

# 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<sup>3</sup> 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°C. The pressure sensor has a wide operating range from 300 to 1100hPa that covers all surface elevations on earth.

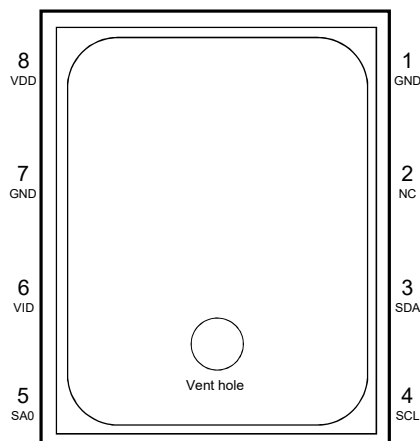
GMP102 can detect absolute barometric pressure with highly accuracy for applications like quadcopter altitude control. The maximum altitude resolution can be up to less than 0.1m. Several operation options further offer large window for user optimization on the power consumption, resolution and filter performance.

## Features

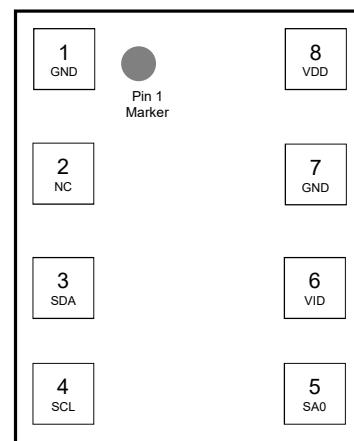
- Operation range:
  - Pressure: 300~1100hPa (Absolute)
  - Temperature: -40~+85°C
- Built-in 24-bit ADC:
  - Pressure resolution: up to 0.18Pa
  - Temperature resolution: up to 0.004°C
- Digital interface:
  - I2C supporting both standard (100kHz), and fast (400kHz) mode
- Supply voltage:
  - VDD: +1.8V ~ +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<sup>2</sup>
  - 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    | NC   | No connection inside              |
| 3    | SDA  | I2C data pin                      |
| 4    | SCL  | I2C clock pin                     |
| 5    | SA0  | I2C slave address select 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    |  | 1.8  | —  | 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<br>OSR=256<br>OSR=1024<br>OSR=4096<br>OSR=16384<br><b><u>OSR=32768 (default)</u></b> | IDD    | VDD = 3.3V<br>20Hz<br>P+T conversion   | —    | 97<br>120<br>190<br>420<br><b><u>800</u></b> | —    | uA   |
| Standby current  | IDDSD  | After POR or soft reset  | —    | 1  | —    | uA   |
| Relative accuracy<br>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<br>pressure  | PABS   |  | —    | 1  | —    | hPa  |

|                                  |      |             |   |     |   |           |
|----------------------------------|------|-------------|---|-----|---|-----------|
| Noise in pressure                |      |             | — | 1.9 | — | Pa<br>RMS |
| Absolute accuracy<br>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

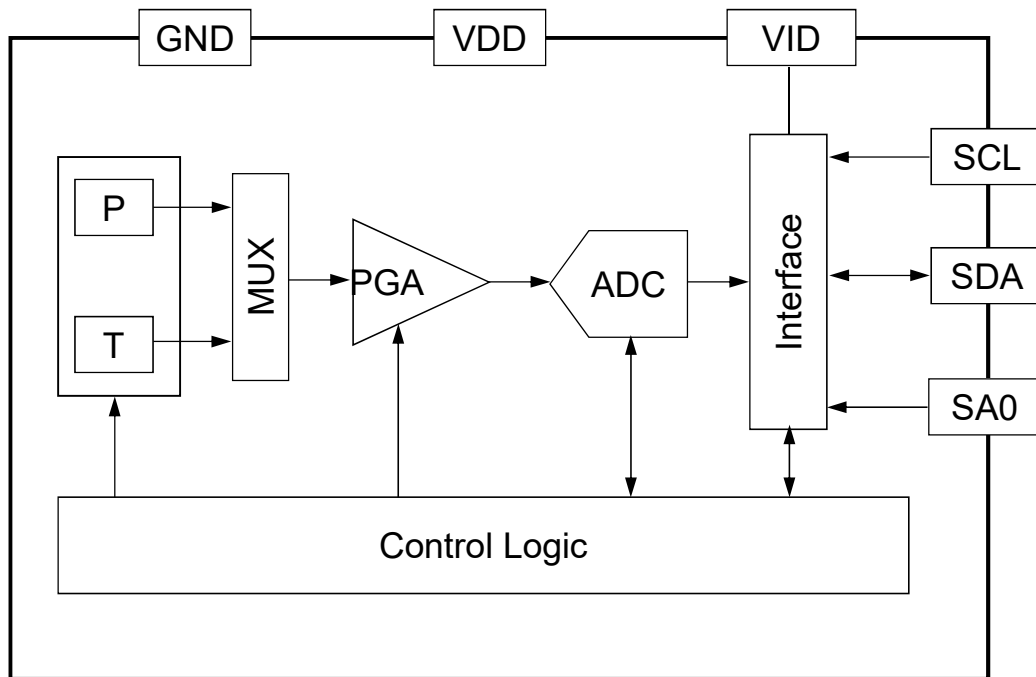


Figure 1: GMP102 Block Diagram

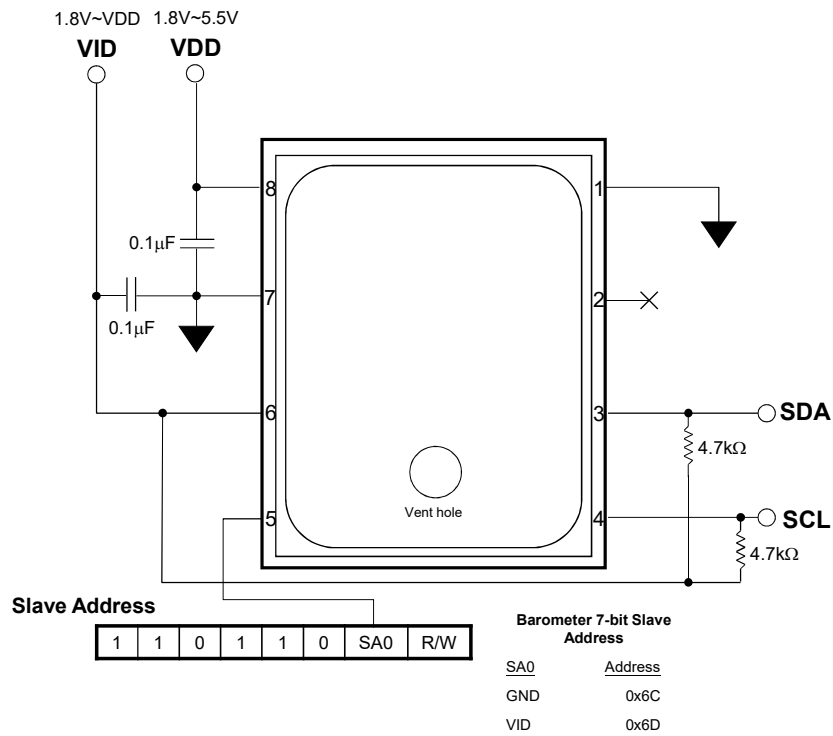


Figure 2: GMP102 I2C Connection Example

## 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 3.

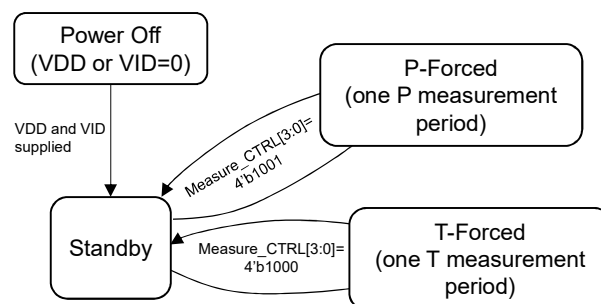


Figure 3: Mode transactions diagram

#### ● 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 4.

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).

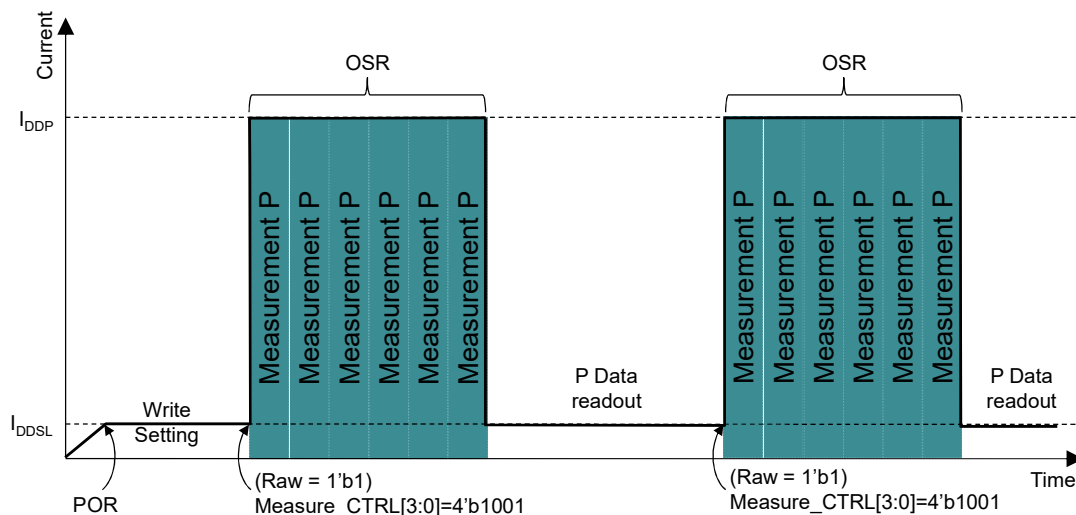


Figure 4: P-Forced mode timing diagram

- 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 5.

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).

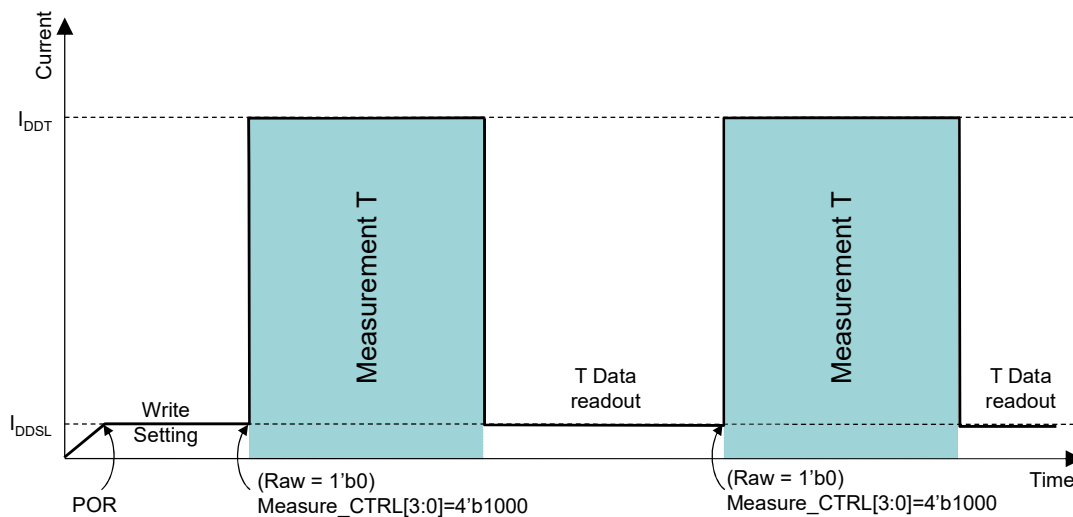


Figure 5: T-Forced mode timing diagram

## User Register Map

Table 4: User Register Map Table

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



## Description of Registers

### Register 00h: RESET Register

| Addr. | Name  | bit7     | bit6 | bit5 | bit4 | bit3 | bit2 | bit1     | bit0 | Access | Default |
|-------|-------|----------|------|------|------|------|------|----------|------|--------|---------|
| 00h   | RESET | Reserved |      | RST  | 0    | 0    | RST  | Reserved |      | 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.

### 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/°C. The central value (0x00) stands for 0°C. Thus the Celsius temperature can be converted from the temperature reading by the following formula:

$$T(^{\circ}\text{C}) = \frac{\text{Temperature}[15:0]}{256}$$

#### 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<br>Make a single shot <b>temperature</b> conversion. |
| 4'b1001           | P-Forced mode<br>Make a single shot <b>pressure</b> 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 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.

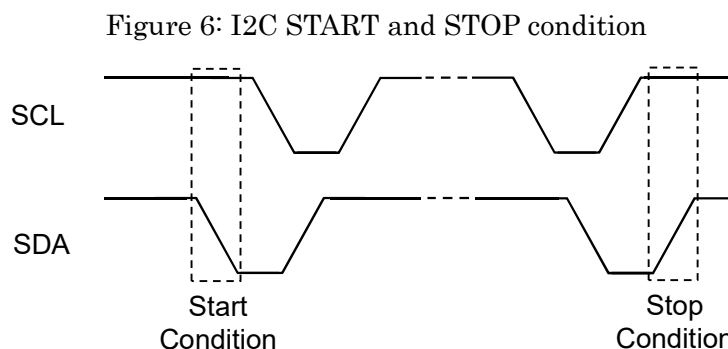
| SA0  | 7-bit Slave Address |
|------|---------------------|
| 1'b0 | 0x6C                |
| 1'b1 | 0x6D                |

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.

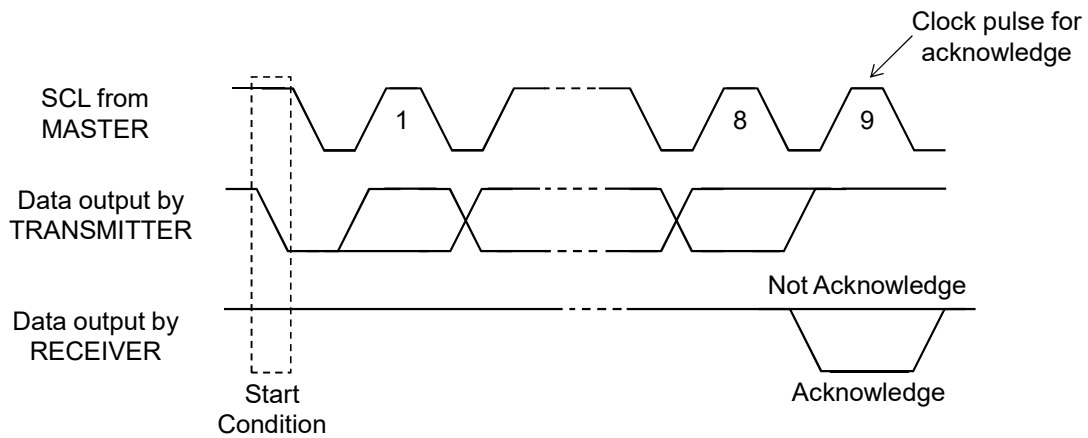
Data transfer begins by bus master indicating a start condition (ST) of a falling edge on SDA when SCL is high. The master terminates transmission and frees the bus by issuing a STOP condition (SP). Stop condition is a rising edge on SDA while SCL is high. The bus remains active if a repeated START (SR) condition is generated instead of a STOP condition. Figure 6 illustrates the 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 7 illustrates the acknowledge signal sequence.

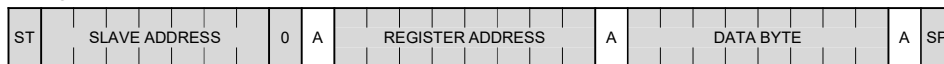
Figure 7: Acknowledge signal sequence



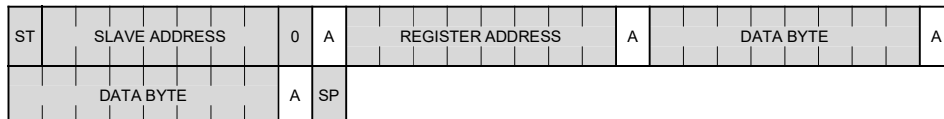
A write to GMP102 includes transmission of a START condition, the slave address with R/W bit=1'b0, one byte of data to specify the register address to write, subsequent one or more bytes of data, and finally a STOP condition. "Single Write" and "Multiple Write" in Figure 8 illustrates the frame format of single and multiple write to GMP102 respectively.

Figure 8: I2C access format: standard and fast mode

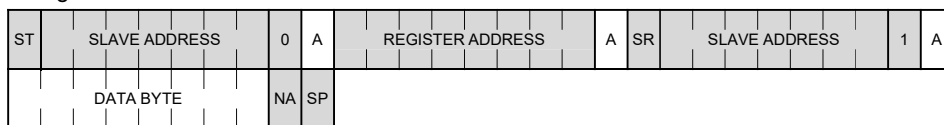
#### Single Write



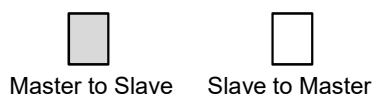
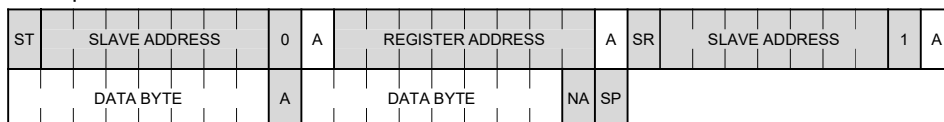
#### Multiple Write



#### Single Read



#### Multiple Read



A = acknowledge  
 NA = not acknowledge  
 ST = START condition  
 SR= repeated START condition  
 SP = STOP condition

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<sup>th</sup> 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 8 illustrates the frame format for reading single or multiple byte from GMP102.

## I2C Specifications

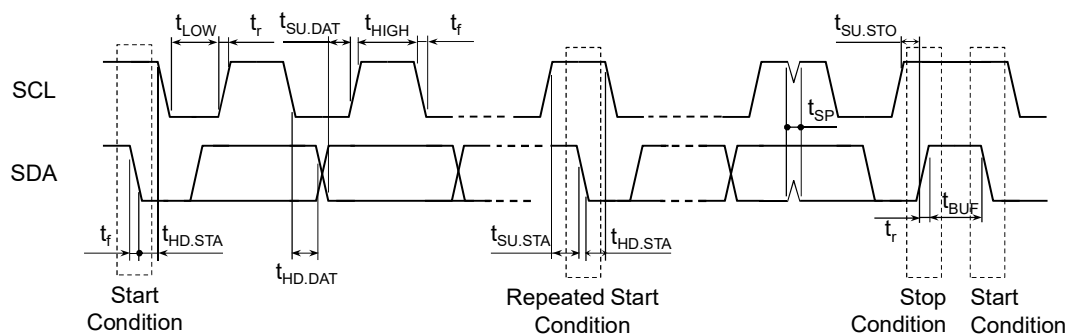
Table 5: I2C Timing Specification: Standard Mode

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

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     | —       | —       | $\mu s$ |
| Clock high period     | $t_{HIGH}$   | 0.6     | —       | —       | $\mu s$ |
| Bus free to new start | $t_{BUF}$    | 1.3     | —       | —       | $\mu s$ |
| Start hold time       | $t_{HD.STA}$ | 0.6     | —       | —       | $\mu s$ |
| Start setup time      | $t_{SU.STA}$ | 0.6     | —       | —       | $\mu s$ |
| Data-in hold time     | $t_{HD.DAT}$ | 0       | —       | —       | $\mu s$ |
| Data-in setup time    | $t_{SU.DAT}$ | 100     | —       | —       | ns      |
| Stop setup time       | $t_{SU.STO}$ | 0.6     | —       | —       | $\mu s$ |
| Rise time             | $t_r$        | —       | —       | 0.3     | $\mu s$ |
| Fall time             | $t_f$        | —       | —       | 0.3     | $\mu s$ |
| Spike width           | $t_{SP}$     | —       | —       | 50      | $\mu s$ |

Figure 9: I2C Timing Diagram: Standard and Fast Mode



## Package

### Outline Dimension

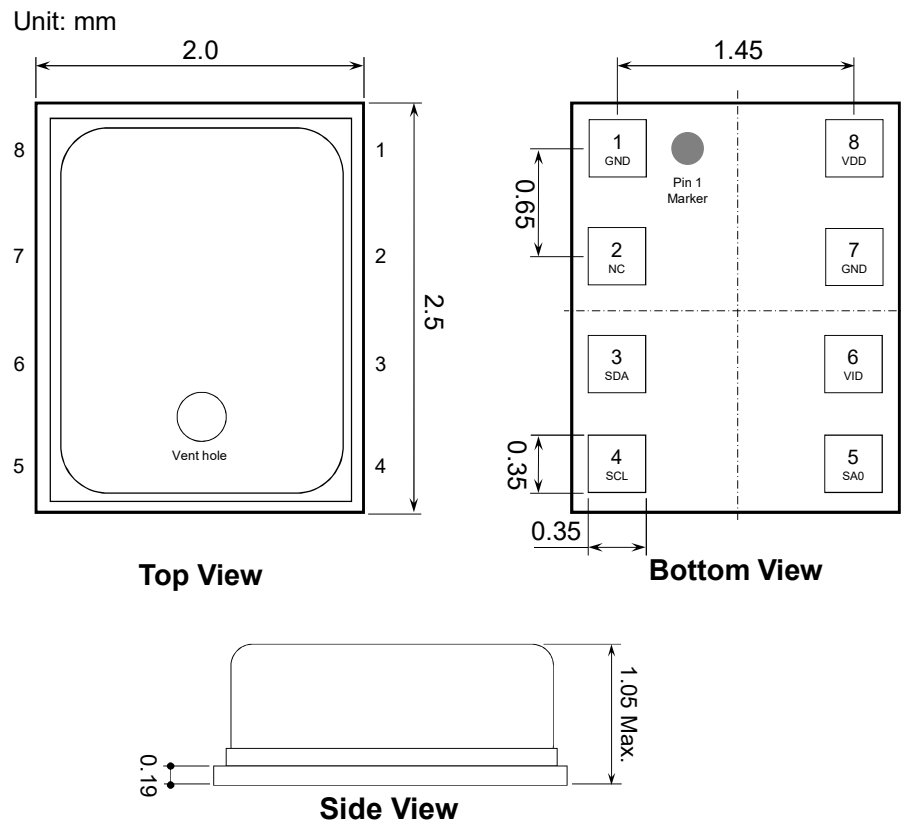


Figure 10: Package Outline Dimension

### 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.



## Recommended PCB Foot Print Layout

Unit: mm

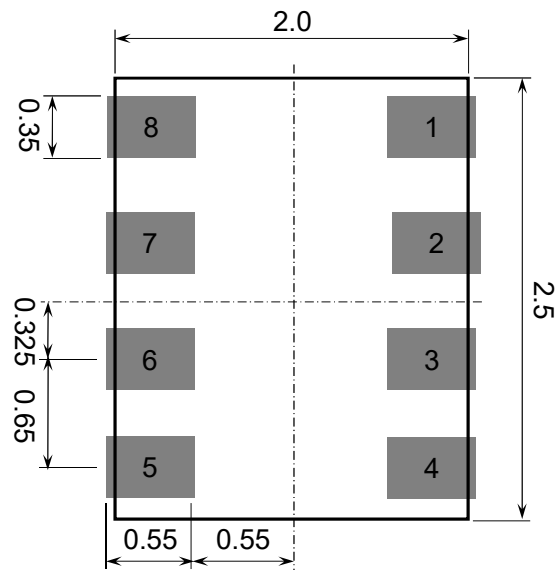


Figure 11: Layout Recommendation for PCB Land Pad

## Moisture Sensitivity Level

GMP102 package MSL rating is Level 3.

### Document History and Modification

| Revision No. | Description   | Date       |
|--------------|---|------------|
| V0.1         | Preliminary first release   | 2016/8/23  |
| V0.2         | Update TBD specification items  | 2016/8/24  |
| V0.3         | <ul style="list-style-type: none"> <li>● Update the initialization step</li> <li>● Update package outline dimension</li> </ul>  | 2016/10/06 |
| V0.4         | <ul style="list-style-type: none"> <li>● Correct Fig2 VDD range typo</li> <li>● Correct default P OSR to 32768</li> <li>● Correct A6h default value to 0x1F</li> <li>● Correct OSR vs. ENOB information</li> <li>● Add OSR vs. conversion time information</li> </ul> | 2017/4/18  |
| V0.5         | <ul style="list-style-type: none"> <li>● Update 30h default value to 0x00</li> <li>● Update package outline dimension</li> </ul>  | 2017/8/16  |
|              |   |            |
|              |   |            |
|              |   |            |
|              |   |            |