GMP102 Digital Barometric Pressure Sensor

General Introduction

GMP102 is a digital barometric pressure sensor especially designed for applications requiring highly-precision pressure measurement like quadcopter altitude control and portable navigation device. It is both a pressure and temperature sensor housed in a compact 2.0×2.5×1.05 mm^3 package. The pressure sensor is based on the industry-recognized piezo-resistive technology featuring long-term stability and EMC robustness. A high-performance 24-bit ADC provides pressure resolution up to 0.18Pa, and temperature resolution up to 0.004℃. The pressure sensor has a wide operating range from 300 to 1100hPa that covers all surface elevations on earth.

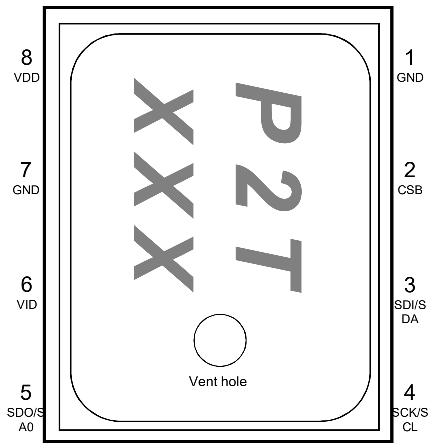
GMP102 can detect absolute barometric pressure with highly accuracy for applications like quadcopter altitude control. The maximum altitude resolution can be up to less than 10cm. Several operation options further offer large window for user optimization on the power consumption, resolution and filter performance.

Features

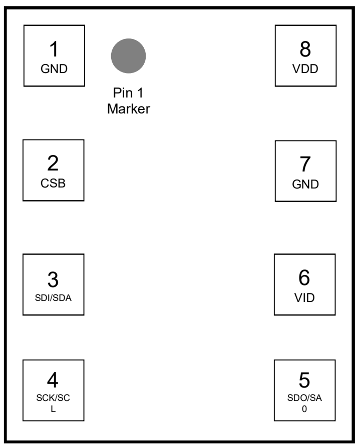
- Operation range:
  - Pressure: 300~1100hPa (Absolute)
  - Temperature: -40~+85℃
- Built-in 24-bit ADC:
  - Pressure resolution: up to 0.18Pa
  - Temperature resolution: up to 0.004℃
- Digital interface:
  - I2C: standard and fast modes
  - SPI: 3-/4-wire, up to 10MHz clock
- Supply voltage:
  - VDD: +1.7V ~ +5.5V
  - VID: +1.2V ~ +5.5V
- Power Consumption:
  - Standby ~ 1uA
- RoHS-compliance package:
  - 8-pin LGA with metal lid
  - Footprint: 2.0 × 2.5 mm^2
  - Height: 1.05 mm.

Applications

Ascending/descending speed estimation, altimetry and barometry, indoor navigation for floor/elevator detection, GPS applications, activity tracking for health care applications



Top View



Bottom View

Specifications

Table 1: Pin Descriptions

Pin#	Name	Description
1	GND	Ground pin
2	CSB	I2C/SPI mode select High for I2C mode Low for SPI mode
3	SDI/SDA	I2C mode: SDA data I/O pin SPI 4-wire mode: SDI data input pin SPI 3-wire mode: SDA data I/O pin
4	SCK/SCL	I2C mode: SCL clock pin SPI mode: SCK clock pin
5	SDO/SA0	I2C mode: slave address select pin SPI mode: data output pin
6	VID	Digital interface power supply in
7	GND	Ground pin
8	VDD	Core circuit power supply in

Table 2: Specification

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Operation voltage	VDD		1.7	—	5.5	V
IO voltage	VID		1.2	—	VDD	V
Temperature range	Ta		-40	25	+85	°C
Pressure range	P		300	—	1100	hPa
Operation current OSR=256 OSR=1024 OSR=4096 OSR=16384 OSR=32768 (default)	IDD	VDD = 3.3V 20Hz P+T conversion	—	 97 120 190 420 800	—	uA
Standby current	IDDSD	After POR or soft reset	—	1	—	uA

Relative accuracy pressure	PREL	Relative accuracy during pressure change between 700 to 950 hPa at any constant temperature between 25°C to 40°C	—	±0.12	—	hPa
Offset temperature coefficient	TCO		—	±1.5	—	Pa/K
Absolute accuracy pressure	PABS		—	1	—	hPa
Noise in pressure			—	1.9	—	Pa RMS
Absolute accuracy temperature	TABS	@25°C	—	0.5	—	°C
		-40 to 85°C	—	1	—	°C
Long term stability			—	±1	—	hPa

Table 3: Absolute Maximum Rating

Parameter	Symbol	Min.	Max.	Unit
Power supply voltage	VDD, VID	-0.3	6.5	V
Signal input voltage	VIS	-0.3	VDD/VID + 0.3	V
Pressure	PMAX	0	20000	hPa
Storage temperature	TST	-40	+125	°C
ESD	HBM	—	±2	kV

Block Diagram and Connection

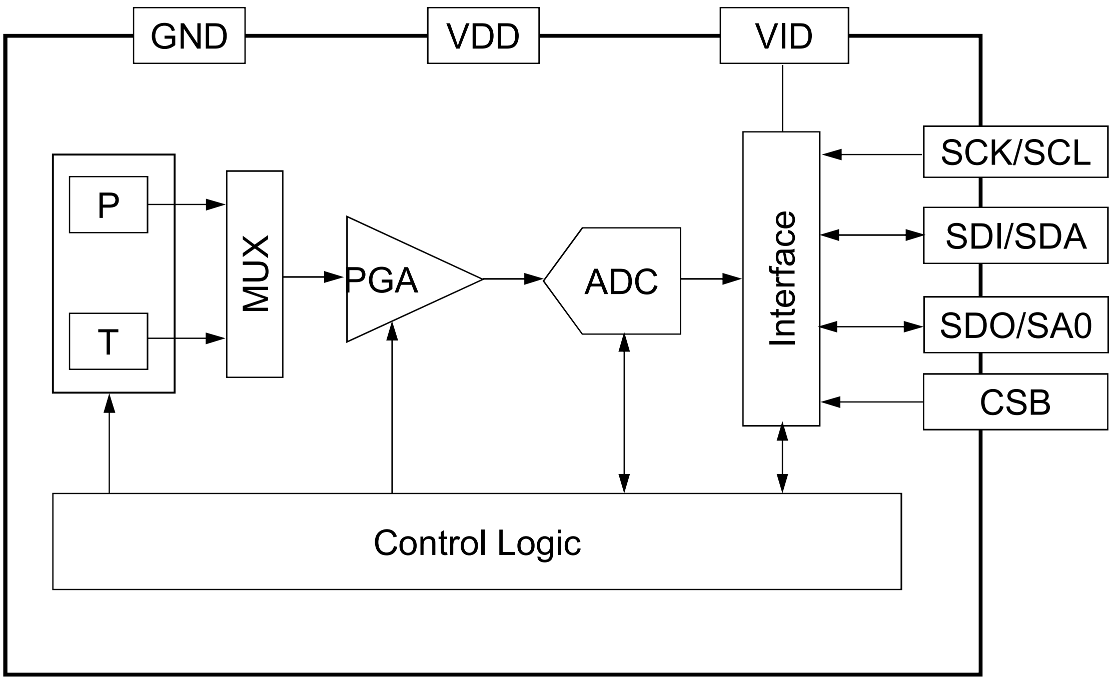


Figure 1: GMP102 Block Diagram

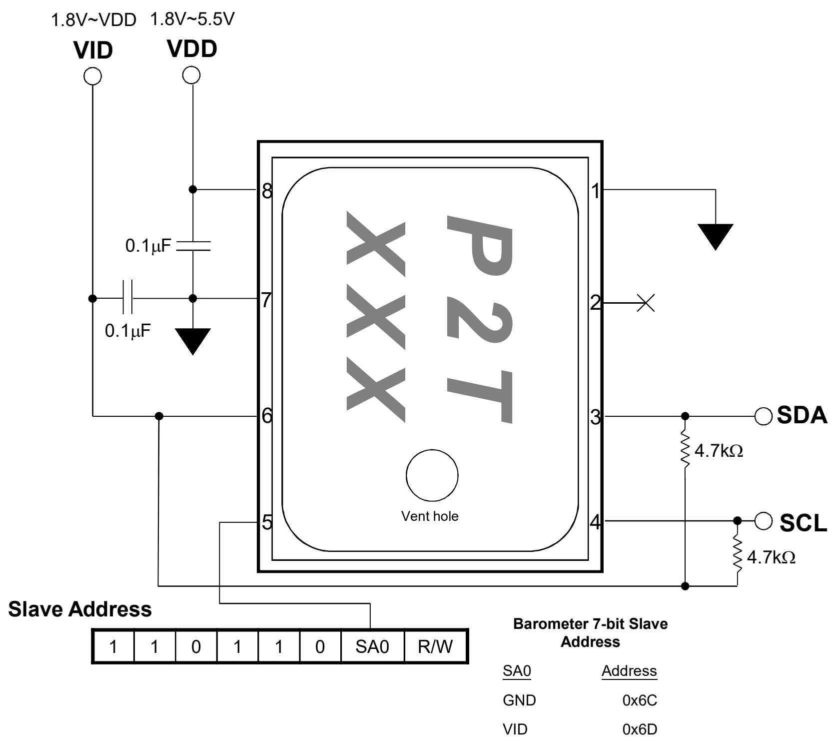


Figure 2: GMP102 I2C Connection Example

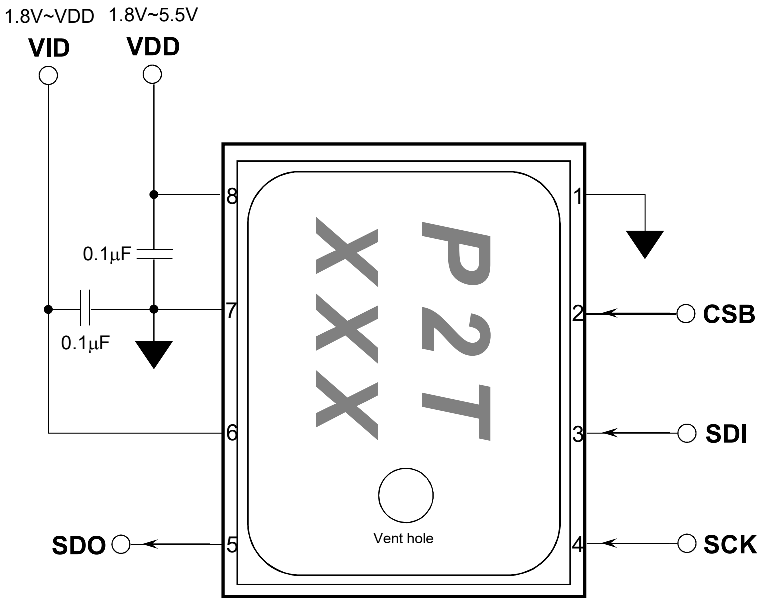


Figure 3: GMP102 SPI 4-Wire Connection Example

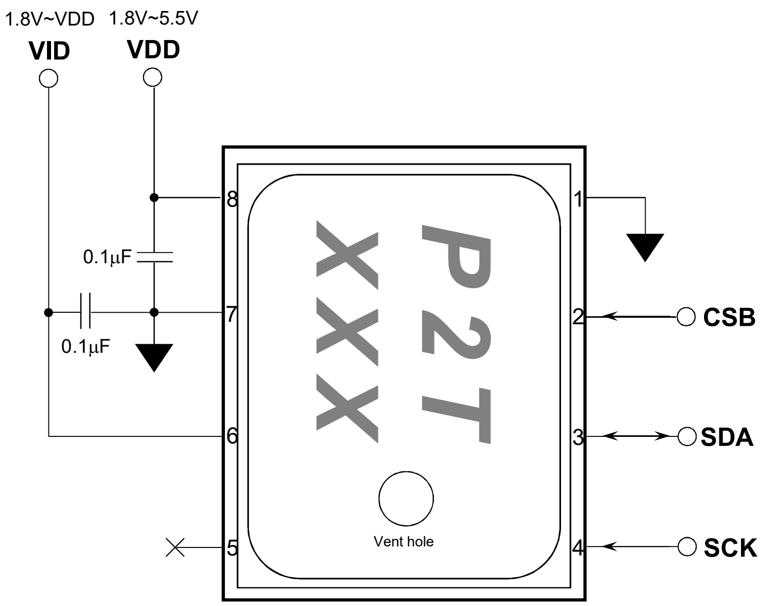


Figure 4: GMP102 SPI 3-Wire Connection Example

Functional Description

Power Management

GMP102 has two separate power supply pins: VDD and VID. VDD is the major power supply pin for all internal analog and digital functional blocks. VID provides a reference voltage level for the digital interface.

When the power is set on, power-on reset (POR) circuit will be active to reset the internal circuits and registers. After the POR sequence, all registers will be initialized to the default values and GMP102 will transit to standby mode.

Reset Functions

GMP102 has two types of reset as summarized below:

- Power-on reset (POR): as described in the previous Power Management section.
- Soft reset: Set RESET register (00h) to 0x24 will trigger the device soft reset by resetting all register to default values.

Initialization

GMP102 will automatically initialize to standby mode upon power-up after POR. The following steps are recommended for initialization:

1. Set RESET register (00h) to 0x24 for device soft reset.
2. Read 18-byte calibration parameters from AAh to BBh. Keep these parameters for use in the pressure sensor calibration.
3. Set four registers AAh ~ ADh to 0x00 to complete the calibration set up.

Power Modes

GMP102 offers three power modes, standby, P-Forced and T-Forced mode, by setting the 30h[3:0] (Measure_CTRL[3:0]) bits, see 30h register description for more detail.

The transitions between different modes are illustrated in Figure 5.

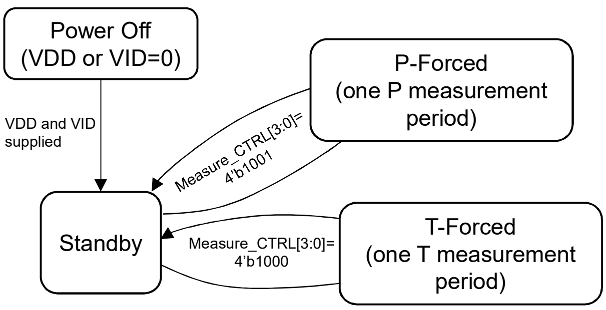


Figure 5: Mode transactions diagram

- Standby mode

GMP102 will enter standby mode after complete POR sequence. In this mode, data measurement stops and the power consumption is at the minimum. All registers, including PID and calibration parameters, are accessible.

- P-Forced mode

In P-Forced mode, GMP102 will take one-time pressure measurement and returns to standby mode automatically. The measurement results can then be obtained from the pressure data registers. Users need to set to P-Forced mode again to have another pressure measurement. The timing diagram of the P-Forced mode is illustrated in the following Figure 6.

Before set to the P-Forced mode, make sure the A5h[1] (Raw) bit value is 1'b1 in order to have the raw pressure ADC output. Below summarized the single shot pressure conversion steps:

1. Make sure A5h[1] (Raw) is set. If not, set A5h = 0x02.
2. Set to the P-Forced mode by set 30h = 0x09.
3. Check 02h[0] (DRDY) bit and wait until its value is set. The data is available in the registers when DRDY = 1'b1.
4. Read the raw pressure ADC output from the pressure data registers (06h~08h).

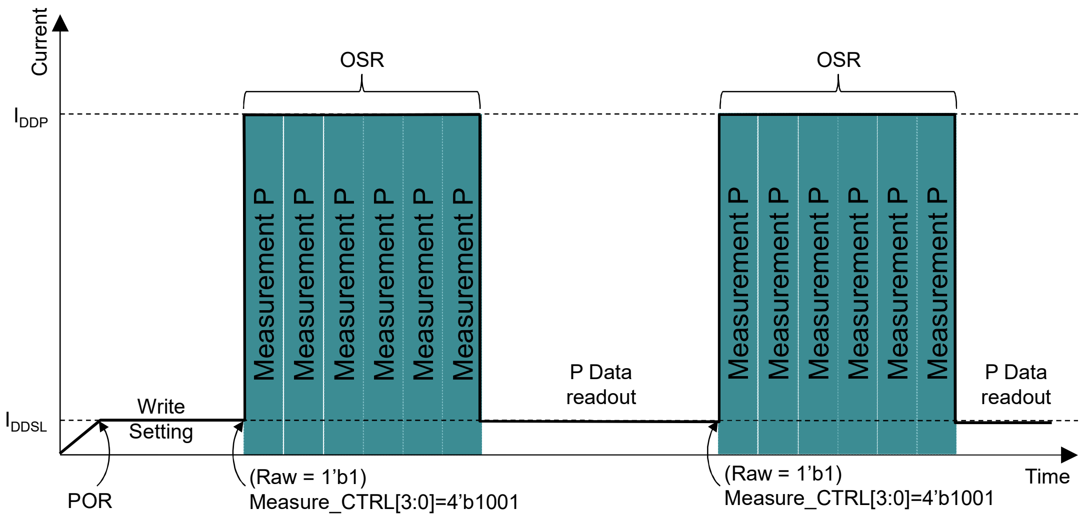


Figure 6: P-Forced mode timing diagram

- T-Forced mode

In T-Forced mode, GMP102 will take one-time temperature measurement and returns to standby mode automatically. The measurement results can then be obtained from the temperature data registers. Users need to set to T-Forced mode again to have another temperature measurement. The timing diagram of the T-Forced mode is illustrated in the following Figure 7.

Before set to the T-Forced mode, make sure the A5h[1] (Raw) bit value is 1'b0 in order to have the calibrated temperature output. Below summarized the single shot temperature conversion steps:

1. Make sure A5h[1] (Raw) is not set. If not so, set A5h = 0x00.
2. Set to the T-Forced mode by set 30h = 0x08.
3. Check 02h[0] (DRDY) bit and wait until its value is set. The data is available in the registers when DRDY = 1'b1.
4. Read the calibrated temperature output from the temperature data registers (09h~0Ah).

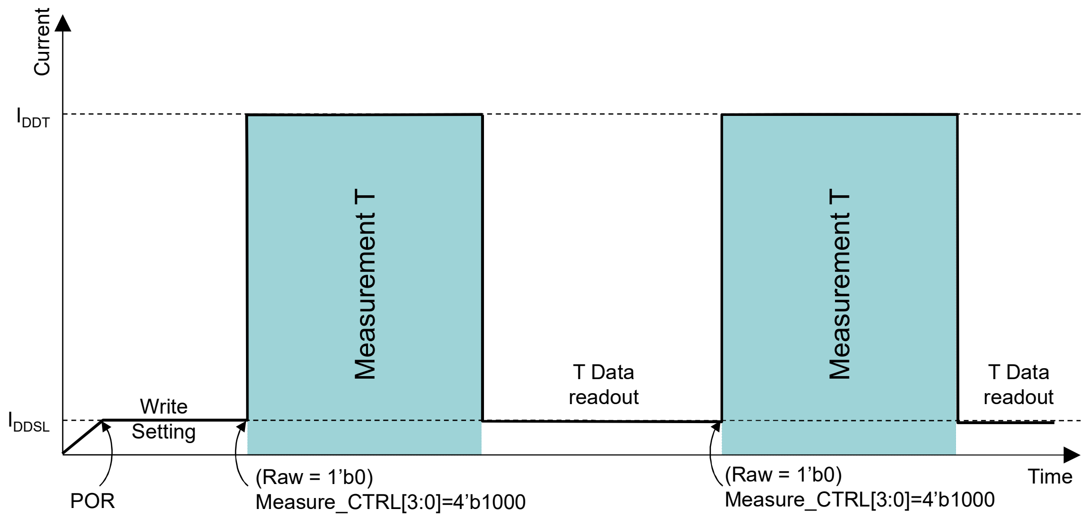


Figure 7: T-Forced mode timing diagram

User Register Map

Table 4: User Register Map Table

<table>
<tr><th>Addr.</th><th>Name</th><th>bit7</th><th>bit6</th><th>bit5</th><th>bit4</th><th>bit3</th><th>bit2</th><th>bit1</th><th>bit0</th><th>Access</th><th>Default</th></tr>
<tr><td>00h</td><td>RESET</td><td>SPI4W</td><td>R'ved</td><td>RST</td><td>0</td><td>0</td><td>RST</td><td>R'ved</td><td>SPI4W</td><td>RW</td><td>0x00</td></tr>
<tr><td>01h</td><td>PID</td><td colspan="8">PID[7:0]</td><td>R</td><td>0x02</td></tr>
<tr><td>02h</td><td>STATUS</td><td colspan="4">Reserved</td><td>0</td><td>0</td><td>0</td><td>DRDY</td><td>R</td><td>NA</td></tr>
<tr><td>06h</td><td>PRESSH</td><td colspan="8">Pressure [23:16]</td><td>R</td><td>NA</td></tr>
<tr><td>07h</td><td>PRESSM</td><td colspan="8">Pressure [15:8]</td><td>R</td><td>NA</td></tr>
<tr><td>08h</td><td>PRESSL</td><td colspan="8">Pressure [7:0]</td><td>R</td><td>NA</td></tr>
<tr><td>09h</td><td>TEMPH</td><td colspan="8">Temperature[15:8]</td><td>R</td><td>NA</td></tr>
<tr><td>0Ah</td><td>TEMPL</td><td colspan="8">Temperature[7:0]</td><td>R</td><td>NA</td></tr>
<tr><td>30h</td><td>CMD</td><td colspan="4">Reserved</td><td colspan="4">Measure_CTRL[3:0]</td><td>RW</td><td>0x00</td></tr>
<tr><td>A5h</td><td>CONFIG1</td><td colspan="6">Reserved</td><td>Raw</td><td>Reserved</td><td>RW</td><td>0x00</td></tr>
<tr><td>A6h</td><td>CONFIG2</td><td colspan="5">Reserved</td><td colspan="3">OSR[2:0]</td><td>RW</td><td>0x1F</td></tr>
<tr><td>AAh
~
BBh</td><td>Calib00
~
Calib17</td><td colspan="8">Calibration data</td><td>R</td><td>NA</td></tr>
</table>

Description of Registers

Register 00h: RESET Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
00h	RESET	SPI4W	R'ved	RST	0	0	RST	R'ved	SPI4W	RW	0x00

Set RESET register (00h) to 0x24 to trigger the device soft reset. All register values will be reset to default. The RST bits will automatically return to 1'b0 when the soft reset complete.

SPI4W bits control the 3-/4-wire SPI selection. Default 0x00 is 3-wire SPI interface. Set 0x81 to RESET register (00h) will switch to the 4-wire SPI.

Register 01h: PID Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
01h	PID	PID[7:0]								R	0x02

PID is the product identification register and the value is fixed to 0x02. This register is available for reading after the device finished the power-on-reset.

Register 02h: STATUS Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
02h	STATUS	Reserved				0	0	0	DRDY	R	NA

The DRDY bit will be set once the data conversion is complete. The output data is ready for reading from pressure or temperature data registers.

Register 06h~08h: Pressure Data Registers

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
06h	PRESSH	Pressure [23:16]								R	NA
07h	PRESSM	Pressure [15:8]								R	NA
08h	PRESSL	Pressure [7:0]								R	NA

The pressure data output is encoded to a 24-bit value and stored across three bytes. Data representation is 2's complement, i.e. MSB (bit 23) is the sign bit with 1'b1 representing negative value.

The pressure data output is raw pressure sensor ADC value. User can then calculate the calibrated pressure value with the calibration parameters (AAh~BBh). Reference calibration code is available upon request.

Register 09h~0Ah: Temperature Data Registers

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
09h	TEMPH	Temperature[15:8]								R	NA
0Ah	TEMPL	Temperature[7:0]								R	NA

The temperature data output is encoded to a 16-bit value and stored across two bytes. Data representation is 2's complement, i.e. MSB (bit 15) is the sign bit with 1'b1 representing negative value.

The temperature sensor has sensitivity of 256 LSB/℃. The central value (0x00) stands for 0℃. Thus the Celsius temperature can be converted from the temperature reading by the following formula:

$$T\,(℃) = \frac{\text{Temperature}[15:0]}{256}$$

Register 30h: CMD Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
30h	CMD	Reserved				Measure_CTRL[3:0]				RW	0x00

Measure_CTRL[3:0] control the signal conversion mode. After each single shot signal conversion, GMP102 will return to standby mode. Available setting is summarized in the following table.

Measure_CTRL[3:0]	Power Mode
4'b1000	T-Forced mode Make a single shot **temperature** conversion.
4'b1001	P-Forced mode Make a single shot **pressure** conversion
Others	Reserved

Register A5h: CONFIG1 Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
A5h	CONFIG1	Reserved						Raw	0	RW	0x00

Set Raw = 1'b0 before making a single shot temperature conversion. This will output calibrated temperature value to the temperature data registers (09h~0Ah).

Set Raw = 1'b1 before making a single shot pressure conversion. This will output raw pressure ADC value to the pressure data registers (06h~08h). User can then calculate the calibrated pressure value with the calibration parameters (AAh~BBh). Reference calibration code is available upon request.

Register A6h: CONFIG2 Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
A6h	CONFIG2	Reserved					OSR[2:0]			RW	0x1F

OSR[2:0] selects the oversampling ratio for the pressure data conversion as summarized in the following table.

OSR[2:0]	Conversion Time (ms)	Oversampling Ratio	Typical Resolution (ENOB)
3'b000	2.5	1024	17.8
3'b001	3.78	2048	18.2
3'b010	6.34	4096	18.7
3'b011	11.46	8192	19.1
3'b100	1.54	256	17
3'b101	1.86	512	17.3
3'b110	21.7	16384	19.4
3'b111	42.18	32768	19.7

Digital Interface: I2C

I2C Interface General Description

The I2C interface is compliant with standard and fast I2C standard. The devices support the 7-bit control functions and SDA and SCL facilitate communication between GMP102 and master with clock rate up to 400kHz.

The 7-bit device slave address can be selected by the SA0 pin as summarized in the below table.

SA0	7-bit Slave Address
1'b0	0x6C
1'b1	0x6D

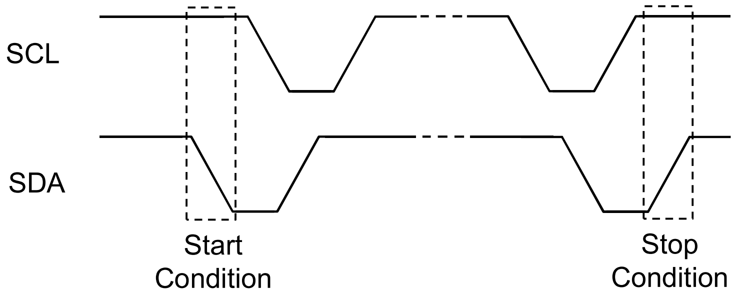
The I2C bus takes master clock through SCL pin and exchanges serial data via SDA. SDA is a bidirectional (input/output) connection. Both are open-drain connection and must be connected externally to VID via a pull-up resistor. The I2C interface supports multiple read and write. When using multiple read/write, the internal I2C address pointer will automatically increase by 1 for the next access.

I2C Access Format: Standard and Fast Mode

One data bit is transferred for each SCL cycle. The SDA must not change level when the SCL is high. The level changes in SDA while SCL is high are reserved control signals. The SDA and SCL remain high when I2C bus is idle.

Data transfer begins by bus master indicating a start condition (ST) of a falling edge on SDA when SCL is high. The master terminates transmission and frees the bus by issuing a STOP condition (SP). Stop condition is a rising edge on SDA while SCL is high. The bus remains active if a repeated START (SR) condition is generated instead of a STOP condition. Figure 8 illustrates the START and STOP condition.

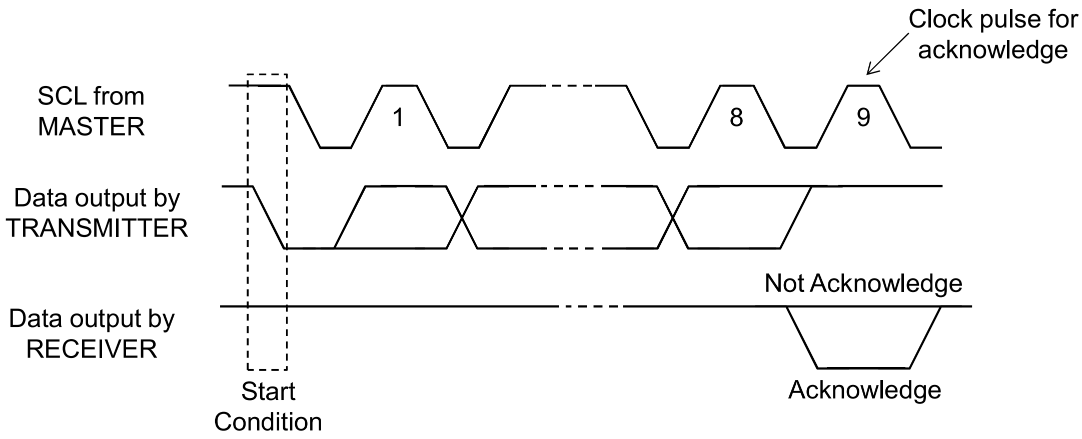
Figure 8: I2C START and STOP condition



After a start condition (ST), the 7-bit slave address + RW bit must be sent by master. If the slave address does not match with GMP102, there is no acknowledge and the following data transfer will not affect GMP102. If the slave address corresponds to GMP102, it will acknowledge by pulling SDA to low and the SDA line should be let free by bus master to enable the data transfer. The master should let the SDA high (no pull down) and generate a high SCL pulse for

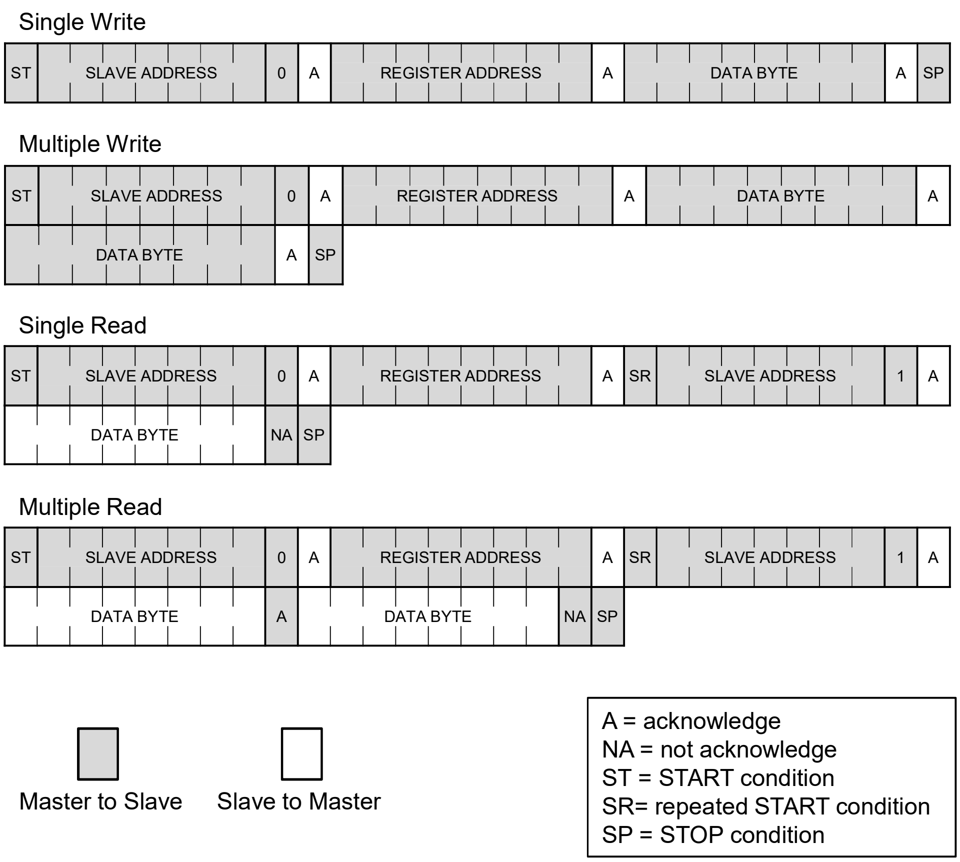
GMP102 acknowledge. Figure 9 illustrates the acknowledge signal sequence.

Figure 9: Acknowledge signal sequence



A write to GMP102 includes transmission of a START condition, the slave address with R/W bit=1'b0, one byte of data to specify the register address to write, subsequent one or more bytes of data, and finally a STOP condition. "Single Write" and "Multiple Write" in Figure 10 illustrates the frame format of single and multiple write to GMP102 respectively.

Figure 10: I2C access format: standard and fast mode



A read from GMP102 starts with transmission of a START condition, the slave address with R/W bit=1'b0, and one byte of data to specify the register address to read. A repeated START condition and the slave address with R/W bit=1’b1 are transmitted subsequently. The slave address with R/W bit=1’b1 initiates a read operation. GMP102 acknowledge receipt of the read operation command by pulling SDA low during the 9^{th} SCL clock and begin transmitting the contents starting from the specified register address. The master must acknowledge all correctly received bytes except the last byte. The final byte must be followed by a not acknowledge from the master and the STOP condition. “Single Read” and “Multiple Read” in Figure 10 illustrates the frame format for reading single or multiple byte from GMP102.

I2C Specifications

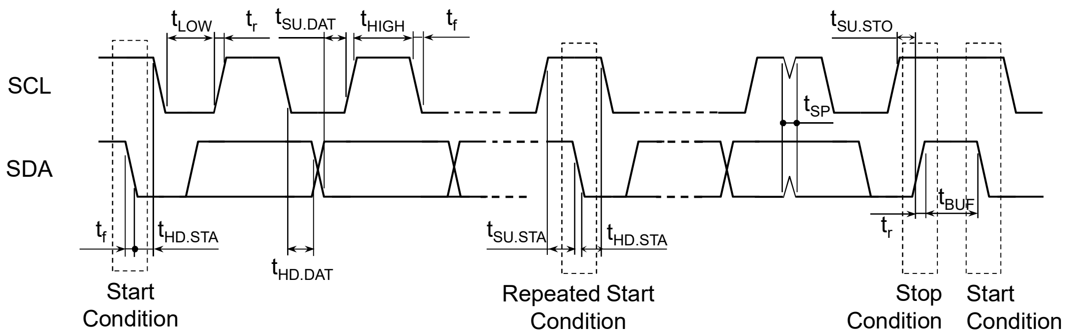
Table 5: I2C Timing Specification: Standard Mode

Parameter	Symbol	Minimum	Typical	Maximum	Unit
SCL clock frequency	f_{SCL}	—	—	100	kHz
Clock low period	t_{LOW}	4.7	—	—	µs
Clock high period	t_{HIGH}	4	—	—	µs
Start hold time	$t_{HD.STA}$	4	—	—	µs
Start setup time	$t_{SU.STA}$	4.7	—	—	µs
Data-in hold time	$t_{HD.DAT}$	0	—	—	µs
Data-in setup time	$t_{SU.DAT}$	250	—	—	ns
Stop setup time	$t_{SU.STO}$	4	—	—	µs
Rise time	t_r	—	—	1	µs
Fall time	t_f	—	—	0.3	µs

Table 6: I2C Timing Specification: Fast Mode

Parameter	Symbol	Minimum	Typical	Maximum	Unit
SCL clock frequency	f_{SCL}	—	—	400	kHz
Clock low period	t_{LOW}	1.3	—	—	µs
Clock high period	t_{HIGH}	0.6	—	—	µs
Bus free to new start	t_{BUF}	1.3	—	—	µs
Start hold time	$t_{HD.STA}$	0.6	—	—	µs
Start setup time	$t_{SU.STA}$	0.6	—	—	µs
Data-in hold time	$t_{HD.DAT}$	0	—	—	µs
Data-in setup time	$t_{SU.DAT}$	100	—	—	ns
Stop setup time	$t_{SU.STO}$	0.6	—	—	µs
Rise time	t_r	—	—	0.3	µs
Fall time	t_f	—	—	0.3	µs
Spike width	t_{SP}	—	—	50	µs

Figure 11: I2C Timing Diagram: Standard and Fast Mode



Digital Interface: SPI

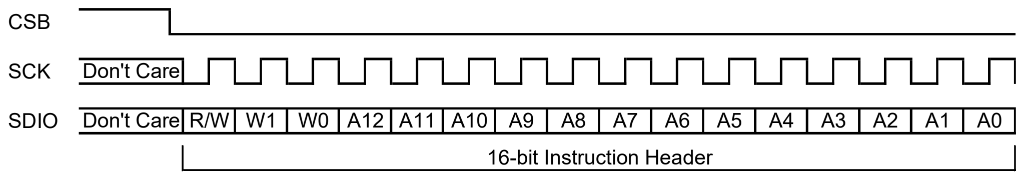
SPI Interface General Description

Both 3-wire and 4-wire SPI interfaces are supported. The SPI4W bits of RESET register (00h) control such selection. See 00h register description for more detail.

The SPI transaction starts with the falling edge of CSB and the rising edge of SCK. The first phase of the transfer is the instruction phase of 16 bits, followed by multiple data bytes (every byte consists of 8 bits).

The first instruction phase is shown in the Figure 12. The instruction phase is divided into several bit fields.

Figure 12: SPI instruction phase bit field



The first bit field is the read/write indicator bit (R/W). When this bit is set, a read operation is requested. On the other hand when this bit is clear, it indicates a write operation.

The second bit field consists of two bits, W1 and W0. They represent the number of data bytes to transfer for either read or write. If the number of bytes to transfer is three or less (W1:W0 = 2'00, 2'b01 or 2'b10), CSB can stall high on byte boundaries. Stalling on a non-byte boundary terminates the communication cycle. If W1:W0 = 2'b11, data can be transferred until CSB transit to high, and CSB is not allowed to stall during the whole streaming process. Table 7 summaries such behaviors for W1:W0 settings.

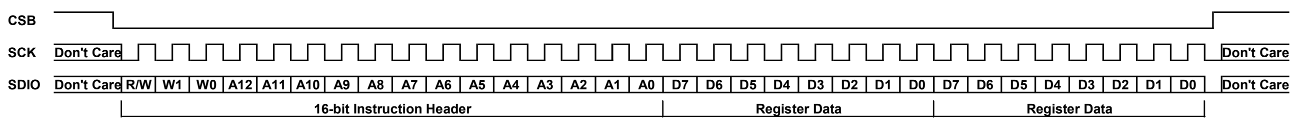
Table 7: W1/W0 settings

W1:W0	Description	CSB stalling
2'b00	1 bytes of data can be transferred	Optional
2'b01	2 bytes of data can be transferred	Optional
2'b10	3 bytes of data can be transferred	Optional
2'b11	4 or more bytes of data can be transferred. CSB must be held low for the entire process.	No

The third bit field of the remaining 13 bits represents the starting address of the data transfer. If more than one word is being sent, sequential addressing is used.

Data follows the instruction phase. Multiple bytes can be transferred in one transaction determined by the W1:W0 bits. Every byte consists of 8 bits. Figure 13 illustrates the timing for transferring two bytes.

Figure 13: SPI access timing

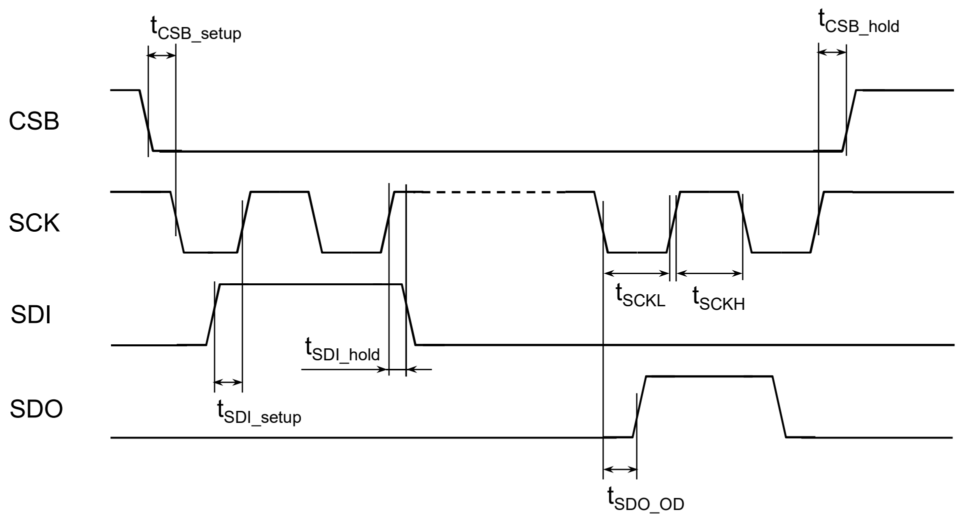


SPI Specification

Table 8: SPI Timing Specification

Parameter	Symbol	Minimum	Maximum	Unit
SCK clock frequency	f_{SCK}	—	10	MHz
SCK clock low pulse	t_{SCKL}	20	—	ns
SCK clock high pulse	t_{SCKH}	20	—	ns
SDI setup time	t_{SDI_setup}	20	—	ns
SDI hold time	t_{SDI_hold}	20	—	ns
SDO/SDI output delay	t_{SDO_OD}	—	30 (25pF) 40 (250pF)	ns
CSB setup time	t_{CSB_setup}	20	—	ns
CSB hold time	t_{CSB_hold}	40	—	ns

Figure 14: SPI Timing Diagram



Package

Outline Dimension

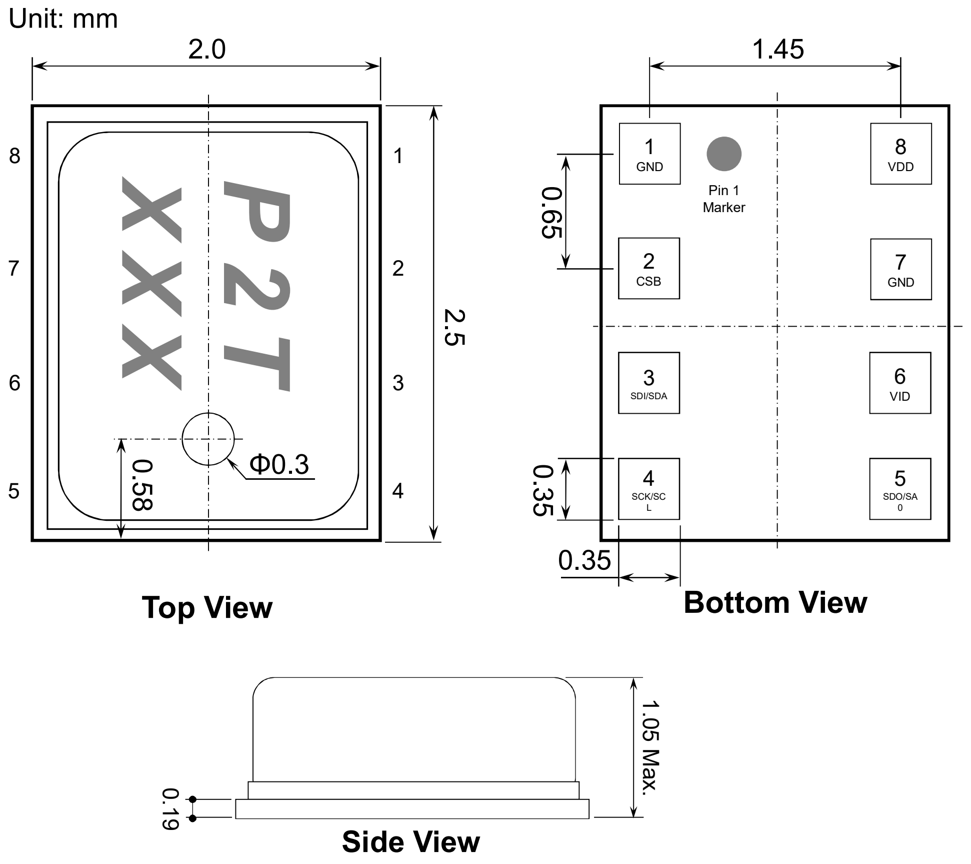


Figure 15: Package Outline Dimension

Recommended PCB Foot Print Layout

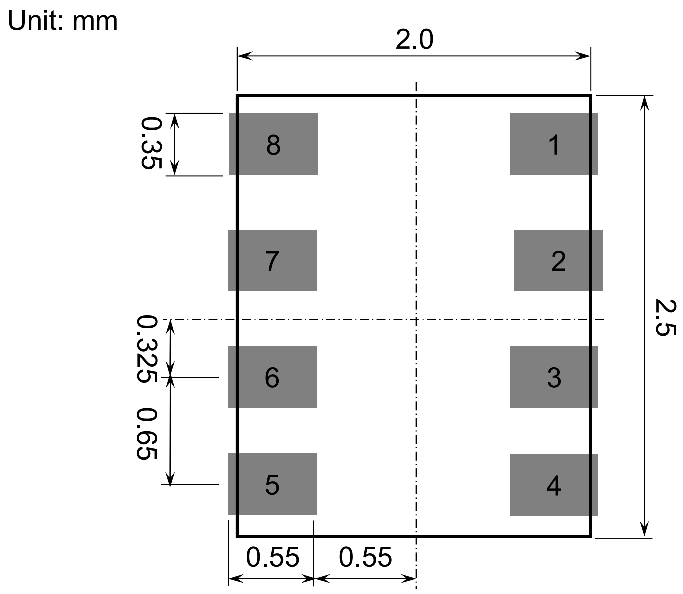


Figure 16: Layout Recommendation for PCB Land Pad

RoHS Compliance

GMEMS LGA with metal lid packaged sensors are compliant with Restrictions on Hazardous Substances (RoHS), having halide-free molding compound (green) and lead-free terminations. Reflow profiles applicable to those processes can be used successfully for soldering the devices.

Moisture Sensitivity Level

GMP102 package MSL rating is Level 3.

Tape Specification

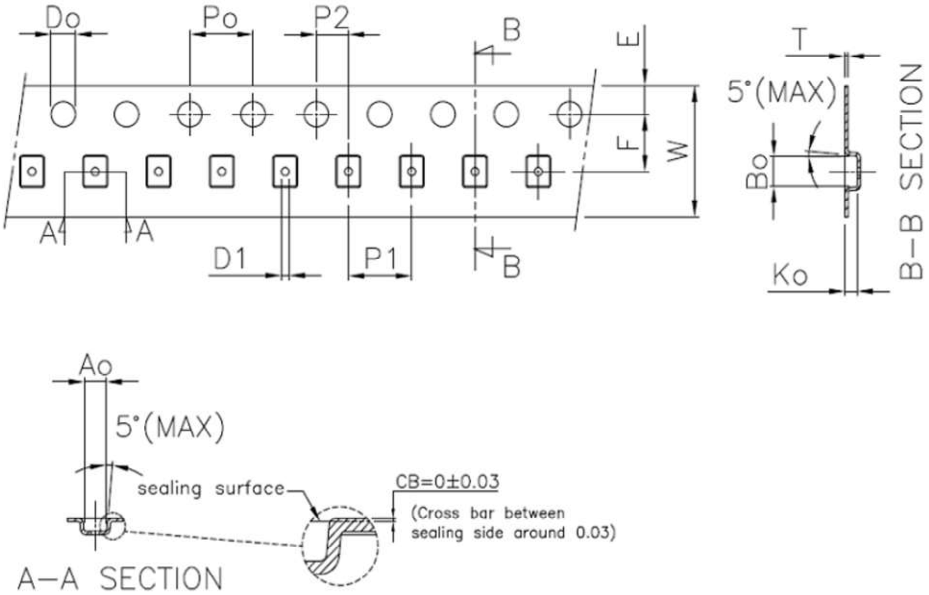


Figure 17: Tape Outline Drawing

Table 9: Tape Dimension

Symbol	Dimension (mm)
A_0	2.35±0.1
B_0	2.85±0.1
K_0	1.25±0.1
P_0	4.0±0.1
P_1	8.0±0.1
P_2	2.0±0.05
T	0.3±0.05
E	1.75±0.1
F	5.5±0.05
D_0	1.5+ 0.1/-0
D_1	Min. 1.5
W	12.0±0.3

Document History and Modification

Revision No.	Description	Date
V1.0	First release	2018/2/6
V1.1	Correct pin name typo	2018/10/22
V1.2	Update vent hole position and dimension	2019/2/11