

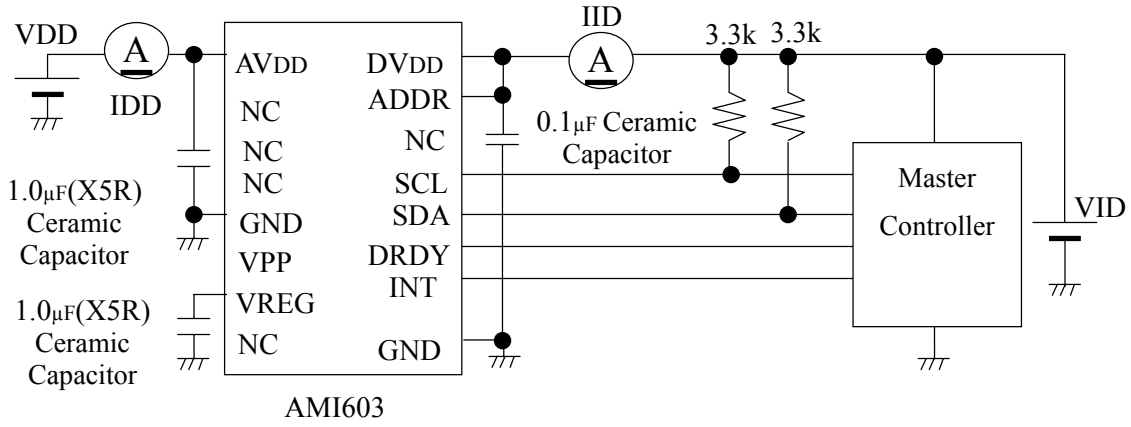
Note2) The manufacturer assures above properties with N2 reflow or 2-time reflow with the condition of Fig. 1 in［19］.

[10] Electrical Characteristics

(AVDD= +2.50V 、 DVDD= +1.80V 、 1.0μF ceramic capacitor between AVDD－GND)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Units
Average Operating Current	I_{DD1}	Output Data Rate = 20ms, Normal State		—	0.5	1	mA
	I_{ID1}			—	0.1	2.0	μA
Standby mode Operating Current	I_{DD2}	AVDD= +2.4V to 2.9V		—	7	30	μA
	I_{ID2}	—		—	0.1	2.0	μA
OFF-mode Leak Current	I_{DD3}	AVDD= Cut Off		—	—	1	μA
Pedometer Operating Current	I_{DD4}	at Walking		—	0.3	0.5	mA
	I_{DD5}	at Stop			0.13		mA
ADC Resolution	—	—		12			bit
I2C Operating Frequency	f_{SCL}	—		0	—	400	kHz
Start Condition Set-Time	t_{sta}	—		0.6	—	—	μs
High Level Input Voltage	V_{IH}	—		70% DVDD	—	—	V
Low Level Input Voltage	V_{IL}	—		—	—	30% DVDD	V
High Level Output Voltage	V_{OH}	—		80% DVDD	—	—	V
Low Level Output Voltage	V_{OL}	IOL = +3mA		—	—	20% DVDD	V
I2C Address	—	—	ADDR=DVDD	0001111			
			ADDR=GND	0001110			
Turn on time 1	tON1	From Power off mode to Standby mode		—	200	300	μs
Turn on time 2	tON2	From Standby mode to Active mode		—	—	8	μs
Turn off time 1	tOFF1	From Active mode to Standby mode		—	—	30	μs

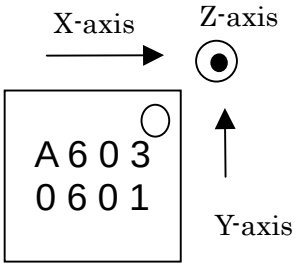
[11] Measuring Circuit



Note1) [8] Magnetometer , [9] Accelerometer and [10] Electrical Characteristics are measured with this circuit.

Note2) In order to obtain stable operation we recommend placing a ceramic capacitor (capacity more than 1.0 μF) between AVDD and GND and a ceramic capacitor (capacity more than 0.1μF) between DVDD and GND and a ceramic capacitor (capacity more than 1.0 μF) between VREG and GND.

[12] Polarity

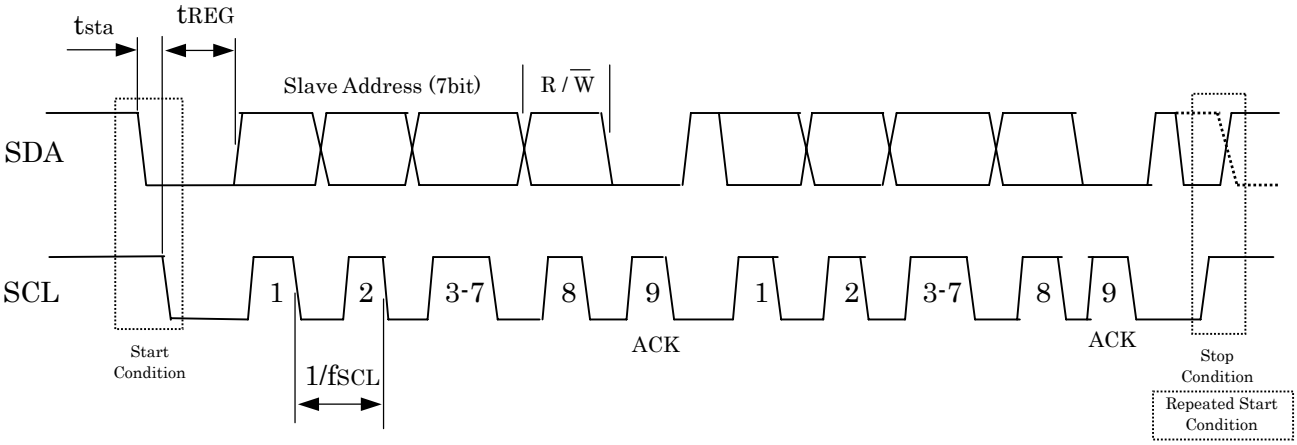


・When the arrow of Magnetometer is directing north output becomes "+".

・When the arrow of Accelerometer is directing vertically towards zenith output becomes "+".

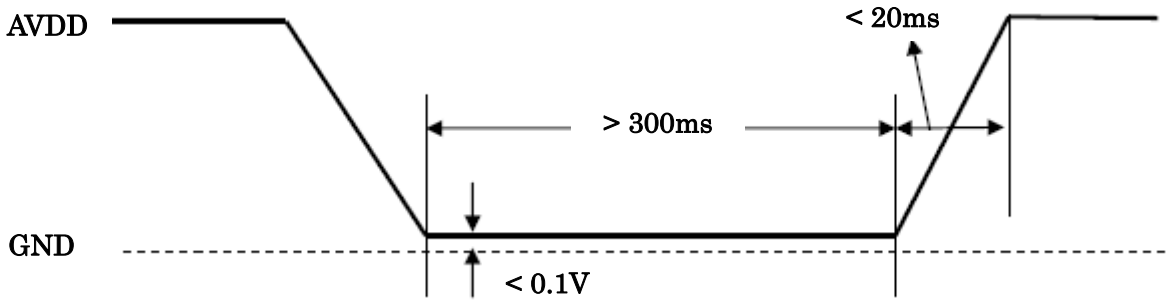
[13] Timing Chart

13-1. I2C BUS Timing Chart



13-2. Power OFF and Power ON

In order to secure stable starting, you have to carry out Power-OFF and Power-ON in the following procedure.



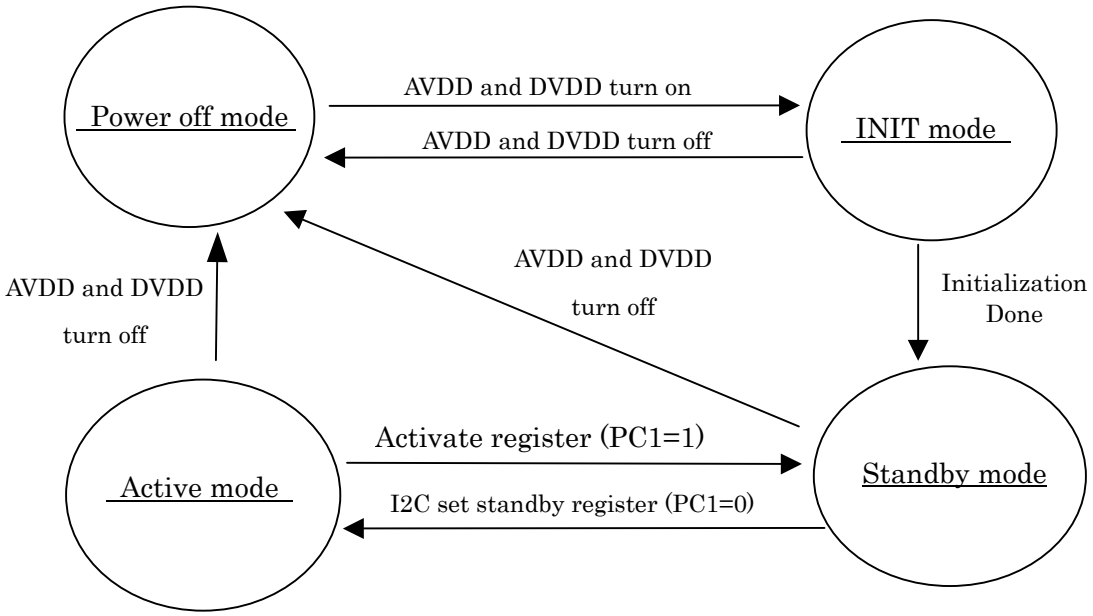
[14] Measurement Sequence

14-1. Functional states

In the functional states, there are two of the following.

States	Contents
Normal State	AMI603 is automatically measured at specified cycle (20ms or 40ms or 60ms or 80ms or 100ms). It enters this state when the pedometer is operated. It is possible to make the magnetometer and the accelerometer work individually.
Force State	AMI603 is measured according to the measurement request from the host. It is possible to make the magnetometer and the accelerometer work individually.

14-2. Mode Transfer



Mode	Contents
Power off mode	The power supply of AVDD and DVDD was intercepted. The value of RAM volatilizes.
INIT mode	After impressing the power supply of AVDD, AMI603 initializes some registers from OTP-ROM, initializes an analog circuit, and initializes RAM.
Standby mode	It is a state of the measurement waiting. At Normal state, AMI603 automatically begins measuring. At Force state, AMI603 begins measuring according to the measurement request from the host. When the measurement is ended, AMI603 automatically becomes Standby mode.
Active mode	AMI603 is a state while measuring it.

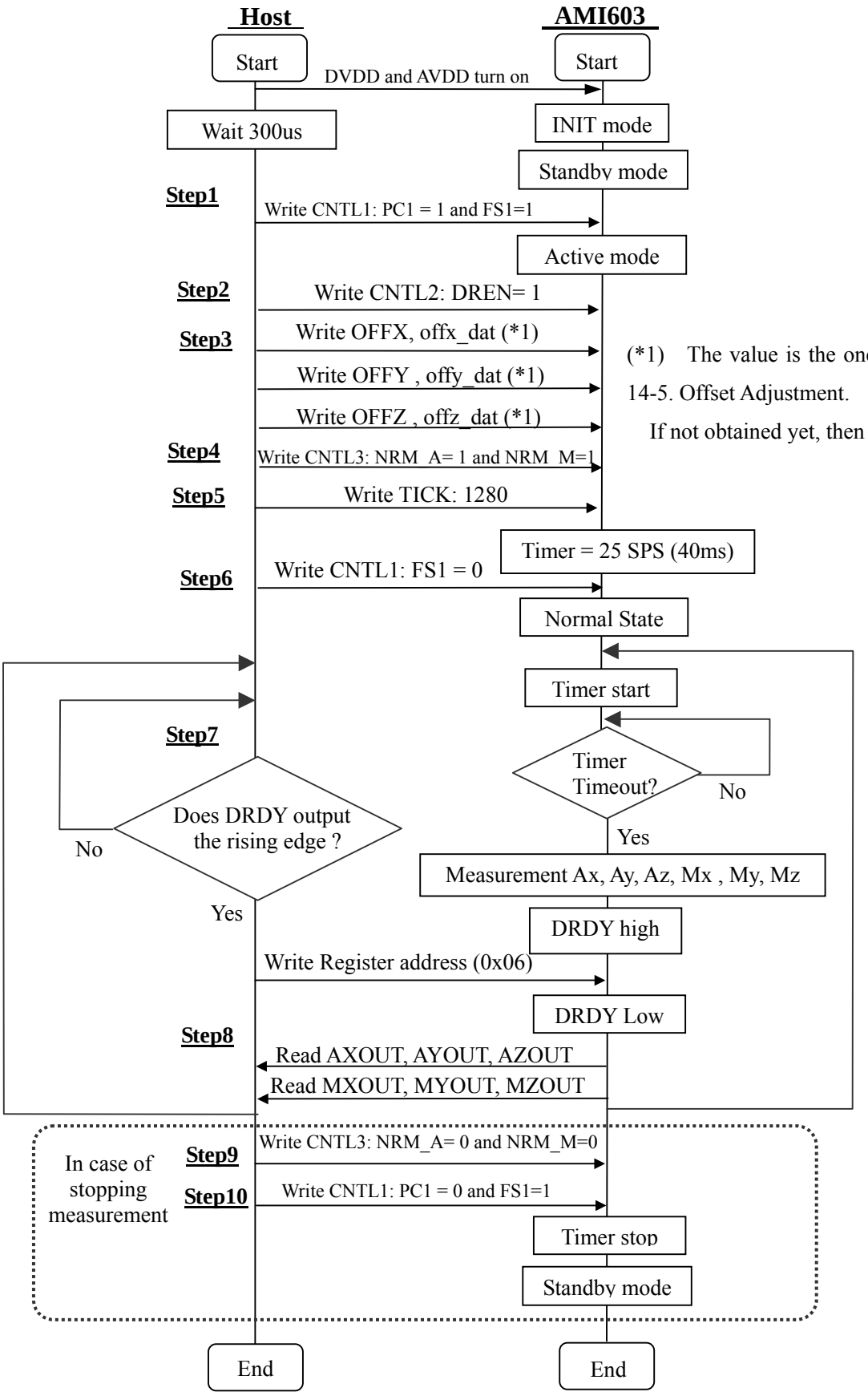
14-3. Normal State

Normal State sequence

Step1	AMI603 Active (Force State)
Step2	Set DRDY ready function enable
Step3	Set offx_dat, offy_dat, offz_dat
Step4	Set accelerometer and magnetometer function enable
Step5	Set Output Data rate
Step6	Set Normal state
Step7	Does DRDY output the rising edge ?
Step8	Read AXOUT, AYOUT, AZOUT, MZOUT, MZOUT, MZOUT
Step9 *1	Set accelerometer and magnetometer function disable
Step10 *1	AMI603 Standby (Force State)

*1 In case of stopping measurement

14-3. Normal State (continuance)



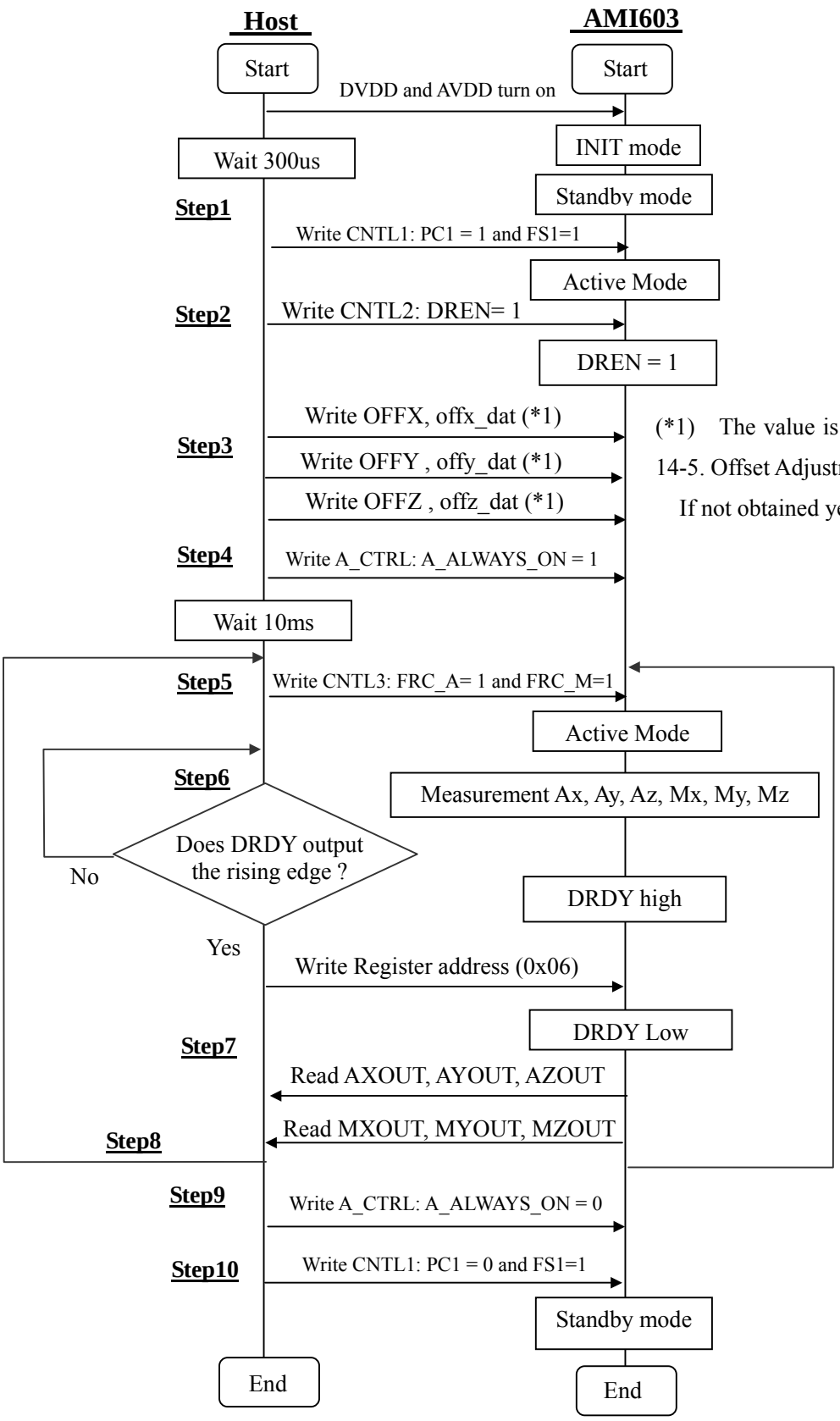
14-4. Force State

Force State sequence

Step1	AMI603 Active (Force State)
Step2	Set DRDY ready function enable
Step3	Set offx_dat, offy_dat, offz_dat
Step4	Accelerometer ON
Step5	Measurement Request
Step6	Does DRDY output the rising edge ?
Step7	Read AXOUT, AYOUT, AZOUT, MZOUT, MZOUT, MZOUT
Step8	Next Step5
Step9 *1	Accelerometer OFF
Step10 *1	AMI603 Standby (Force State)

*1 In case of stopping measurement

14-4. Force State (continuance)



(*1) The value is the one obtained at 14-5. Offset Adjustment.
If not obtained yet, then skip.

14-5. Offset Adjustment

14-5-1. Outline of Offset Adjustment

Offset Adjusting is to make the output value around zero under magnetic environment after the implementation by changing movement point electrically.

14-5-2. HOST Parameter

After measuring the following parameter according to 14-5-3. Procedures , HOST should save it in memory, and it is necessary to set after power supply injection of AMI603.

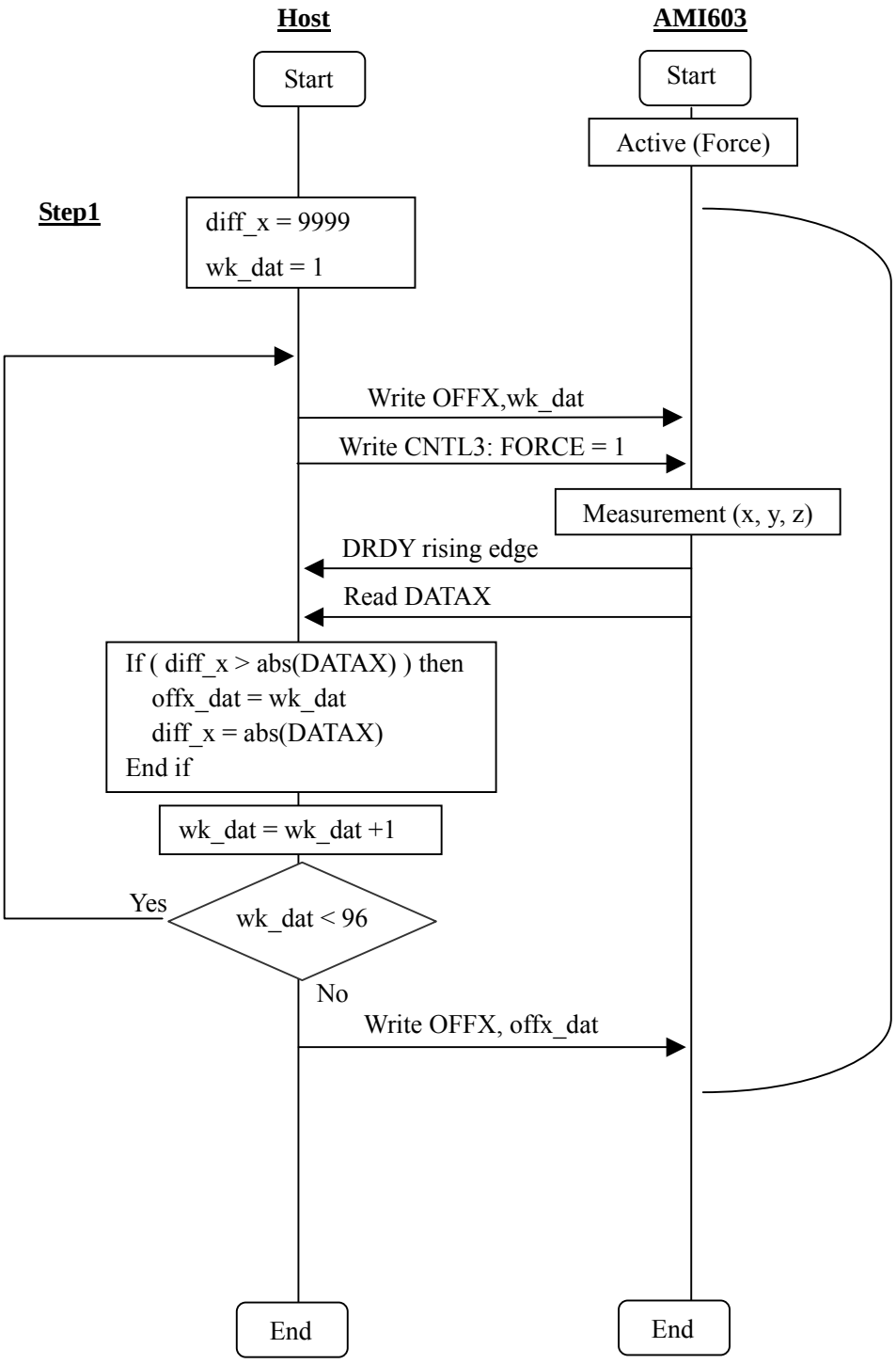
No	Parameter	Contents
1	offx_dat	Adjusted value of X-axis offset
2	offy_dat	Adjusted value of Y-axis offset
3	offz_dat	Adjusted value of Z-axis offset

14-5-3. Procedures

Procedure of Offset Adjusting is as follows.

Step1	offx_dat is obtained by finding the combination of each OFFX:FINE

14-5-3. Procedures (continuance)



14-5-4. Offset registers

There are fine in the Offset register. Fine is used for the fine-tuning.

The table below shows the structure of the Offset X register

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
OFFX	0x92	fine							
		X	X	X	X	X	X	X	X

Offset Y register and Offset Z register have same structure.

14-6. Setting of cycle period at Normal State

Normal State period setting an example is shown below. Magnetometer and accelerometer measurement period is determined by TICK_INTERVAL. And the period of the pedometer, DR_CTRL3 / 4 (Ratio of TICK_INTERVAL) depends.

Measurement mode: Magnetometer and Accelerometer

Register	Measurement period					
	20ms	40m	60ms	80ms	100ms	・・・
TICK_INTERVAL	640	1280	1920	2560	3200	・・・
CNTL3	0x0C	0x0C	0x0C	0x0C	0x0C	-
DR_CTRL3	-	-	-	-	-	-
DR_CTRL4	-	-	-	-	-	-

Measurement mode: Magnetometer, Accelerometer and Pedometer

Register	Measurement period	
	20ms	40m
TICK_INTERVAL	640	1280
CNTL3	0x0C	0x0C
DR_CTRL3	0x10	0x00
DR_CTRL4	0x10	0x00

Measurement mode: Pedometer

Register	Measurement period
	40ms (Pedometer check・at walking) 1.28s (Static condition)
TICK_INTERVAL	1280
CNTL3	0x00
DR_CTRL3	0x50
DR_CTRL4	0x00

[15] Control Interface

15-1. Power Supplies

15-1-1. AVDD

AVDD is main power supply. AMI603 works by using this power supply current.

15-1-2. DVDD

DVDD gives the voltage reference for digital logic interface.

15-1-3. Internal dropout regulator

AMI603 is equipped with a constant voltage regulator in order to stabilize AVDD power supply.

15-2. I2C slave interface

I2C interface is shown below

Terminal	Content
SCL	I2C Clock
SDA	I2C Data

Master/ slave	Slave only
Address	Consists of 7-bit address. The address of the IC is 0001111b (0x1F/read, 0x1E/write) when ADDR is connected to DVDD. The address of the IC is 0001110b (0x1D/read, 0x1C/write) when ADDR is connected to GND.
Tranfer Rate	Fast mode 400kHz

15-3. Interrupt signal

Interrupt signal is a function to observe the signal level input to AMI603. When the signal that exceeds the threshold inputs, INT pin outputs the signal.

The relating register is as follows.

Pedometer's Accumulated step interrupt (P_ACCS)

Interrupt signal	Setting pattern		Condition of Interrupt signal		
	INC1:IEN	INC2: PASE	INT terminal	STA1: A_INT	INS2: P_ACCS
STATUS_CNT exceeded ACC_CNT_TH.	1	1	Active	1	1
	1	0	No-Active	0	1
	0	1	No-Active	0	1

Pedometer's Step interrupt (P_STPS)

Interrupt signal	Setting pattern		Condition of Interrupt signal		
	INC1:IEN	INC2: PSIE	INT terminal	STA1: A_INT	INS2: P_STPS
The number of steps after the state of the pedometer had changed to "Walking" exceeded WALK_CNT_TH. (*1)	1	1	Active	1	1
	1	0	No-Active	0	1
	0	1	No-Active	0	1

(*1) The state of the pedometer is cleared and changing from "Walking" to "Walking Check" clears the number of steps including the final regulation match.

Pedometer's State change interrupt (P_STCS)

Interrupt signal	Setting pattern		Condition of Interrupt signal		
	IEN	INC2: PSCE	INT terminal	STA1: G_INT	INS2: P_STCS
Pedometer State In case of "Stop"⇔"Walking Check" or "Walking Check"⇔"Walking "	1	1	Active	1	1
	1	0	No-Active	0	1
	0	1	No-Active	0	1

Registers except above three registers

Registers	Contents
INC1: IEA	Active level Low / High of INT terminal
INC1: IEL	Signal latched/one pulse of INT terminal
INL	Interrupt clear

(※1) Accumulated step interrupt:
When STATUS_CNT exceeds ACC_CNT_TH, Interrupt signal outputs.

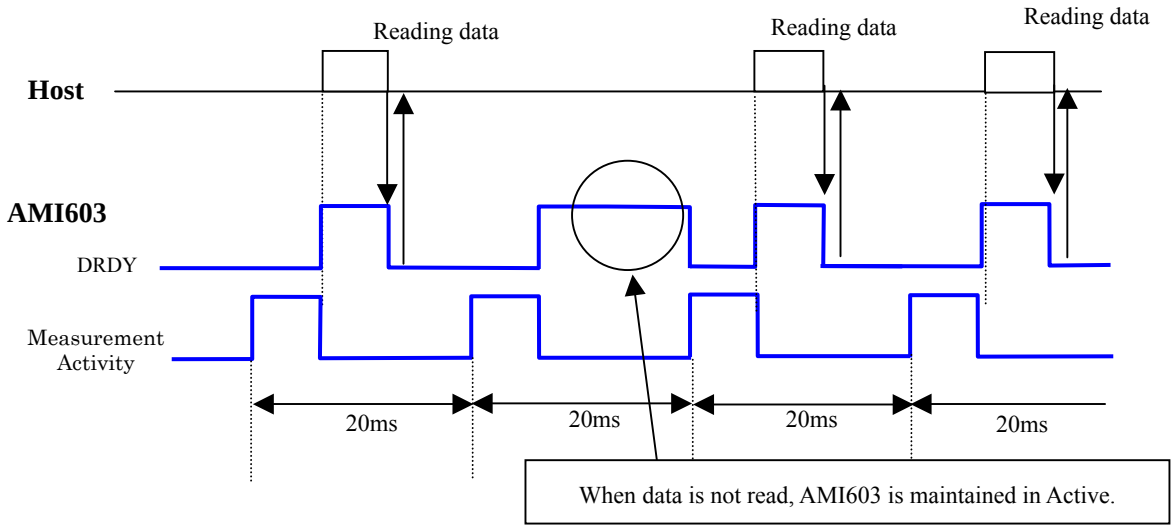
(※2) Step interrupt:
When the number of steps exceeds WALK_CNT_TH, Interrupt signal outputs.

(※3) State change interrupt:
When STATUS_STAT (state of walking) is changed, Interrupt signal outputs.

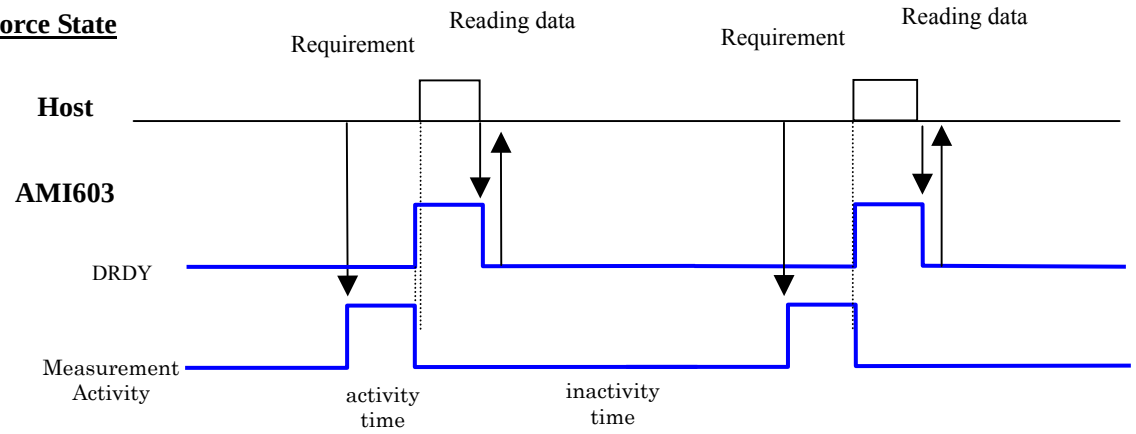
15-4. DRDY signal

The sequence of DRDY signal is shown below. This signal becomes active after measurement results become available. It turns non-active again with the execution of next measurement.

Normal State （Measurement period: 20ms , Pedometer: 40ms）



Force State



Note) In case the measurement results have not been read out during inactivity time, STAT1:DOR is set.

The related registers are as follows:

Register	Content
CNTL2:DREN	DRDY Terminal Enable/ disable
CNTL2:DRP	DRDY Terminal Active Level　Low / High
STA1:DRDY	DRDY Status of Terminal
STA1:DOR	Output Data Overrun

[16] Command

16-1. Command Sequence

There are 2 patterns of commands: read command and write command.
Read command is used for reading registers and accessing output values.
Write command is used for register setup.

The command sequences are shown below.

16-1-1. Read Command

Master	S	SAD+ W (*1)		RAD		S r	SAD+ R (*1)			A		A		N	P
Slave			A		A			A	RDA1		RDA2		・		

Term	Definition	Term	Definition
S	Start Condition	SAD + W	slave address + write (0x1E or 0x1C)
Sr	Restart Condition	SAD + R	slave address + read (0x1F or 0x1D)
A	ACK（SDA_Low）	RAD	Read-in address (register)
N	NACK（SDA_High）	RDA1	Read-in data1
P	Stop Condition	RDA2	Read-in data2

(*1)

7	6	5	4	3	2	1	0
SAD							W/R

16-1-2. Write Command

Master	S	SAD+W (*1)		WAD		WDA1		WDA2		・・・		P
Slave			A		A		A		A		A	

Term	Definition	Term	Definition
S	Start Condition	SAD + W	slave address + write (0x1E or 0x1C)
A	ACK（SDA_Low）	WAD	Write-in address (register)
N	NACK（SDA_High）	WDA1	Write-in data 1
P	Stop Condition	WDA2	Write-in data 2

(*1)

7	6	5	4	3	2	1	0
SAD							W/R

[17] Register

17-1. Register type

The register types are as follows:

Type	Attribution	Content
TYPE1	Control and Condition	Unsigned 1 byte (unsigned char).
TYPE2	-	-
TYPE3	Output of Sensors	2´s complement signed 2 byte. -2048d = 0xF800 0d = 0x0000 2047d = 0x07FF Storage Form is in Little Endian.
TYPE4	Interrupt threshold Temperature	unsigned 2 byte. 0d = 0x0000 2047d = 0x0FFF Storage Form is in Little Endian.
TYPE5	Pedometer	unsigned 4 byte. 0d = 0x00000000 2047d = 0x000007FF Storage Form is in Little Endian.

17-2. Register Map

The table below provides a listing of the registers. Each address data with is of 8 bit.

Register Name	Address	Type	R/W	Set Contents	Remark
-	0x00-0x05	-	-	Reserved	-
AXOUT	0x06/0x07	TYPE3	R	Acceleration X Output value	-
AYOUT	0x08/0x09	TYPE3	R	Acceleration Y Output value	-
AZOUT	0x0A/0x0B	TYPE3	R	Acceleration Z Output value	-
MXOUT	0x0C/0x0D	TYPE3	R	Magnetic X Output value	-
MYOUT	0x0E/0x0F	TYPE3	R	Magnetic Y Output value	-
MZOUT	0x10/0x11	TYPE3	R	Magnetic Z Output value	-
-	0x12-0x16	-	-	Reserved	-
INS2	0x17	TYPE1	R	Interrupt Source 2	-
STA1	0x18	TYPE1	R	Status of Measurement 1	-
-	0x19	-	-	Reserved	-
INTREL	0x1A	TYPE1	R	Interrupt Latch release	-
CNTL1	0x1B	TYPE1	R/W	Control setting 1	-
CNTL2	0x1C	TYPE1	R/W	Control setting 2	-
CNTL3	0x1D	TYPE1	R/W	Control setting 3	-
INC1	0x1E	TYPE1	R/W	Interrupt Control 1	-
INC2	0x1F	TYPE1	R/W	Interrupt Control 2	-
-	0x20-0x29	-	-	Reserved	-
-	0x2A/0x2B	-	-	Refer to [18] Pedometer	
-	0x2C-0x3E	-	-	Reserved	-
I2C_PAGE_NO	0x3F	TYPE1	R/W	Change I2C Page No	-
-	0x40-0x6F	TYPE1	R/W	Refer to [18] Pedometer	-
-	0x70-0x83	-	-	Reserved	
TICK_INTERVAL	0x84	TYPE4	R/W	Tick Interval	-
-	0x85-0x91	-	-	Reserved	-
OFFZ	0x92	TYPE1	R/W	Magnetic Z Offset value	-
OFFY	0x95	TYPE1	R/W	Magnetic Y Offset value	-
OFFX	0x98	TYPE1	R/W	Magnetic X Offset value	-
-	0x99-0xB3	-	-	Reserved	
A_CNTL	0xB4	TYPE1	R/W	Accelerometer Control	
-	0xB5-0xB7	-	-	Reserved	
INFO	0xB8 / 0xB9	TYPE4	R	More Info	
WIA	0xBA	TYPE1	R	Who I Am	
VER	0xBC / 0xBD	TYPE4	R	Firmware version	-
SN	0xBE / 0xBF	TYPE4	R	Serial Number	-
-	0xC0-0xD5	-	-	Reserved	
TEMP	0xD6 / 0xD7	TYPE4	R	Temperature value	
-	0xD6-0xFF	-	-	Reserved	

Note1) Please communicate TYPE3 and TYPE4 bringing 2bytes together.

Note1) Please communicate TYPE5 bringing 2bytes together.

17-3. Register Map Details

AXOUT : Accelerometer output of X axis

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
AXOUT	0x06	X	X	X	X	X	X	X	X
	0x07	X	X	X	X	X	X	X	X

AYOUT : Accelerometer output of Y axis

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
AYOUT	0x08	X	X	X	X	X	X	X	X
	0x09	X	X	X	X	X	X	X	X

AZOUT : Accelerometer output of Z axis

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
AZOUT	0x0A	X	X	X	X	X	X	X	X
	0x0B	X	X	X	X	X	X	X	X

MXOUT : Magnetometer output of X axis

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
MXOUT	0x0C	X	X	X	X	X	X	X	X
	0x0D	X	X	X	X	X	X	X	X

MYOUT : Magnetometer output of Y axis

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
MYOUT	0x0E	X	X	X	X	X	X	X	X
	0x0F	X	X	X	X	X	X	X	X

MZOUT : Magnetometer output of Z axis

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
MZOUT	0x10	X	X	X	X	X	X	X	X
	0x11	X	X	X	X	X	X	X	X

INS2 ：To hold the Interrupt event of Accelerometer with each axis measure.

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
INS2	0x17	-	-	-	-	-	P_STCS	P_ACCS	P_STPS

bit	Name	Content	Default
7	-	Reserved	0
6	-	Reserved	0
5	-	Reserved	0
4	-	Reserved	0
3	-	Reserved	0
2	P_STCS	state change indication of pedometer 0 – no pedometer state change detected 1 – a pedometer state change detected	0
1	P_ACCS	interrupt indication of the accumulated step of pedomete 0 – accumulated step has not exceeded ACC_CNT_TH register 1 – accumulated step has exceeded ACC_CNT_TH register	0
0	P_STPS	interrupt indication of walking step of pedometer 0 – step count has not exceeds WALK_CNT_TH within current walk-state 1 – step count has exceeds WALK_CNT_TH within current walk-state	0

Refer to 15-3. Interrupt signal

STA1 ：Store pin output information

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
STA1	0x18	-	DRDY	DOR	-T	A_INT	-	-	-

bit	Name	Content	Default
7	-	Reserved	0
6	DRDY	This bit is output to the DRDY to inform the preparation status of the measuring data 0: Not ready NG 1: Ready OK	0
5	DOR	Set 1 = In case the measurement results have not been read out during inactivity time ・After setting of 1, it is cleared by reading command.	0
4	-	Reserved	-
3	A_INT	This bit is output to INT pin to inform Accelerometer Interrupt event. 0 = No Interrupt event 1 = Interrupt event occurred ・ INS2 tells in which the event occurred. ・ After setting of 1, it is cleared by reading INTREL. ・ Refer to 15-3. Interrupt signal	0
2	-	Reserved	-
1	-	Reserved	-
0	-	Reserved	-

INTREL : interrupt release register

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
INTREL	0x1A	-	-	-	-	-	-	-	-

bit	Name	Content	Default
7:0	-	When this register is read, the return value will always become ZERO.	0

CNTL1 : Set the Power mode and Measure mode

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
CNTL1	0x1B	PC1	FS1	-	PEDOE	-	-	-	-

bit	Name	Content	Default
7	PC1	Set Power Mode. 0 = Standby 1 = Active Note) Control from Active to Standby Step1: CNTL1:PEDOE=0 Step2: CNTL2:NRM_M=0 ,NRM_A=0 Step3: CNTL1:PC1=0	0
6	FS1	Set Measurement Mode. 0 = Normal State 1 = Force State	1
5	-	Not used	-
4	PEDOE	Pedometer enable. It will take effect only in normal state. 0 = Disable 1 = Enable	0
3	-	Reserved	0
2	-	Reserved	0
1	-	Reserved	0
0	-	Reserved	0

Note) In Standby mode (PC1= 0), some settings of the chip will be parked to the states as below.

- It will be in force state (FS1= 1).
- INS2 will be cleared.
- STA2 will be cleared.
- INT pin and DRDY pin will be inactive.

CNTL2 : Set to the Enable or Disable for Interrupt or DRDY pin.

	address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
CNTL2	0x1C	DREN	DRP	-	-	-	-	-	-

bit	Name	Content	Default
7	DREN	Set the enable for DRDY. 0 = Disable 1 = Enable	0
6	DRP	DRDY polarity setting. 0 = Low 1 = High	1
5	-	Reserved	1
4	-	Reserved	1
3	-	Reserved	1
2	-	Reserved	1
1	-	Reserved	1
0	-	Reserved	1

CNTL3 : Set the control parameter

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
CNTL3	0x1D	SRST	FRC_M	FRC_A	-	NRM_M	NRM_A	-	-

bit	Name	Content	Default
7	SRST	Soft reset, perform to same routine as POR 0 = no action 1 = start immediately POR routine -This bit is reset to zero after POR routine	0
6	FRC_M	Starts forced measurement of MI. 0 = no action 1 = start MI measurement immediately - This bit is reset to zero after Magnetometer done - This bit can be set only when force state selected (CNTL1, bit FS1=1).	0
5	FRC_A	FRC_G: Starts forced measurement of accelerometer. 0 = no action 1 = start accelerometer measurement immediately -This bit is reset to zero after accelerometer measurement done -This bit can be set only when force state selected (CNTL1, bit FS1=1).	0
4	-	Reserved	0
3	NRM_M	Enable measurement of MI in normal state. 0 = disable 1 = enable This bit will take effect only when normal state selected (CNTL1, bit FS1=0).	0
2	NRM_A	Enable measurement of accelerometer in normal state. 0 = disable 1 = enable This bit will take effect only when normal state selected (CNTL1, bit FS1=0).	0
1	-	Not used	0
0	-	Not used	0

INC1 : Set of Interrupt Control Parameter.

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
INC1	0x1E	-	-	-	-	IEN	IEA	IEL	IEU

bit	Name	Content	Default
7	-	Reserved	-
6	-	Reserved	-
5	-	Reserved	-
4	-	Reserved	-
3	IEN	Set Interrupt port 0 = Disable 1 = Enable	0
2	IEA	Set Interrupt Active 0 = Low 1 = High	1
1	IEL	Set Interrupt Signal 0 = Latched 1 = One pulse (0.05ms)	0
0	-	Reserved	-

INC2 : Set of Interrupt Control Parameter.

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
INC2	0x1F	-	-	-	-	-	PSCE	PASE	PSIE

bit	Name	Content	Default
7	-	Reserved	-
6	-	Reserved	-
5	-	Reserved	-
4	-	Reserved	-
3	-	Reserved	-
2	PSCE	Pedometer state change interrupt enable (0 = Disable, 1 = Enable)	1
1	PASE	Pedometer accumulated step interrupt enable	1
0	PSIE	Pedometer step interrupt enable	1

I2C_PAGE_NO : Set of I2C Page Number

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
I2C_PAGE_NO	0x3F	-	-	-	-	NO3	NO2	NO1	NO0

bit	Name	Content	Default
7	-	Reserved	0
6	-	Reserved	0
5	-	Reserved	0
4	-	Reserved	0
3	NO3	Page Number	0
2	NO2	Page Number	0
1	NO1	Page Number	0
0	NO0	Page Number	1

OFFZ : The offset value of Z axis magnetometer is set. An initial value is different in each individual.

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
OFFZ	0x92	X	X	X	X	X	X	X	X

OFFY : The offset value of Y axis magnetometer is set. An initial value is different in each individual.

	Address	7bit	6bit	5b	4bit	3bit	2bit	1bit	0bit
OFFY	0x95	X	X	X	X	X	X	X	X

OFFX : The offset value of X axis magnetometer is set. An initial value is different in each individual.

	Address	7bit	6bit	5b	4bit	3bit	2bit	1bit	0bit
OFFX	0x98	X	X	X	X	X	X	X	X

A_CNTL : Accelerometer Control

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
A_CNTL	0xB4	-	-	-	-	-	-	-	A_ALWAYS_ON

bit	Name	Content	Default
7	-	Reserved	-
6	-	Reserved	-
5	-	Reserved	-
4	-	Reserved	-
3	-	Reserved	-
2	-	Reserved	-
1	-	Reserved	-
0	A_ALWAYS_ON	When set, the accelerometer circuit will always be on, and user can do the measurement of acceleration at any time except the 1st one.	0

INFO : More information

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
INFO	0xB8	X	X	X	X	X	X	X	X
	0xB9	X	X	X	X	X	X	X	X

WIA : Who I Am

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
WIA	0xBA	0x45							

VER : Firmware version

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
VER	0xBC	RES	Firmware version						
	0xBD	RES	RES	RES	RES	RES	RES	RES	RES

SN : Serial number

	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
SN	0xBE	X	X	X	X	X	X	X	X
	0xBF	X	X	X	X	X	X	X	X

TEMP： Temperature sensor value

	Address	7bit	6bit	5b	4bit	3bit	2bit	1bit	0bit
TEMP	0xD6	X	X	X	X	X	X	X	X
	0xD7	X	X	X	X	X	X	X	X

17-4. OTP map

OTP map is shown in the following. The width of data of each address is two bytes.

OTP Name	Address	R/W	Set Contents	Remark
GAIN_PARA_AX	0xAC / 0xAD	R	Axis interference Accelerometer X value	-
SENSMX	0xB4 / 0xB5	R	Magnetometer sensitivity of X-axis. Amount of signal change at 0.1mT.	-
SENSMY	0xB6 / 0xB7	R	Magnetometer sensitivity of Y-axis. Amount of signal change at 0.1mT.	-
SENSMZ	0xB8 / 0xB9	R	Magnetometer sensitivity of Z-axis. Amount of signal change at 0.1mT.	-
GAIN_PARA_MX	0xA6 / 0xA7	R	Axis interference Magnetometer X value	-
GAIN_PARA_MY	0xA8 / 0xA9	R	Axis interference Magnetometer Y value	-
GAIN_PARA_MZ	0xAA/ 0xAB	R	Axis interference Magnetometer Z value	-
ORGAX	0xC4 / 0xC5	R	Accelerometer X Origin value	-
ORGAY	0xC6 / 0xC7	R	Accelerometer Y Origin value	-
ORGAZ	0xC8 / 0xC9	R	Accelerometer Z Origin value	-
SENSAX	0xCA / 0xCB	R	Accelerometer sensitivity of X-axis. Amount of signal change at 2g.	-
SENSAY	0xCC / 0xCD	R	Accelerometer sensitivity of Y-axis. Amount of signal change at 2g.	-
SENSAZ	0xCE / 0xCF	R	Accelerometer sensitivity of Z-axis. Amount of signal change at 2g.	-

Detail is below.

GAIN_PARA_AX : Output value of X axis to non-reactive axis of Accelerometer.

GAIN_PARA_AX	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
GAIN_PARA_AXZ	0xAC	X	X	X	X	X	X	X	X
GAIN_PARA_AXY	0xAD	X	X	X	X	X	X	X	X

GAIN_PARA_MX : Output value of X axis to non-reactive axis of Magnetometer.

GAIN_PARA_MX	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
GAIN_PARA_MXZ	0xA6	X	X	X	X	X	X	X	X
GAIN_PARA_MXY	0xA7	X	X	X	X	X	X	X	X

GAIN_PARA_MY : Output value of X axis to non-reactive axis of Magnetometer.

GAIN_PARA_MY	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
GAIN_PARA_MYZ	0xA8	X	X	X	X	X	X	X	X
GAIN_PARA_MYX	0xA9	X	X	X	X	X	X	X	X

GAIN_PARA_MZ : Output value of X axis to non-reactive axis of Magnetometer.

GAIN_PARA_MZ	Address	7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit
GAIN_PARA_MZY	0xAA	X	X	X	X	X	X	X	X
GAIN_PARA_MZX	0xAB	X	X	X	X	X	X	X	X

17-5. OTP reading procedure

The reading procedure of OTP is shown in the following.

Step1	Write I2C_PAGE_NO 15 (*1)
Step2	Read of 17-4. OTP map Read SENSMX Read SENSMY …… Read SENSAZ
Step3	Write I2C_PAGE_NO 0x00

(*1) When PAGE_NO is #15, Host can not access 17-2. Register Map.

[18] Pedometer

18-1. Register map of Pedometer

Register Name	Address	Type	R/W	Set Contents	Remark
DR_CTRL3	0x2A	TYPE1	R/W	Ratio of dividing frequency (Stop)	-
DR_CTRL4	0x2B	TYPE1	R/W	Ratio of dividing frequency (Walking Check, Walking)	-
REST_OUT_TH	0x42	TYPE1	R/W	Refer to 18-2. Threshold detail	-
REST_IN_TIME	0x43	TYPE1	R/W		-
REST_IN_CNT	0x44	TYPE1	R/W		-
REST_IN_TH	0x45	TYPE1	R/W		-
STEP_UP_TH	0x46	TYPE1	R/W		-
STEP_DW_TH	0x47	TYPE1	R/W		-
STEP_MS	0x48	TYPE1	R/W		-
STEP_STOP_MS	0x49	TYPE1	R/W		-
IIR_WEIGHT1	0x4A	TYPE1	R/W		-
IIR_WEIGHT2	0x4B	TYPE1	R/W		-
IIR_WEIGHT3	0x4C	TYPE1	R/W		-
TWO_STEP_MIN	0x4D	TYPE1	R/W		-
TWO_STEP_MAX	0x4E	TYPE1	R/W		-
STATUS_CNT	0x4F/0x50 0x51/0x52	TYPE5	R	Number of steps	-
STATUS_TIME	0x53/0x54 0x55/0x56	TYPE5	R	Number of steps (s)	
STATUS_STAT	0x57	TYPE1	R	State of Pedometer 0: Stop 1: Walking Check 2: Walking	
RST_STATUS	0x58	TYP1	R	Clearness of the following register STATUS_CNT STATUS_TIME STATUS_STAT	
-	0x59-0x5E	-	-	Reserved	
ACC_CNT_TH	0x5F/0x60 0x61/0x62	TYPE5	R/W	Threshold of Accumulated step interrupt	
WALK_CNT_TH	0x63/0x64	TYPE4	R/W	Threshold of step interrupt	
ZERO_CROSS_CHK	0x65	TYPE1	R/W	Refer to 18-2. Threshold detail	-
TWO_STEP_DEF	0x66	TYPE1	R/W		-
TWO_STEP_CHK	0x67	TYPE1	R/W		-
-	0x68/0x6F	-	-	Reserved	

Note1) Please communicate TYPE3 and TYPE4 bringing 2bytes together.
Note2) Please communicate TYPE5 bringing 4bytes together.

18-2. Threshold detail

Symbol		Threshold	Description	Initial value	Unit for 1LSB	Setting Range (*3)
TH1	REST_OUT_TH	Acceleration from ”Stop” to “Walking Check”	Threshold value of acceleration to judge the transfer from Stop to Walking Check.	50	1mg	1～255
TH2	REST_IN_TIME	Judging time for ”Waking Check “ to “Stop”	One judging time of transfer from Walking Check to Stop	25 (1s)	40 ms	2～255
TH3	REST_IN_CNT	Judging number of ”Walking Check” to “Stop”	Judging number of acceleration difference within the time TH2 compared with the threshold TH4. If this number is within consecutively the preset number, the status is judged to be Stop	3	1 回	1～255
TH4	REST_IN_TH	Acceleration from “Walking Check” to ”Stop”	Threshold value of acceleration to judge the transfer from Walking Check t o Stop.	50	1 mg	1～255
TH5	STEP_UP_TH	Stepping threshold 1	Acceleration change of stepping (dynamic acceleration) Threshold value for upward movement (*1)	30	1 mg	1～255 (*4)
TH6	STEP_DW_TH	Stepping threshold 2	Acceleration change of stepping (dynamic acceleration) Threshold value for downward movement (*1)	15	1 mg	1～255 (*4)
TH7	STEP_MS	Stepping threshold 3	Minimum time duration for stepping (*2)	5 (200ms)	40 ms	1～255
TH8	STEP_STOP_MS	Judging time for “Walking Stop”	In Walking, if no stepping is observed in certain time, transfer to the Walking Check.	50 (2s)	40 ms	1～255
TH9	IIR_WEIGHT1	Digital filter setting 1	Digital filter constant for first degree IIR	4	Coefficient	1～255
TH10	IIR_WEIGHT2	Digital filter setting 2	Digital filter constant for second degree IIR （*6）	9	Coefficient	1～255
TH11	IIR_WEIGHT3	Digital filter setting 3	Digital filter constant for vertical axis judgment	50	Coefficient	1～255
TH12	ZERO_CROSS_CHK	Amplitude number of acceleration change	Amplitude number of acceleration change in 5 steps.	15	15 (15 times)	1 to 255
TH13	TWO_STEP_MIN	Walking period setting 1	Minimum time of 2-step cycle to detect 2-step walking period in 6-step judgment	15 (600ms)	40 ms	1 ～ 255
TH14	TWO_STEP_MAX	Walking period setting 2	Maximum time of 2-step cycle to detect 2-step walking period in 6-step judgment （*7）	50 (2s)	40 ms	1 ～ 255
TH15	TWO_STEP_DEF	Walking period setting 3	2-step walking period error in 6-step judgment to detect 2-step walking period	18 (720ms)	40 ms	1 ～ 255
TH16	TWO_STEP_CHK	Walking period setting 4	2-step walking period interval check number to to detect 2-step walking period in 6-step judgment	3 (3time)	1time	1 ～ 4

（*1） Step is accepted when both upward and downward movements are above each threshold

（*2） Within in this interval after the first step, even if the acceleration change larger than TH5 or TH6 is observed, it is not considered to a step.

（*3） Correct pedometer operation will not be assured when the parameters out of the setting range is set.

（*4） The value should be larger than ”TH1” or ”TH4”.

（*5） 「”6CH data” + “pedometer” operates 40 ms only

（*6） “TH10” should be bigger than “TH9”.

（*7） “TH14” should be bigger than “TH13”

18-3. Pedometer Managing Status

Status	Description
Stop	Small acceleration which can not be attributed to walking
Walking Check	Acceleration exist, checking walking or not
Walking	Walking (including running). Steps are counted by the pedometer in this status. Walking time is defined as the time in this Walking status.

18-4. Status Transfer Conditions

Status Transfer	Transfer Conditions
Stop to Walking Check	3-axis accelerometer data at present moment and 1.28s (**DR_CTRL3**) before are compared, and found that the difference exceeds **TH1**.
Walking Check to Stop	3-axis accelerometer data never exceeded **TH4** within 3 seconds (**TH3**) at 40ms sampling.
Walking Check to Walking	Step (**TH5, TH6, TH7**) is observed regularly for 6 steps. If the status transferred from Walking Check to Walking, 6 steps are added to the step number and the time for the 6 steps is added to walking time.
Walking to Walking Check	No step was observed for 2000ms (**TH8**).The sensor attitude is significantly changed (the gravity axis are changed).

18-5. Procedure of Pedometer

Procedure of Pedometer is shown in the following.

Step1	14-3. Normal State step1-step3
Step2	Interrupt enable (INT pin Active-High, Latch) Write INC1 0x0C
Step3	Setting of Interrupt threshold Write ACC_CNT_TH * Write WALK_CNT_TH * (When the interruption is not used, it skips.)
Step4	Setting of measurement period (Refer to14-6. Setting of cycle period at Normal State) Write TICK_INTERVAL 1280 Write DR_CTRL3 0x50 Write DR_CTRL4 0x00
Step5	Pedometer Enable (Normal-State / Active) Write CNTL1 0x90

[19] Environmental and Mechanical Characteristics

Test Item	Test Method	Preparation *	Evaluated Characteristics	n(C=0) [LTPD]
Vibration	10～500Hz, 100m/s^2	—	Electric, Mechanical Characteristics	11[20%]
Mechanical Shock	20000m/s^2, ±X,Y,Z each 3 times	—	Electric, Mechanical Characteristics	11[20%]
Free Fall Test	170cm, ±X,Y,Z each 1 time in Succession.	—	Electric, Mechanical Characteristics	11[20%]
Repeated Fall Test	5～30cm、±X,Y, Z each 10 times in Succession.	—	Electric, Mechanical Characteristics	11[20%]
Solder Heat Resistance	Infrared reflow (See Fig.1), 3 times.	1)	Change rate of the electro-magnetic characteristics must be less than ±20%	22[10%]
High Temperature Storage	+125±2℃、1000h	—		22[10%]
Low Temperature Storage	-40±3℃、1000h	—		22[10%]
Temperature Humidity Storage	+85±2℃、85±5%RH、1000h	1)+2)		22[10%]
Temperature Cycling Test	-40 ～ 125 ℃ ,(30min,5min,30min), 1000cycle	1)+2)		22[10%]
High Temperature Operation	+125±2℃,+3.6V, 1000h	—		22[10%]
High Temp/Humidity Bias	+85±2℃、85±5%RH, ＋3.6V, 1000h	1)+2)		22[10%]
ESD Sensitivity (Human Body Model)	100pF、1.5kΩ、±1,000V、3 times	—	Electric Characteristics	11[20%]
ESD Sensitivity (Machine Model)	200pF、0Ω、±200V、5 times	—	Electric Characteristics	11[20%]
Latch Up Strength	Trigger Current: ±100mA	—	Electric Characteristics	11[20%]
Circuit Board Flex	Support Span 90mm、Flex 3mm、5±1sec hold	—	Electric Characteristics	22[10%]

*［Preparation］（Ref.: EIAJ ED4701-2 B101A）

1) Saturation Humidification processing:
   (Ta= +85°C, RH= 30%, t= 168 hours, + Ta= +30°C, RH= 70%, t= 168 hours)
2) Infrared Reflow (continuously for 3 times)
3) Water vapor aging (4 hours)

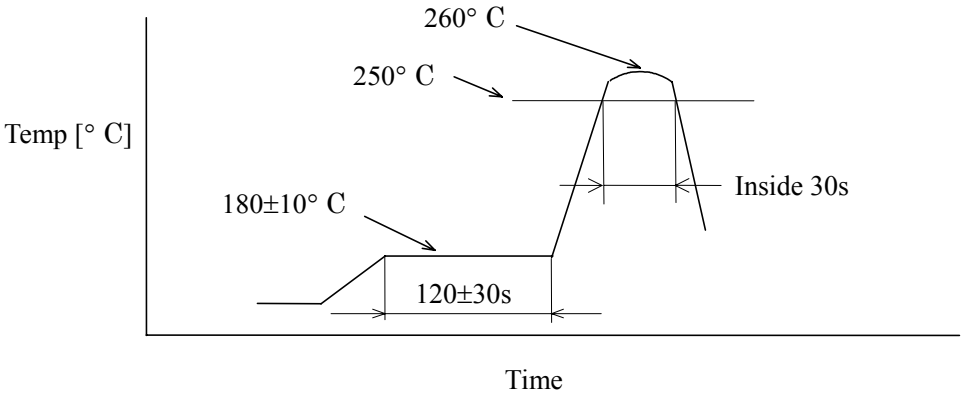
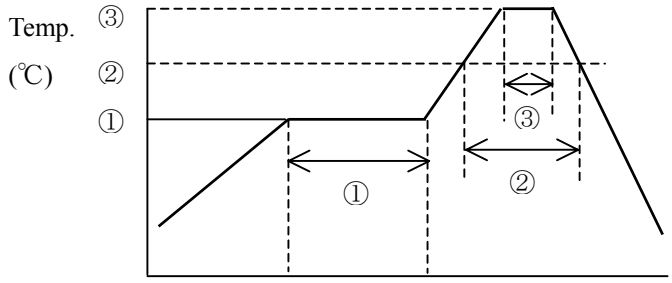


Fig.1. Infrared Reflow Heating Conditions

[20] Reflow Soldering Conditions



① Pre-heat：(+150～+190℃) × (90±30 sec)
② +220℃ band width：20～50 sec
③ Soldering ： +235 ～ +250 ℃ peak （less than 10sec）
④ Heating atmosphere：air or N_2

Fig.2 Reflow soldering condition

For repair, + 250～+270℃×30 sec or less, heating time 150 or less (including 70 sec pre-heat)
If the device contains moisture, bake the device before repair.

[21] Notes

1) This device uses a C-MOS IC. Please take precautions to prevent damage due to electrical static discharge.
2) Memory data in OTP is not rewritable.
3) In order to obtain stable operation we recommend placing a ceramic capacitor (capacity more than 1.0μF) between AVDD and GND and a ceramic capacitor (capacity more than 0.1μF) between DVDD and GND.
4) The writing pattern to AVDD and GND should be as wide as possible in order to reduce high frequency impedance.
5) Sensor Characteristics may be changed by the effect of the implementation substrate or the heating at the implementation time. It is recommended to calibrate the sensitivity and the offset of the magnetic sensor and the offset of the accelerometer after implementation.
6) This products should not be mounted to the position where cause the strong magnetic field such as ferromagnetic part.
7) This product may damage the device if this product becomes moist and is heated drastically.
8) Storage Method (moisture-proof and packed condition)
   a) Please do not leave the device in the following environments:
   * High temperature and high humidity
   * Places with direct sun light
   * Places with extreme temperature changes
   * Dusty places
   * In corrosive gas
   b) Recommended storage temperature and humidity:
   * +5℃～+30℃, below 70%RH, please use device within one year.

(If the device does not used over one year, the specification may not be satisfied.)

9) Usage after Opening the Moisture Proofed Packaging

a) Please apply devices within 7days under the condition of +5℃～+30℃、below 70％RH.
The storage in the moisture-proof room (+5℃～+30℃、below 30％RH) is recommended.

b) When the devices storage in the moisture- proof room (+30℃、below10％RH), please apply them within 1 year.

c) Over 7days after opening the package with a) condition above, please apply baking according to the following conditions.

＜Baking Conditions＞

i) +60℃×168Hr or +40℃×200Hr by taping condition

ii) +125℃×24Hr by heat resistant tray

iii) Maximum 2 times for baking

Baking is recommended to wear out after opening package for the first time.

10) If the component is dropped from a height greater than 5 cm or directly impacted by a hard object during assembly, it should be discarded and not used.

11) Please mount the capacitor of 1.0μF near the terminal VREG and the terminal GND.

12) Please mount by using a rubber Colette to avoid impacts to AMI603.