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Pressure Sensor series

Pressure Sensor IC

BM1386GLV

General Description

BM1386GLV is piezo-resistive pressure sensor.
BM1386GLV performs temperature compensation for MEMS inside chip internally, so it's very easy to get pressure information.

Key Specifications

- Pressure Range: 300hPa to 1300hPa
- Relative Pressure Accuracy: ±0.12hPa(Typ)
- Absolute Pressure Accuracy: ±1hPa(Typ)
- Operating Temperature Range: -40°C to +85°C

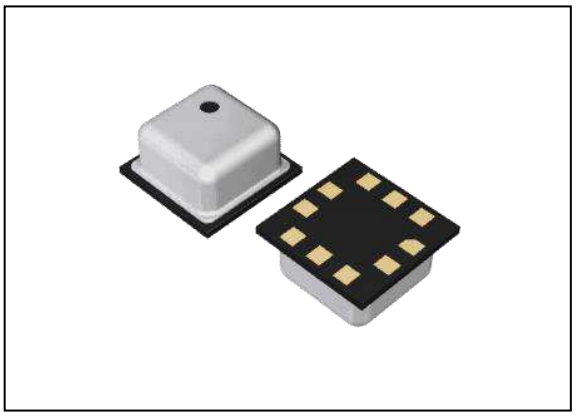
Features

- Piezo-resistive pressure sensor
- Pressure range is from 300hPa to 1300hPa
- Built-in temperature compensation function.
- I2C bus interface (f/s mode support)
- Built-in FIFO
- Small package

Package

W(Typ) x D(Typ) x H(Max)

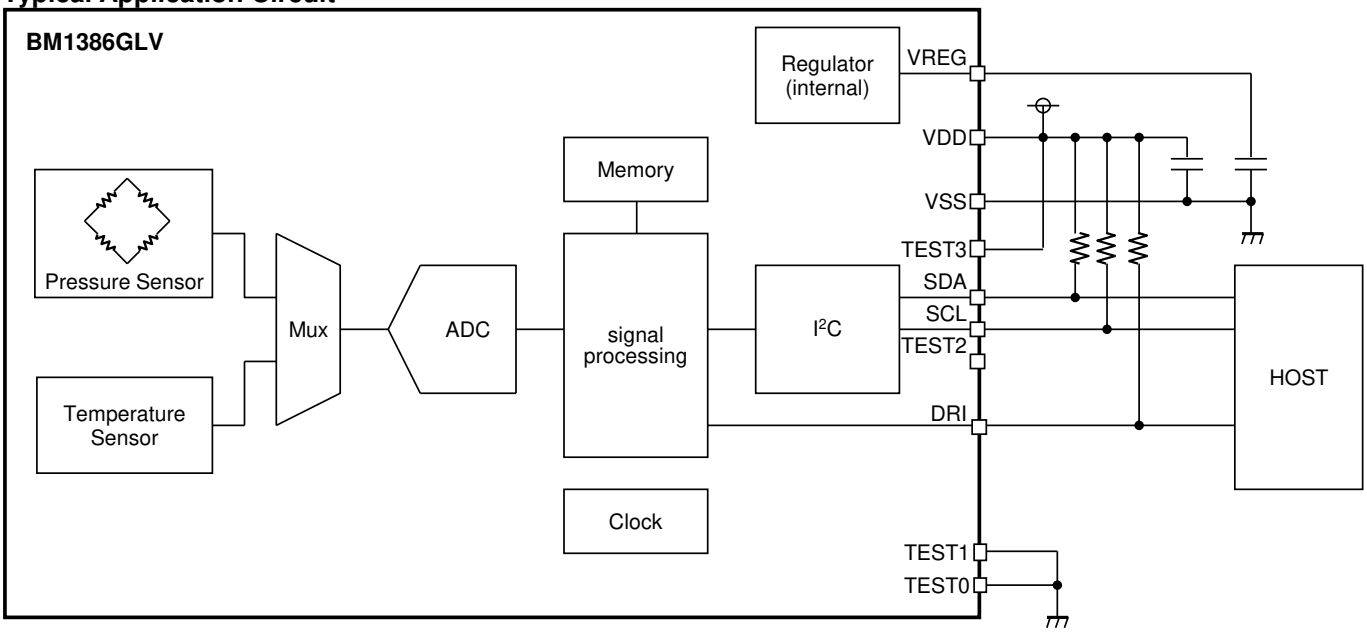
CLGA10V020A 2.0mm x 2.0mm x 1.0mm



Applications

- Smartphone, Healthcare, mobile device (e.g. game).

Typical Application Circuit

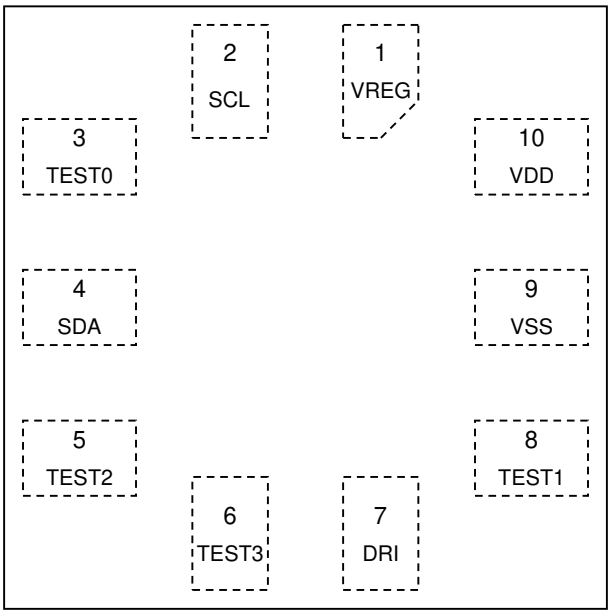


○Product structure : Silicon monolithic integrated circuit ○This product has no designed protection against radioactive rays

Contents

Pin Configuration

Top View
(pads not visible)

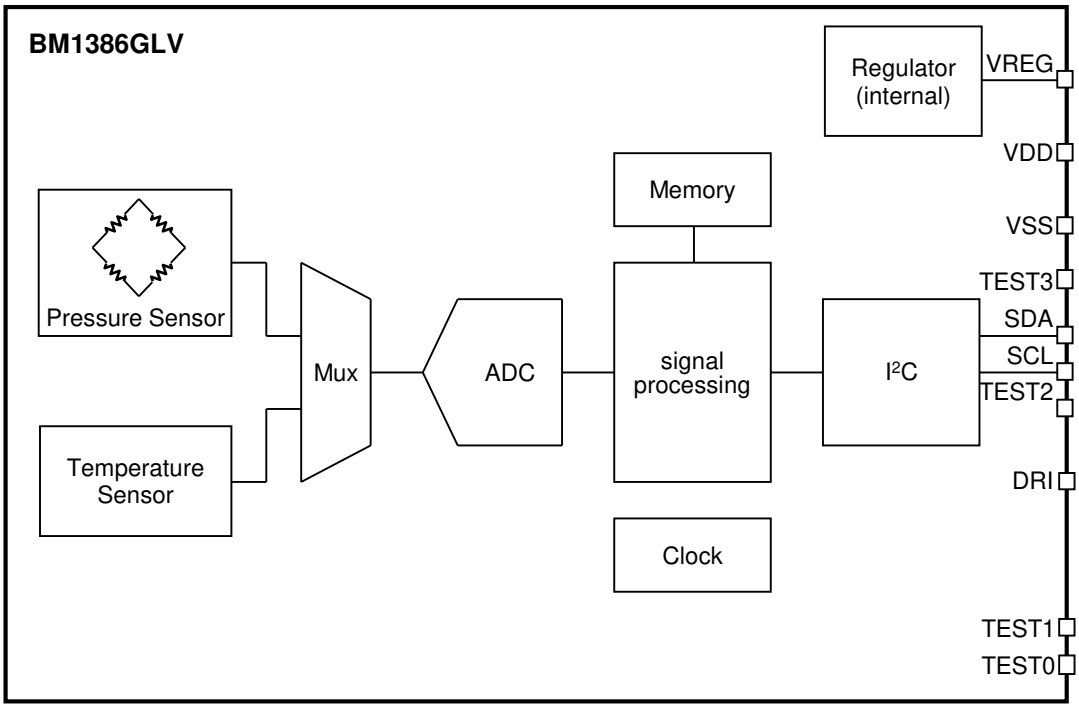


Pin Description

Pin No.	Pin Name	Function
1	VREG	Internal power supply pin(Note 1)
2	SCL	I2C serial bus colck pin
3	TEST0	Test pin (connect to VSS)
4	SDA	I2C serial bus data pin
5	TEST2	Test pin (open)
6	TEST3	Test pin (connect to VDD)
7	DRI	Interrupt notice output pin
8	TEST1	Test pin (connect to VSS)
9	VSS	Ground pin
10	VDD	power voltage pin(Note 2)

(Note 1) Dispose a bypass capacitor as close as possible to the IC.
Please set a bypass capacitor of 0.22µF between DREG and VSS.
Please do not use this pin for external power source.
(Note 2) Dispose a bypass capacitor as close as possible to the IC.

Block Diagram



Absolute Maximum Ratings (Ta = 25°C)

Parameter	Symbol	Rating	Unit
Power Supply	V_{DD_MR}	4.5	V
Input Voltage1 *(Note 1)*	V_{IN1MR}	-0.3 to +4.5	V
Input Voltage2 *(Note 2)*	V_{IN2MR}	-0.3 to (VDD+0.3) or +4.5 whichever is less	V
Storage Temperature	Tstg	-40 to +125	°C
Maximum Junction Temperature	Tjmax	125	°C
Pressure	Povr	20000	hPa

(Note 1) DRI, SCL, SDA pin
(Note 2) except DRI, SCL, SDA pin

Caution 1: *Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.*

Caution 2: *Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the maximum junction temperature rating.*

Thermal Resistance *(Note 1)*

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s *(Note 3)*	2s2p *(Note 4)*	
CLGA10V020A				
Junction to Ambient	θ_{JA}	339.7	217.5	°C/W
Junction to Top Characterization Parameter *(Note 2)*	Ψ_{JT}	154	140	°C/W

(Note 1) Based on JESD51-2A(Still-Air)
(Note 2) The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.
(Note 3) Using a PCB board based on JESD51-3.

Layer Number of Measurement Board	Material	Board Size
Single	FR-4	114.3mm x 76.2mm x 1.57mmt

Top	
Copper Pattern	Thickness
Footprints and Traces	70µm

(Note 4) Using a PCB board based on JESD51-7.

Layer Number of Measurement Board	Material	Board Size
4 Layers	FR-4	114.3mm x 76.2mm x 1.6mmt

Top		2 Internal Layers		Bottom	
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70µm	74.2mm x 74.2mm	35µm	74.2mm x 74.2mm	70µm

Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Power Supply	V_{DD}	1.7	1.8	3.6	V
Input Voltage1 *(Note 1)*	V_{IN1}	0.0	-	3.6	V
I^2C clock Input Frequency	f_{SCL}	-	-	400	kHz
Operating Temperature	Topr	-40	+25	+85	°C

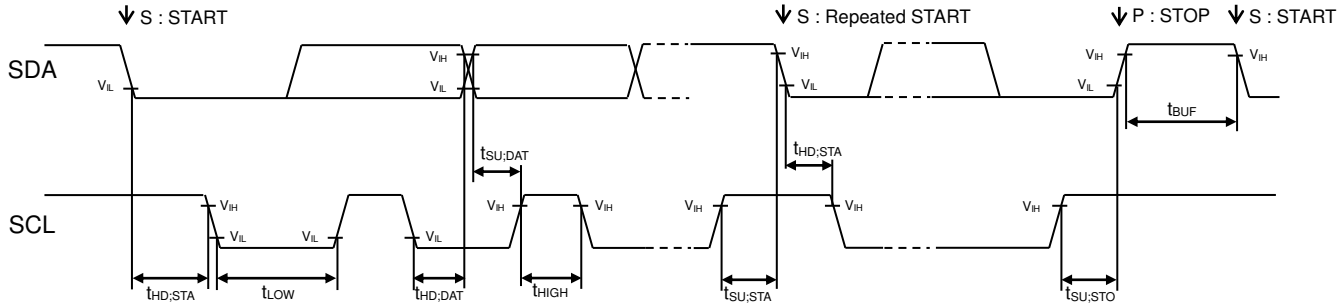
(Note 1) DRI, SCL, SDA pin

Electrical Characteristics (Unless otherwise specified VDD=1.8V Ta=25°C)

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Current Consumption						
Power Down Mode Current	I_{SS}	-	1	5	µA	PWR_DOWN=0, RSTB=0
Logic						
L Input Voltage *(Note 1)*	V_{IL}	-	-	0.3 * VDD	V	
H Input Voltage *(Note 1)*	V_{IH}	0.7 * VDD	-	-	V	
L Input Current *(Note 1)*	I_{IL}	-10	-	-	µA	VIL = GND
H Input Current *(Note 1)*	I_{IH}	-	-	10	µA	VIH = VDD
L Output Voltage 1 *(Note 2)*	V_{OL1}	-	-	0.2 * VDD	V	IL = -0.3mA
L Output Voltage 2 *(Note 3)*	V_{OL2}	-	-	0.2 * VDD	V	IL = -3mA
Pressure characteristics						
Pressure Detection Range	P_R	300	-	1300	hPa	0°C to 65°C
Relative Pressure Accuracy *(Note 4)*	Prel	-	±0.12	-	hPa	950hPa to 1050hPa
Absolute Pressure Accuracy	Pabs	-	±1	-	hPa	1000hPa
Temperature Accuracy	Tabs	-	±2	-	°C	25°C to 85°C
Measurement Time *(Note 5)*	Tm	-	-	6	msec	AVE_NUM=000

(Note 1) SDA, SCL pin
(Note 2) DRI pin
(Note 3) SDA pin
(Note 4) Target values
(Note 5) Measurement time is changed by average number of measurement data. It is written in Measurement time more detail.

I²C Bus Timing Characteristics (Unless otherwise specified VDD=1.8V, Ta=25°C)



Parameter	Symbol	Min	Typ	Max	Unit	Conditions
SCL Clock frequency	f_{SCL}	0	-	400	kHz	
'L' Period of the SCL Clock	t_{LOW}	1.3	-	-	µs	
'H' Period of the SCL Clock	t_{HIGH}	0.6	-	-	µs	
Setup Time for Repeated START	$t_{SU;STA}$	0.6	-	-	µs	
Hold Time for START	$t_{HD;STA}$	0.6	-	-	µs	
Data Setup Time	$t_{SU;DAT}$	100	-	-	ns	
Data Hold Time	$t_{HD;DAT}$	0	-	-	µs	
Setup Time for STOP	$t_{SU;STO}$	0.6	-	-	µs	
Bus Free Time between STOP and START	t_{BUF}	1.3	-	-	µs	

I²C Bus Communication

1. Write Format

(1) Indicate register address

S	Slave Address	W 0	ACK	Register Address	ACK	P

(2) Write data after indicating register address

S	Slave Address	W 0	ACK	Register Address	ACK

Data specified at register address field	ACK	· · ·	ACK	Data specified at register address field + N	ACK	P

2. Read Format

(1) Read data after indicating register address

S	Slave Address	W 0	ACK	Register Address	ACK

S	Slave Address	R 1	ACK	Data specified at register address field	ACK

Data specified at register address field + 1	ACK	· · ·	ACK	Data specified at register address field + N	NACK	P

(2) Read data from the specified register

S	Slave Address	R 1	ACK	Data specified at register address field	ACK

Data specified at register address field + 1	ACK	· · ·	ACK	Data specified at register address field + N	NACK	P

from master to slave from slave to master

I²C bus Slave Address

The slave address is “1011101”.

Register Map *(Note 1)*

Register Address	Register Name	R/W	D7	D6	D5	D4	D3	D2	D1	D0
0x0F	MANUFACTURER ID	R	MANUFACTURER ID [7:0]							
0x10	PART ID	R	PART ID [7:0]							
0x12	POWER_DOWN	RW	0	0	0	0	0	0	0	PWR_ DOWN
0x13	RESET	RW	0	0	0	0	0	0	0	RSTB
0x14	MODE_CONTROL	RW	AVE_NUM[2:0]			DR_EN	FULL _EN	WTM _EN	MODE[1:0]	
0x15	IIR, FIFO CONTROL	RW	FIFO_ EN	WTM_ LEVEL	0	0	0	0	IIR_MODE[1:0]	
0x18	FIFO data	R	0	0	FIFO_LEV[5:0]					
0x19	STATUS	R	0	0	0	0	0	RD_ FULL	RD_ WTM	RD_ DRDY
0x1A	PRESSURE	R	PRESS_OUT[15:8]							
0x1B		R	PRESS_OUT[7:0]							
0x1C		R	PRESS_OUT_XL[5:0]						0	0
0x1D	TEMPERATURE	R	TEMP_OUT[15:8]							
0x1E		R	TEMP_OUT[7:0]							

(Note 1) Do not write any commands to other addresses except above. Do not write ‘1’ to the fields in which value is ‘0’ in above table.
Address from 0x14 to 0x1E registers can be accessed only when PWR_DOWN=1 and RSTB=1. (In other case Write: Ignored, Read: 0xXX)

(0x0F) MANUFACTURER ID

Fields	Function
MANUFACTURER ID [7:0]	Manufacturer ID : 0xE0

(0x10) PART ID

Fields	Function
PART ID [7:0]	Part ID : 0x33

(0x12) POWER_DOWN

Fields	Function
PWR_DOWN	0: power down 1: active

default value 0x00

(0x13) RESET

Fields	Function
RSTB	0: Measurement control block is reset 1: Measurement control block is active

default value 0x00

(0x14) MODE_CONTROL

Fields	Function
AVE_NUM[2:0]	Seting of the averaging number of measurement data 000: single, 001: 2 times, 010: 4 times, 011: 8 times, 100: 16 times, 101: 32 times, 110: 64 times, 111: Prohibited
DR_EN	DRI pin Enable for Data Ready Details are written in Interrupt. 0 : DRI pin Disable, 1 : DRI pin Enable
FULL_EN	DRI pin Enable for FULL Details are written in Interrupt. 0 : DRI pin Disable, 1 : DRI pin Enable
WTM_EN	DRI pin Enable for Water Mark Details are written in Interrupt. 0 : DRI pin Disable, 1 : DRI pin Enable
MODE[1:0]	Measurement mode setting (Pressure and Temperature are measured at one rate) 00 : Stand by, 01 : One shot, 10 : Continuous, 11 : Prohibited

default value 0x00

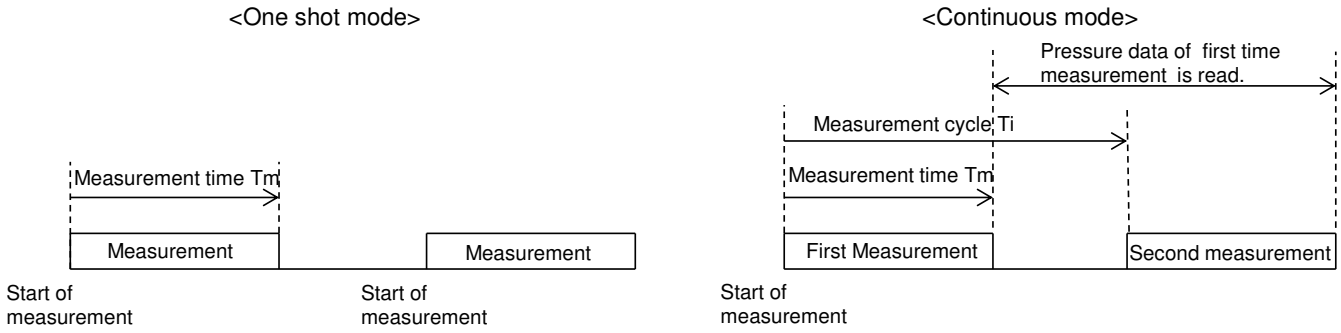
Measurement time and RMS noise against number of average

AVE_NUM	Measurement time T_m max[ms]	Measurement cycle T_i max[ms]	RMS noise [hPa]
000	6	60	0.090
001	9	60	0.063
010	16	60	0.045
011	30	60	0.032
100	60	60	0.023
101	120	120	0.016
110	240	240	0.011

RMS noise is calculated as standard deviation of 32 data points (1σ).
RMS noise is a reference value and it's not the value with guarantee.
Condition VDD=1.8V, Ta=25°C, IIR_MODE=00

Measurement time

One shot mode perform one measurement. Measurement data is updated when measurement completed, so it should be read more than T_m after measurement start.
Continuous mode repeat measurement in every measurement cycle T_i. The latest measurement data which is completed is read.
Measurement time T_m and measurement cycle T_i is determined by number of average.



Operation mode transition

Please refer to the below figure of operation mode transition.

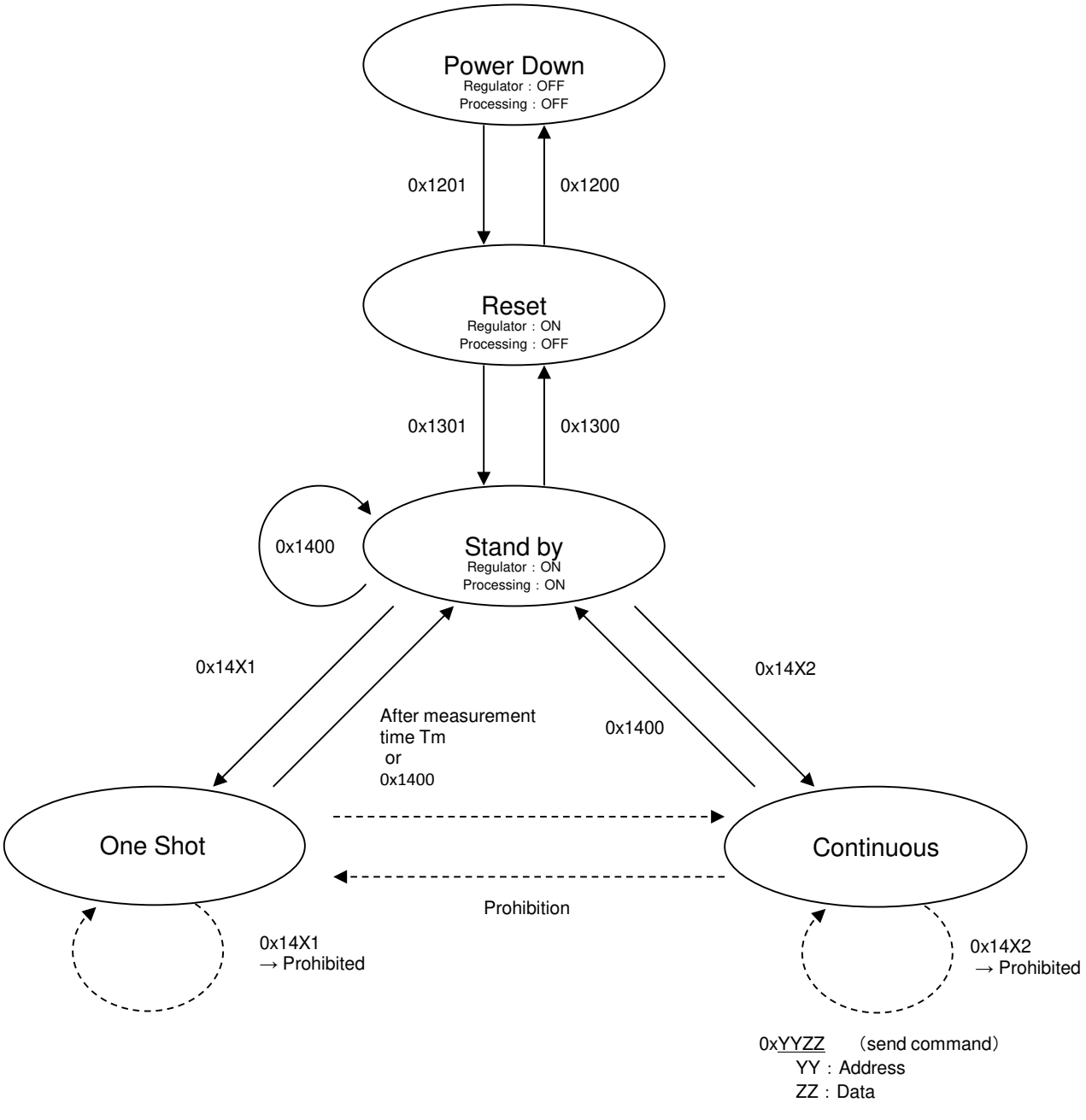
Power down mode is the smallest current consumption mode due to circuit is OFF. Please set this mode when reducing current consumption. Measurement is not available in this mode, so the measurement is performed after switching to standby mode.

In reset mode, regulator for internal blocks is active and measurement control block is reset. Register is initialized in Reset mode. Measurement command is acceptable when “1” is written in “RSTB”

There are 2 measurement modes. One shot mode and Continuous mode. They are transferred from stand by mode. Then, please set “AVE_NUM” register at the same time.
Please write “0x1400” when transferring to standby mode again.

In one shot mode, a single measurement is performed when “01” is written in “MODE”. After the measurement completes, it is transferred to standby mode automatically. When “0x1400” is written before end of measurement, mode is switched to standby immediately but pressure value is not updated.
Transition to the other measurement mode during measurement in one shot mode is forbidden.

In Continuous mode, when “10” is written in “MODE”, measurement starts and it continues until “0x1400” is written. Transition to the other measurement mode from Continuous mode is forbidden.



(0x15) IIR, FIFO CONTROL

Fields	Function
FIFO_EN	FIFO mode setting Details are written in FIFO. 0: Bypass mode, 1: FIFO mode
WTM_LEVEL	Water Mark level setting Details are written in FIFO. 0: Water Mark interrupt occur when FIFO memory is 24 or above. 1: Water Mark interrupt occur when FIFO memory is 28 or above.
IIR_MODE[1:0]	IIR filter enable and coefficient setting 00 : IIR OFF, 01 : IIR ON (weak) 10 : IIR ON (middle), 11 : IIR ON (strong)

default value 0x00

(0x18) FIFO data

Fields	Function
FIFO_LEV[5:0]	Number of sample in FIFO

default value 0x00

FIFO_LEV[5:0]

D5	D4	D3	D2	D1	D0	Description
0	0	0	0	0	0	FIFO empty
0	0	0	0	0	1	Number of sample in FIFO =1
:	:	:	:	:	:	
1	0	0	0	0	0	FIFO FULL

(0x19) STATUS

Fields	Function
RD_FULL	FIFO overrun (FULL) status This register is cleared when this is read. RD_FULL is not updated unless data are read. 0: FIFO is not full; 1: FIFO is full.
RD_WTM	FIFO threshold (Water Mark) status This register is cleared when FIFO memory become less than threshold level. 0: Number of sample in FIFO is lower than threshold level. 1: Number of sample in FIFO is equal or higher than threshold level.
RD_DRDY	Pressure and temperature measurement data ready bit This register is cleared when ‘1’ is read. Do not care RD_DRDY in FIFO mode (FIFO_EN=1). 0: data is not updated 1: data is updated

default value 0x00

(0x1A / 0x1B / 0x1C) PRESSURE

Fields	Function
PRESS_OUT[15:0] PRESS_OUT_XL[5:0]	pressure data

default value 0x000000

Conversion to pressure value is below.

Pressure counts = PRESS_OUT[15:8] x 2^{14} + PRESS_OUT[7:0] x 2^{6} + PRESS_OUT_XL[5:0] [counts] (dec)
Pressure value [hPa] = Pressure counts [counts] / 2048 [counts/hPa]

Data registers (0x1A, 0x1B, 0x1C) should be read by burst read.
Data is updated at the timing of measurement completion.
If they are not read by burst read, data might be mixed up with the data of different measurement.

(0x1D / 0x1E) TEMPERATURE

Fields	Function
TEMP_OUT[15:0]	temperature data

default value 0x0000

Conversion to temperature value is below. Please note that TEMP_OUT is data with sign (two's complement).

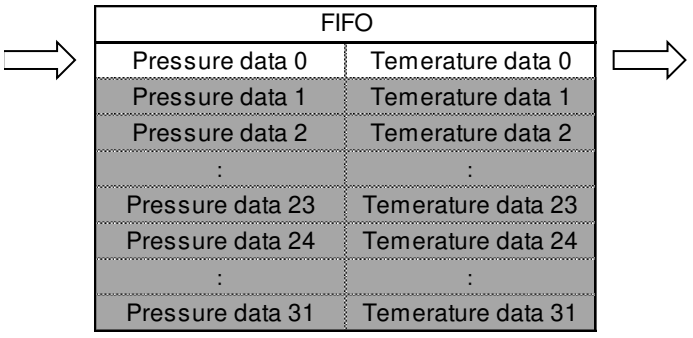
Temp counts = TEMP_OUT[15:8] x 2^{8} +TEMP_OUT[7:0] [counts] (dec)
Temperature value [°C] = Temp counts [counts] / 32 [counts/°C]
(in case of positive number)

Data registers (0x1D,0x1E) should be read by burst read.
Data is updated at the timing of measurement completion.
If they are not read by burst read, data might be mixed up with the data of different measurement.

FIFO

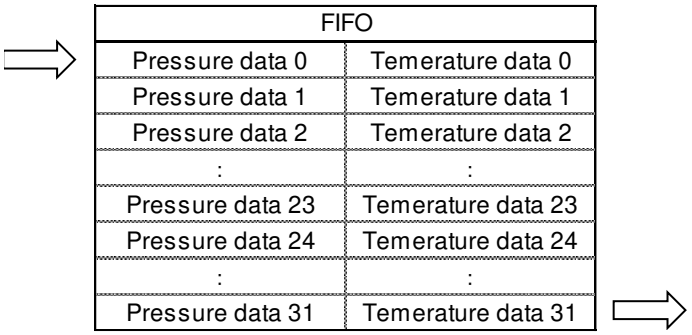
This IC embeds a 32-slot FIFO to store the pressure and temperature output values.
FIFO has Bypass mode (FIFO_EN=0) and FIFO mode (FIFO_EN=1).
In FIFO mode, the pressure and temperature output values are stored in FIFO when measurement is completed.
The data is read from oldest data.
Interrupt for WTM and FULL is available in FIFO mode.
WTM interrupt is enable when WTM_EN is set to '1'. In this mode, when FIFO memory reach the number set in WTM_LEVEL, RD_WTM goes to '1'.
FULL interrupt is enable when FULL_EN is set to '1'. In this mode, when 32 data are stored in FIFO, RD_FULL goes to '1'.
FIFO_LEV is the number of sample in FIFO.
FIFO is only available in Continuous mode.

<Bypass mode>
FIFO is not operational in Bypass mode (FIFO_EN=0).
New data is overwritten to old data due to only the first slot of FIFO is in use.
FIFO and FIFO_LEV are initialized in Bypass mode.



FIFO	
Pressure data 0	Temerature data 0
Pressure data 1	Temerature data 1
Pressure data 2	Temerature data 2
:	:
Pressure data 23	Temerature data 23
Pressure data 24	Temerature data 24
:	:
Pressure data 31	Temerature data 31

<FIFO mode>
FIFO is operational in FIFO mode (FIFO_EN=1). Pressure data is read from the address 0x1A, 0x1B and 0x1C and temperature data is read from the address 0x1D and 0x1E.
The data is read from oldest data. FIFO stops storing data when FIFO is FULL.

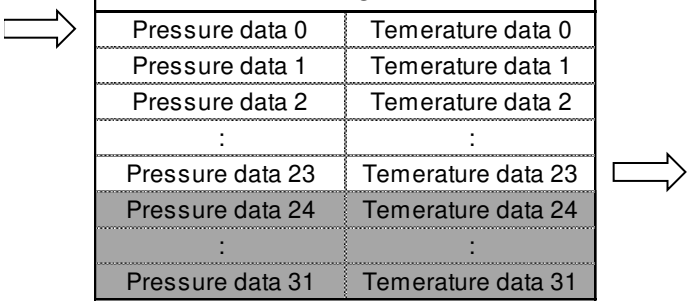


FIFO	
Pressure data 0	Temerature data 0
Pressure data 1	Temerature data 1
Pressure data 2	Temerature data 2
:	:
Pressure data 23	Temerature data 23
Pressure data 24	Temerature data 24
:	:
Pressure data 31	Temerature data 31

Water Mark interrupt

Water Mark interrupt occur when stored data in FIFO is equal to or more than the number set in WTM_LEVEL.
Water Mark level is selectable from 24 (WTM_LEVEL=0) and 28 (WTM_LEVEL=1).
RD_WTM goes to '1' when Water Mark interrupt occur
Water Mark interrupt keep active state while FIFO_LEV is equal to or more than WTM_LEVEL. And it is released, when FIFO_LEV go below WTM_LEVEL.
DRI pin status is determined by Water Mark interrupt, when WTM_EN is '1'.

Case of Water Mark occurs at 24 of Water Mark level

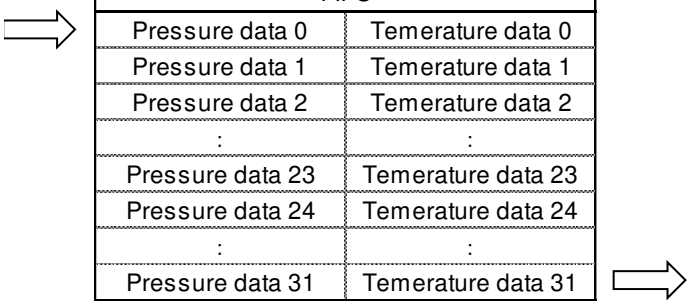


FIFO	
Pressure data 0	Temerature data 0
Pressure data 1	Temerature data 1
Pressure data 2	Temerature data 2
:	:
Pressure data 23	Temerature data 23
Pressure data 24	Temerature data 24
:	:
Pressure data 31	Temerature data 31

FULL interrupt

FULL interrupt occur when stored data in FIFO is 32. RD_FULL goes '1'.
RD_FULL goes '0' when RD_FULL is read.
FIFO and RD_FULL are not updated by measurement after FULL interrupt occur. Then FIFO_LEV is fixed to 32.
DRI pin status is determined by FULL interrupt, when FULL_EN is '1'.

Case of FULL occurs



FIFO	
Pressure data 0	Temerature data 0
Pressure data 1	Temerature data 1
Pressure data 2	Temerature data 2
:	:
Pressure data 23	Temerature data 23
Pressure data 24	Temerature data 24
:	:
Pressure data 31	Temerature data 31

Interrupt function

Interrupt factor is Data Ready, FIFO FULL and FIFO WTM.
The condition is listed below.
The status register is always operational.
The status register goes '1' when interrupt occur.
When the DRI pin enable register for each factor is '1', DRI pin status is determined by the interrupt state of factor. When interrupt occur, DRI pin output 'L'.
The status register and DRI pin keeps the state until the interrupt is cleared.
FIFO FULL and FIFO WTM are not available in Bypass mode (FIFO_EN=0)
Do not care Data Ready in FIFO mode (FIFO_EN=1).

Interrupt factor

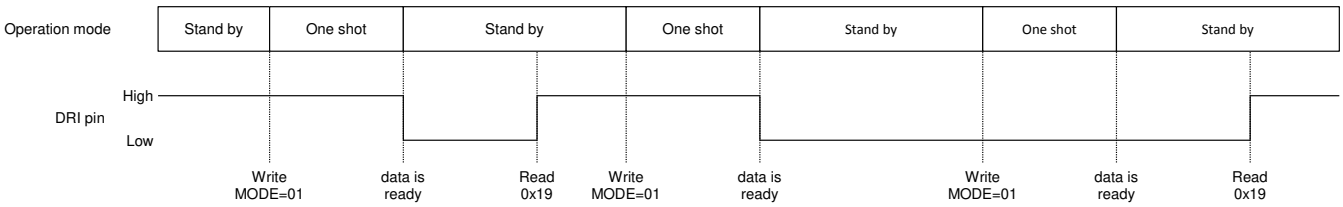
Factor	Status register	Interrupt condition	Interrupt Clear condition
Data Ready	RD_DRDY	Measurement completion	Read RD_RDRY
FIFO FULL	RD_FULL	FIFO is Full	Read RD_FULL
FIFO WTM	RD_WTM	FIFO_LEV≧WTM level	FIFO_LEV＜WTM level

Relation between factor and DRI pin enable

Factor	DRI pin enable
Data Ready	DR_EN
FIFO FULL	FULL_EN
FIFO WTM	WTM_EN

DRI pin is Nch open drain so this terminal should be pull-up to voltage source by an external resister.
DRI pin is high impedance just after VDD is supplied.
DRI pin becomes inactive (High impedance) by reading RD_DRDY register or setting reset mode.
VDD current (approximately 6μA at VDD=1.8V) is consumed during DRI is active.
When disabling interrupt function, please disable after clearing interrupt.

＜Example of Data Ready interrupt ：1shot mode＞



Typical Performance Curves

(Reference data)

(Unless otherwise specified VDD=1.8V Ta=25°C)

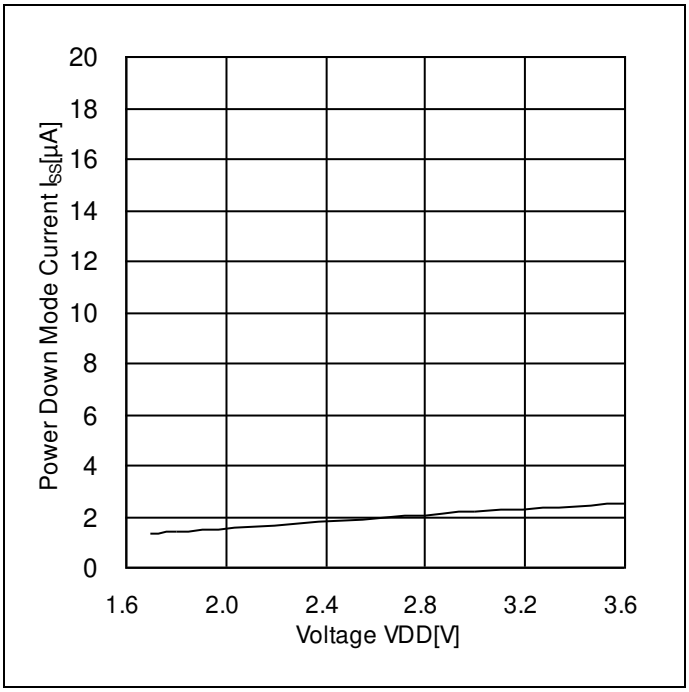


Figure 1. Current vs VDD
(PWR_DOWN=0, RSTB=0)

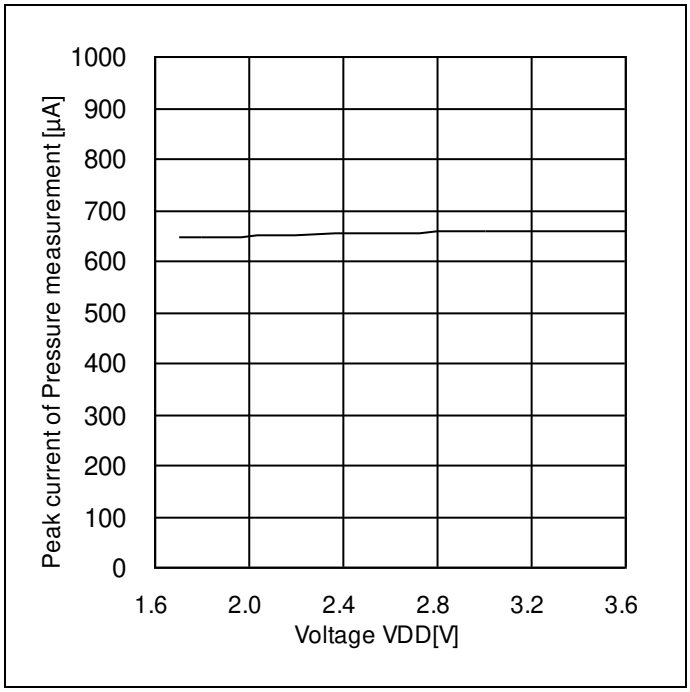
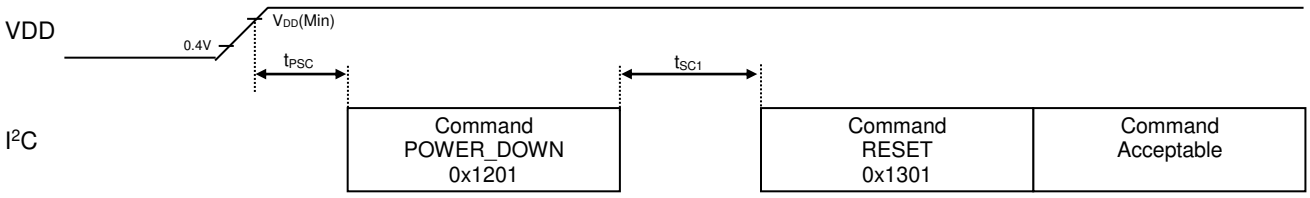


Figure 2. Current vs VDD
(During measurement)

Control sequence

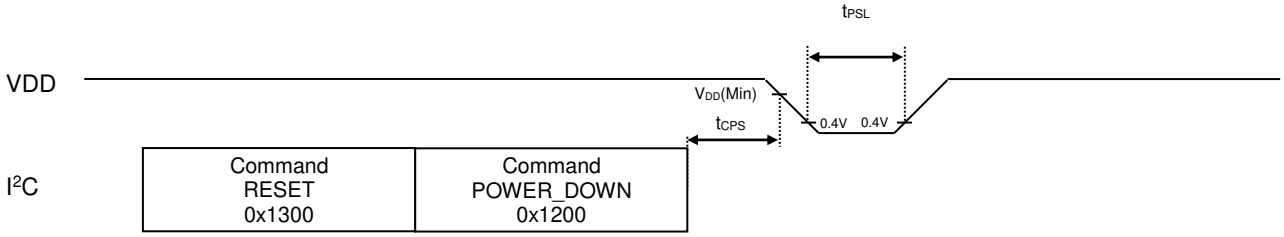
1. Power-on sequence



Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Command input time after power-on	t_{PSC}	100	-	-	µs	
Reset cancel wait time	t_{SC1}	1	-	-	ms	VREG:0.22µF

t_{PSC} after VDD power-on, command can be input.
Please send reset cancel command (RSTB=1) more than t_{sc1} after regulator for internal blocks become active (PWR_DOWN=1)

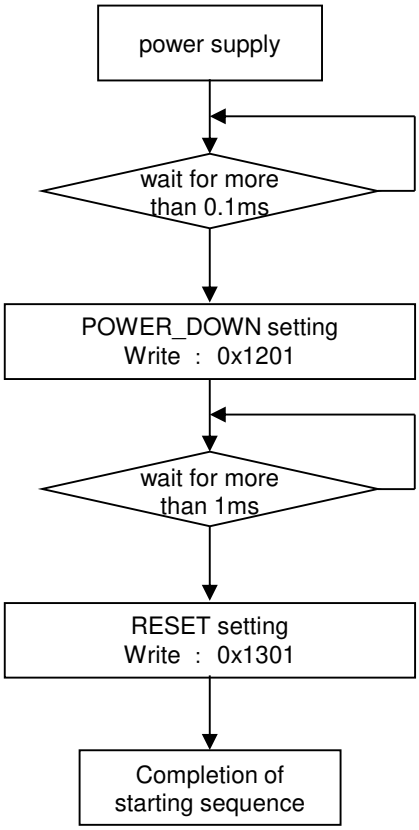
2. Power-off sequence



Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Wait time from power down command	t_{CPS}	0	-	-	µs	
Power supply OFF time	t_{PSL}	1	-	-	ms	

Please send reset command (RSTB=0) to turn regulator for internal blocks off (PWR_DOWN=0) t_{CPS} before the VDD power-off.
Please keep VDD Low (VDD<0.4V) more than t_{PSL} before VDD power-on

3. Starting sequence

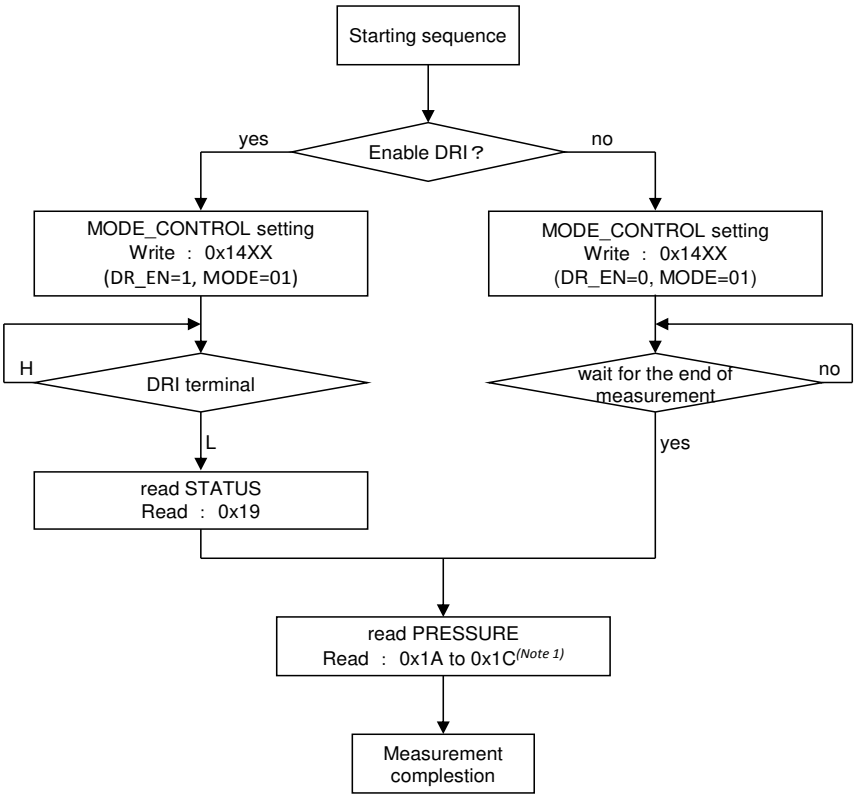


: release Power down

: release Reset mode

: Completion of operation preparation

4. Measurement sequence: One Shot Mode



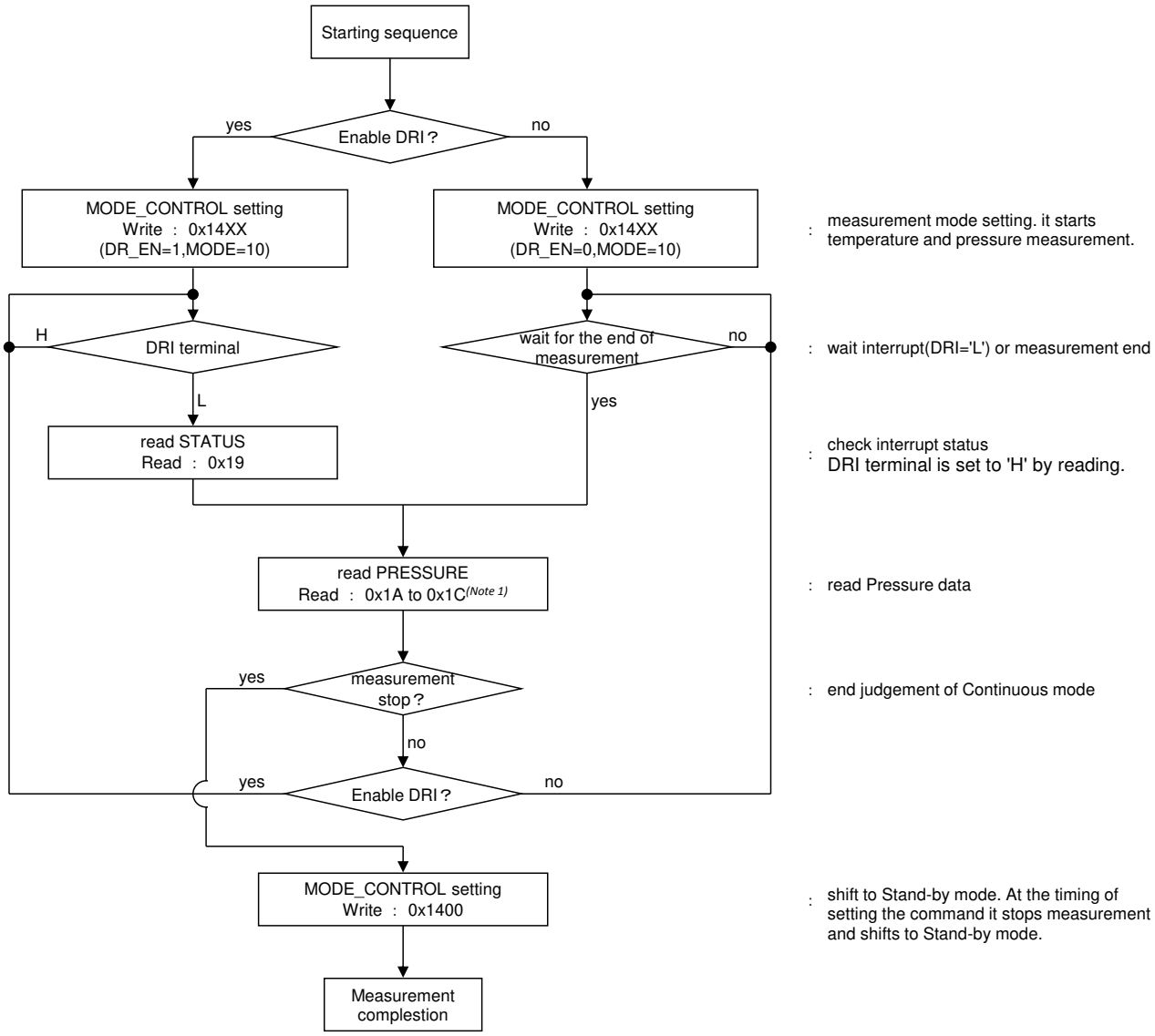
: measurement mode setting. it starts temperature and pressure measurement.

: wait interrupt(DRI='L') or measurement end

: check interrupt status
DRI terminal is set to 'H' by reading.

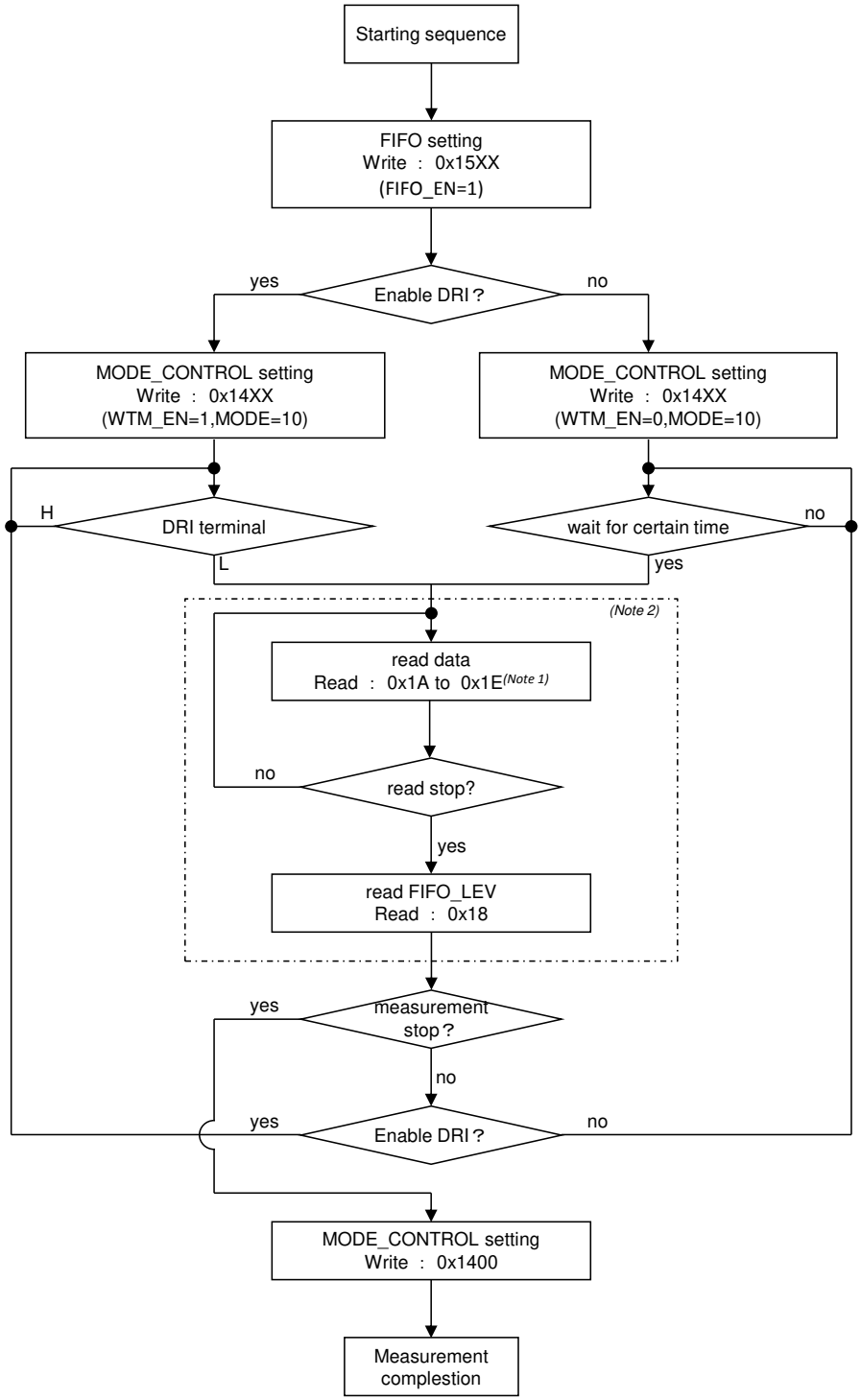
(Note 1) Data registers (0x1A, 0x1B, 0x1C) should be read by burst read.

5. Measurement sequence: Continuous Mode (50ms/100ms/200ms)



(Note 1) Data registers (0x1A, 0x1B, 0x1C) should be read by burst read.

6. Measurement sequence: Use case of FIFO



: measurement mode setting. it starts temperature and pressure measurement.

: wait interrupt(DRI='L') or certain time

: read measurement data

: check number of sample in FIFO

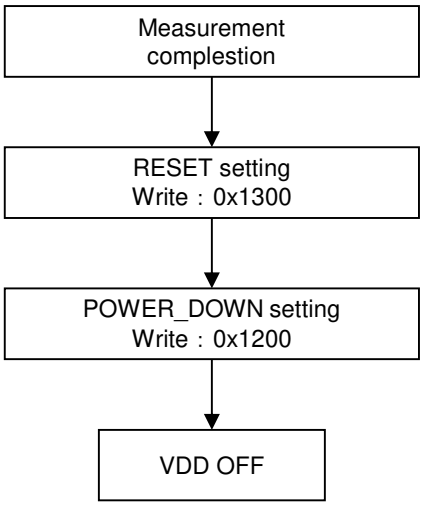
: end judgement of Continuous mode

: shift to Stand-by mode. At the timing of setting the command it stops measurement and shifts to Stand-by mode.

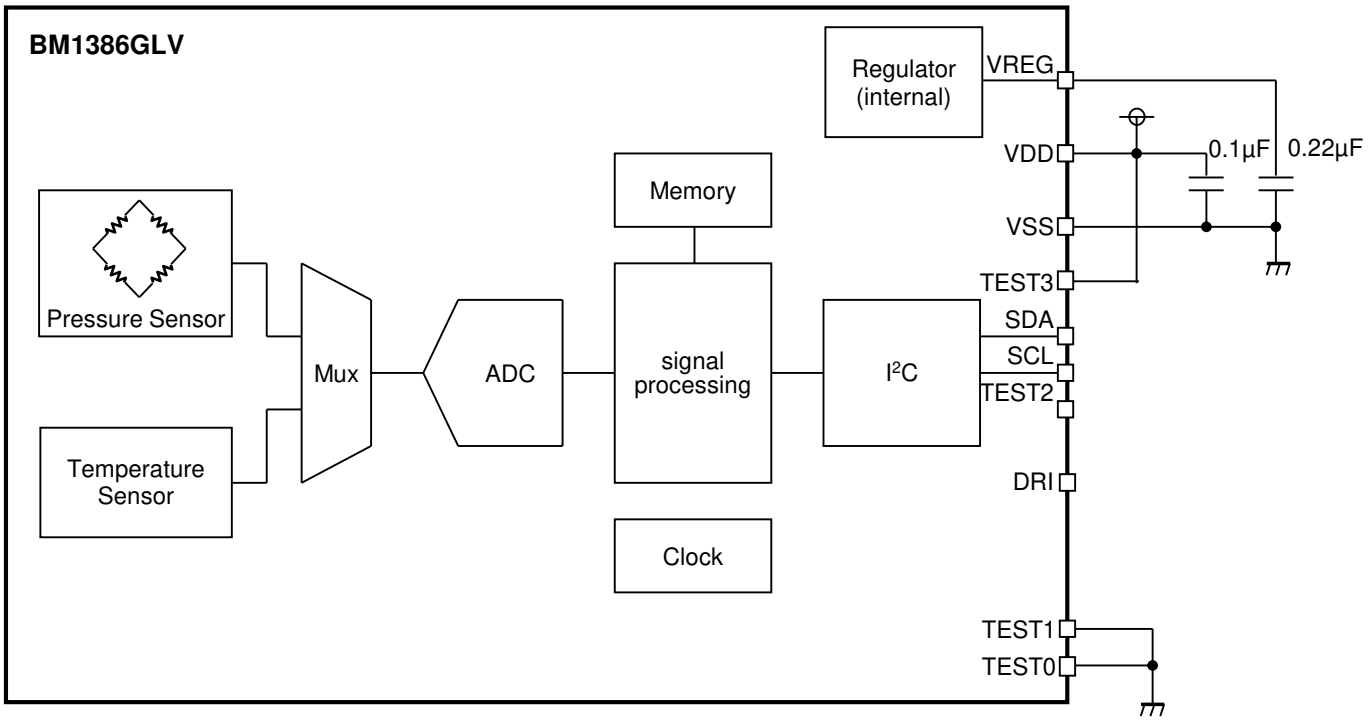
(Note 1) Data registers (0x1A, 0x1B, 0x1C, 0x1D, 0x1E) should be read by burst read.

(Note 2) During a period form a start of FIFO reading (write to address 0x1A) to FIFO_LEV reading (write to address 0x18), do not communicate with this device. When communicating with this device during FIFO reading, read FIFO_LEV and finish FIFO read sequence before other communication. If don't read FIFO_LEV before other communication, there is a possibility to lose FIFO data.

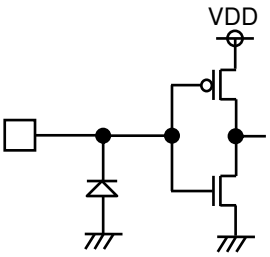
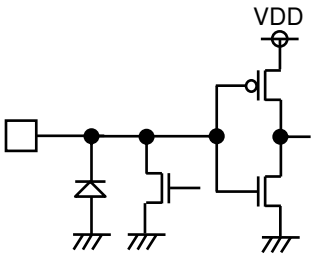
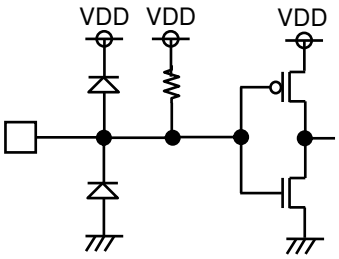
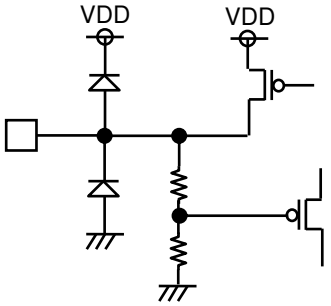
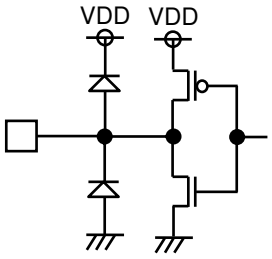
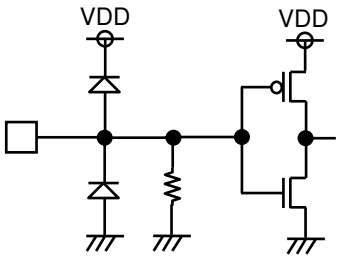
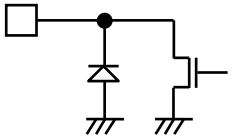
7. Ending sequence



Application Example



I/O Equivalent Circuits

Pin Name	Equivalent Circuit	Pin Name	Equivalent Circuit
SCL		SDA	
TEST3		VREG	
TEST2		TEST0 TEST1	
DRI			

Operational Notes

1. **Reverse Connection of Power Supply**
   Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

2. **Power Supply Lines**
   Design the PCB layout pattern to provide low impedance supply lines. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. **Ground Voltage**
   Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

4. **Ground Wiring Pattern**
   When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. **Recommended Operating Conditions**
   The function and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions of each item specified by the electrical characteristics.

6. **Inrush Current**
   When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

7. **Operation Under Strong Electromagnetic Field**
   Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

8. **Testing on Application Boards**
   When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

9. **Inter-pin Short and Mounting Errors**
   Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

10. **Unused Input Pins**
    Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.