# GMP102N Digital Barometric Pressure Sensor

## *General Introduction*

GMP102N is a digital barometric pressure sensor especially designed for applications requiring precise pressure measurement. GMP102N includes both pressure and temperature sensors in a small 2.0×2.5×1.05 mm³ module. It can output calibrated pressure and temperature data without the need for user calibration.

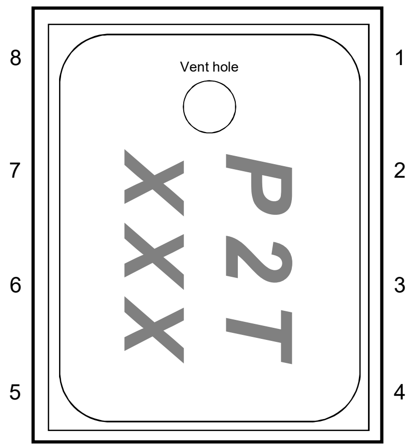
The pressure sensor is based on the industry-recognized piezo-resistive technology featuring long-term stability and EMC robustness. A high-performance 24-bit ADC provides altitude resolution up to 20cm, and temperature resolution up to 0.004℃. The pressure sensor has a wide operating range from 300 to 1100hPa that covers all surface elevations on earth. Several operation options further provide flexible window for user optimization on the power consumption and resolution.

## *Features*

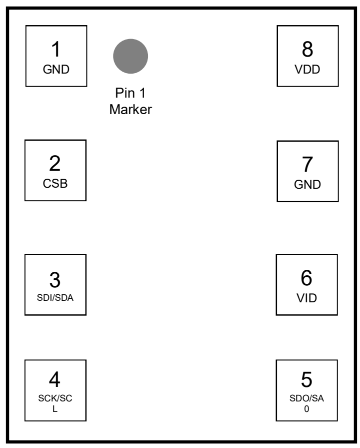
- Operation range:
  - Pressure: 300~1100hPa (Absolute)
  - Temperature: -40~+85℃
- Built-in 24-bit ADC:
  - Altitude resolution: up to 20cm
  - Temperature resolution: up to 0.004℃
- Digital interface:
  - I2C: standard and fast modes
  - SPI: 3-/4-wire, up to 10MHz clock
- Calibrated P and T data output, no need for user calibration
- Operation mode:
  - T-/P-Forced mode
  - Continuous (T+P) mode
- 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 2.0×2.5mm², height 1.05mm

## *Applications*

Mobile altimetry and barometry, 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<br>High for I2C mode<br>Low for SPI mode |
| 3 | SDI/SDA | I2C mode: SDA data I/O pin<br>SPI 4-wire mode: SDI data input pin<br>SPI 3-wire mode: SDA data I/O pin |
| 4 | SCK/SCL | I2C mode: SCL clock pin<br>SPI mode: SCK clock pin |
| 5 | SDO/SA0 | I2C mode: SA0, slave address select pin<br>SPI mode: SDO, 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 | Full accuracy | 300 | — | 1100 | hPa |
| Operation current<br>OSR=256<br>OSR=1024<br>OSR=4096<br>OSR=16384<br>OSR=32768 (default) | ICC | VDD = 3.3V<br>20Hz<br>P+T conversion | — | <br>97<br>120<br>190<br>420<br>800 | — | uA |
| Standby current | ICCSD | 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 | — | ±0.5 | — | hPa |
| Absolute accuracy pressure | PABS | | — | ±2 | — | hPa |
| Noise in pressure | | | — | 3.5 | — | Pa RMS |
| Absolute accuracy temperature | TABS | @25°C | — | 0.5 | — | °C |
| | | -40 to 85°C | — | 1 | — | °C |
| Long term stability | | | — | ±2 | — | 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 | VID + 0.3 | V |
| Pressure | PMAX | 0 | 20000 | hPa |
| Storage temperature | TST | -40 | +125 | °C |
| ESD | HBM | — | ±2 | kV |

## Block Diagram and Connection

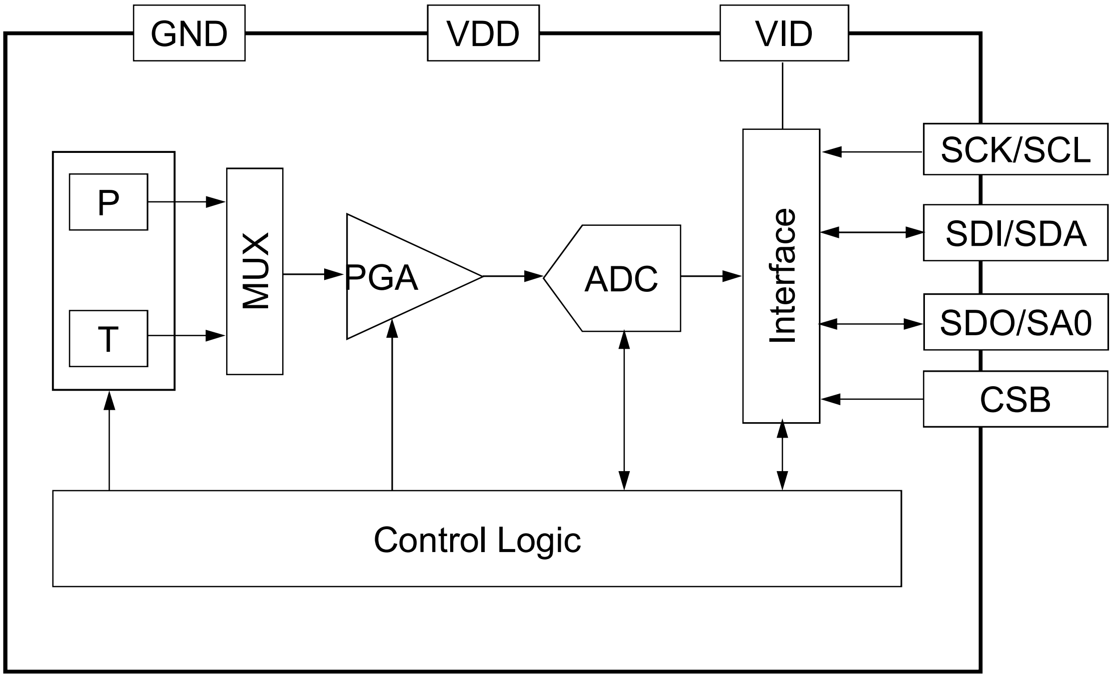



Figure 1: GMP102N Block Diagram

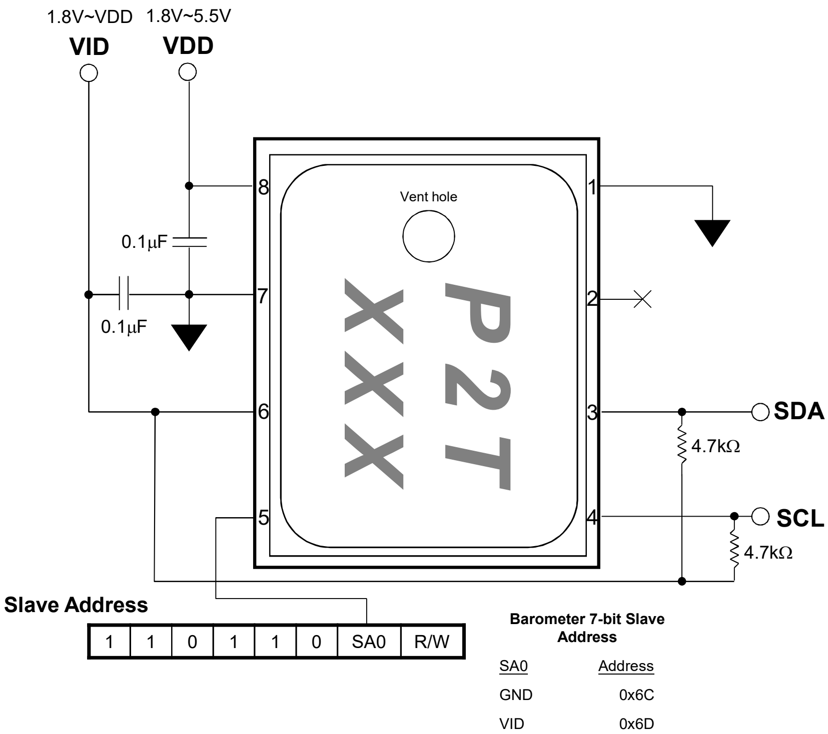



Figure 2: GMP102N I2C Connection Example

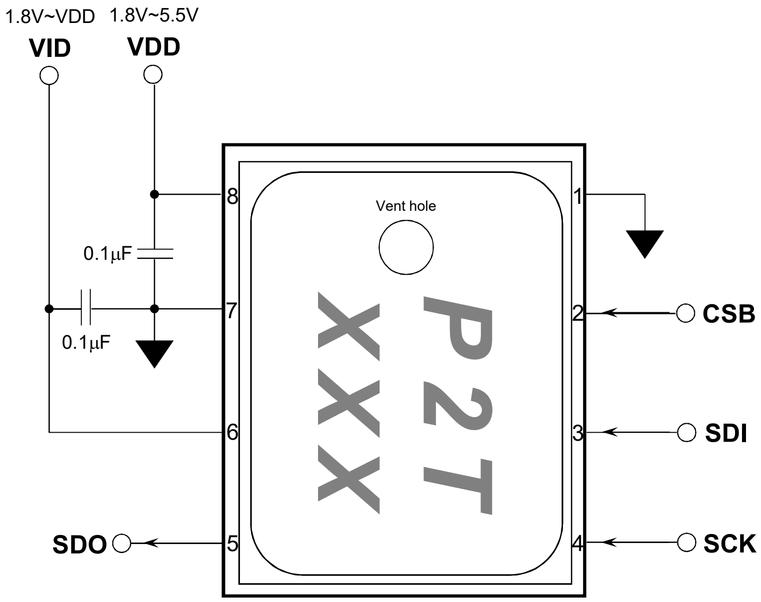



Figure 3: GMP102N SPI 4-Wire Connection Example

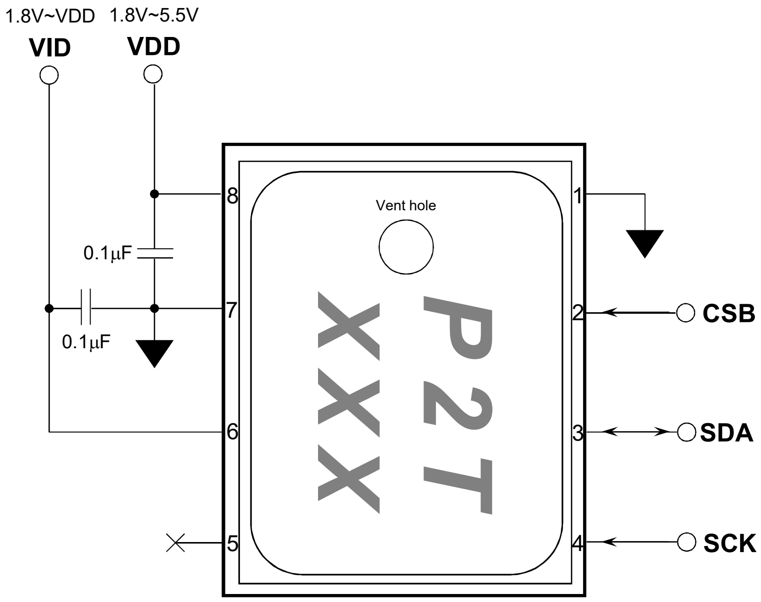



Figure 4: GMP102N SPI 3-Wire Connection Example

## Functional Description

### Power Management

GMP102N 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 GMP102N will transit to standby mode.

### Reset Functions

GMP102N 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

GMP102N will automatically initialize to standby mode upon power-up after POR. Or one can use soft reset for register initialization as required. There is nothing further to do except to set the power mode for operation. See below “Power Modes” section for description.

### Power Modes

GMP102N offers four power modes, standby, P-Forced, T-Forced and continuous 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.

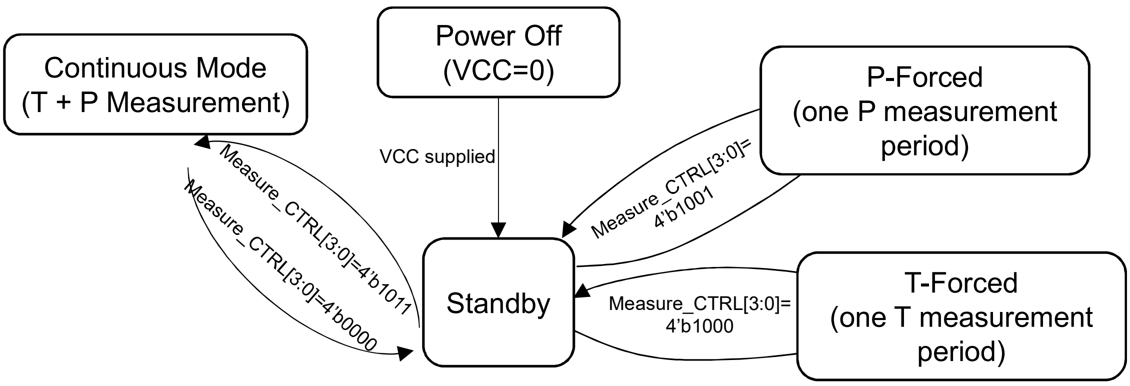



Figure 5: Mode transactions diagram

- Standby mode

GMP102N will enter standby mode after complete POR sequence or soft reset. Or user can enter standby mode at any time by set 30h = 0x00.

In this mode, data measurement stops and the power consumption is at the minimum. All registers, including PID data and control registers, are accessible.

- P-Forced mode

In P-Forced mode, GMP102N 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.

Below summarized the single shot pressure conversion steps:

1. Set to the P-Forced mode by set 30h = 0x09.
2. Check 02h[0] (DRDY) bit and wait until its value is set. The data is available in the registers when DRDY = 1'b1.
3. Read the calibrated pressure data from the pressure data registers (06h~08h).
4. Divide the pressure data by 64 to get pressure in Pa.

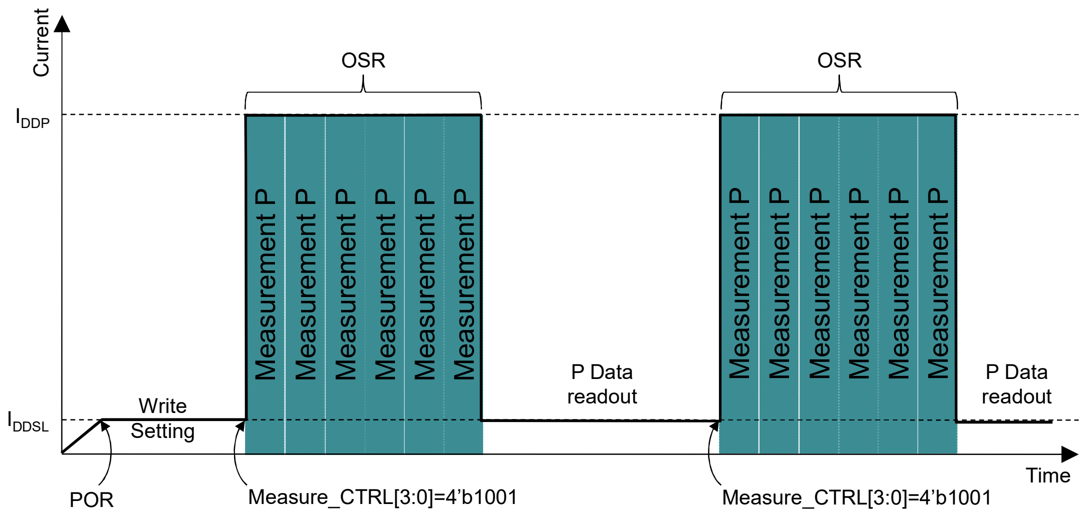



Figure 6: P-Forced mode timing diagram

- T-Forced mode

In T-Forced mode, GMP102N 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.

Below summarized the single shot temperature conversion steps:

1. Set to the T-Forced mode by set 30h = 0x08.
2. Check 02h[0] (DRDY) bit and wait until its value is set. The data is available in the registers when DRDY = 1'b1.
3. Read the calibrated temperature output from the temperature data registers (09h~0Ah).
4. Divide the temperature data by 256 to get temperature in Celsius degree.

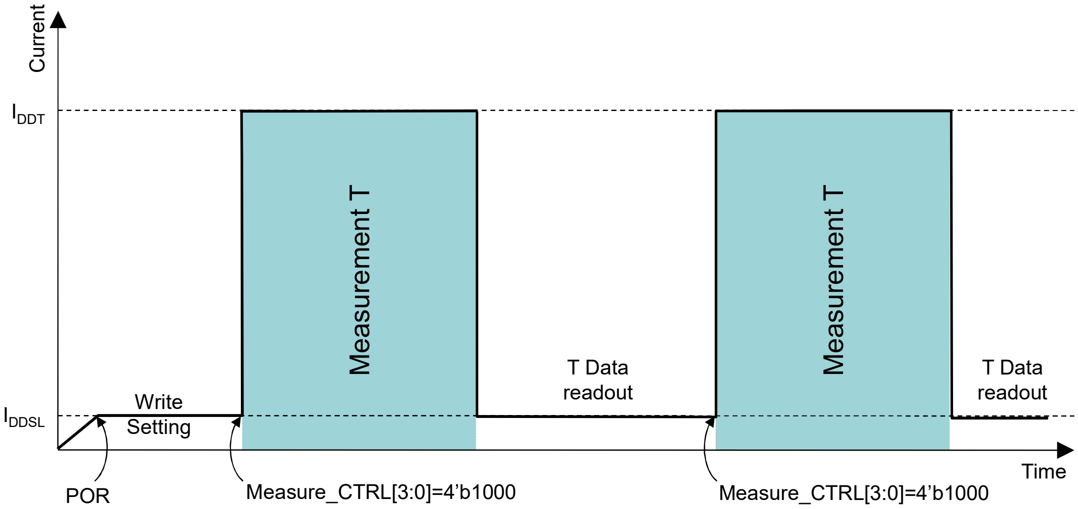



Figure 7: T-Forced mode timing diagram

- Continuous mode

In continuous mode, GMP102N will periodically power up and perform once temperature measurement, once pressure measurement, and then return to a sleep interval. The duration of the sleep interval is configured by the Standby_Time[3:0] bits of 30h register. The device will not get back to standby mode until manually set 30h = 0x00. The measurement results can be obtained from the data registers. The timing diagram of the continuous mode is illustrated in the following Figure 8.

Below summarized the continuous mode setup steps:

1. Set the sleep time interval by setting Standby_Time[3:0] bits of 30h register.
2. Set to the continuous mode by set 30h = 0x0B.

Calibrated temperature output can be read from the temperature data registers (09h~0Ah). Divide the temperature data by 256 to get temperature in Celsius degree.

Calibrated pressure output can be read from the pressure data registers (06h~08h). Divide the pressure data by 64 to get pressure in Pa.

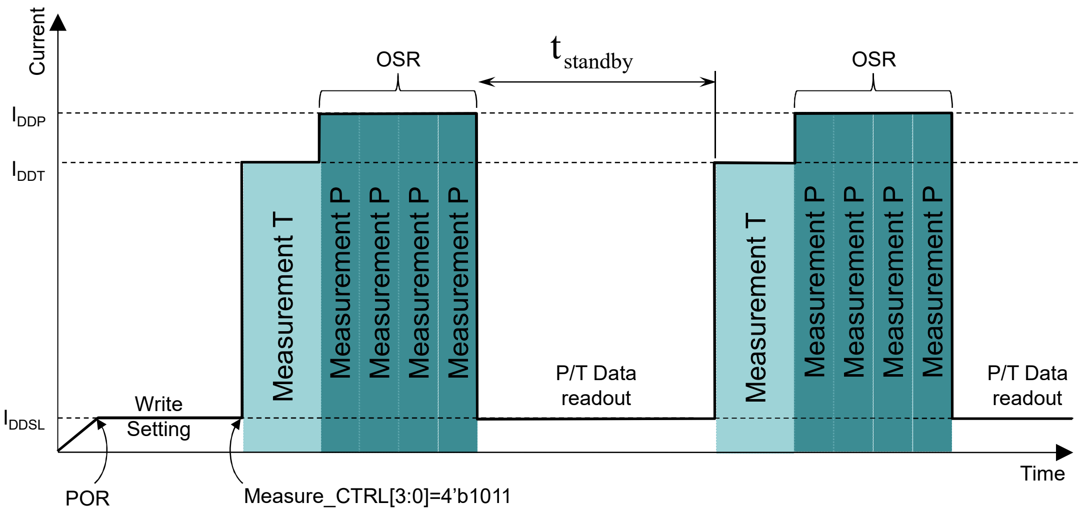



Figure 8: Continuous mode timing diagram

## User Register Map

Table 4: User Register Map Table

| Addr. | Name | bit7 | bit6 | bit5 | bit4 | bit3 | bit2 | bit1 | bit0 | Access | Default |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00h | RESET | SPI4W | R'ved | RST | 0 | 0 | RST | R'ved | SPI4W | 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 | Standby_Time[3:0] | | | | Measure_CTRL[3:0] | | | | RW | 0x00 |
| A6h | CONFIG2 | Reserved | | | | | OSR[2:0] | | | RW | 0x27 |

## 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 has sensitivity of 64 LSB/Pa. The central value (0x00) stands for 0 Pa. Thus the pressure value can be converted from the pressure reading by the following conversion:

$$P\,(\mathrm{Pa}) = \frac{\mathrm{Pressure}[23:0]}{64}$$

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 | Standby_Time[3:0] | | | | Measure_CTRL[3:0] | | | | RW | 0x00 |

Measure_CTRL[3:0] control the signal conversion mode. For the T- or P-Forced mode, GMP102N will return to standby mode after each conversion. While in the continuous mode, the device will periodically power up and performs once temperature conversion, once pressure signal conversion and a standby interval defined by the Standby_Time[3:0] bits. Available setting is summarized in the following table.

| Measure_CTRL[3:0] | Power Mode |
|---|---|
| 4'b1000 | T-Forced mode<br>Make a single shot **temperature** conversion. |
| 4'b1001 | P-Forced mode<br>Make a single shot **pressure** conversion |
| 4'b1011 | Continuous mode<br>Periodically perform P and T conversion with an standby interval set by Standby_Time[3:0] |
| Others | Reserved |

Standby_Time[3:0] control the standby interval between periodic conversions in the continuous mode, see Figure 8 for illustration. One code defined by Standby_Time represents 62.5ms. That is

$$t_{standby}\,(\text{ms}) = \text{Standby\_Time}[3:0] \times 62.5$$

Register A6h: CONFIG2 Register

| Addr. | Name | bit7 | bit6 | bit5 | bit4 | bit3 | bit2 | bit1 | bit0 | Access | Default |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A6h | CONFIG2 | Reserved | | | | | OSR[2:0] | | | RW | 0x27 |

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 GMP102N 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 |

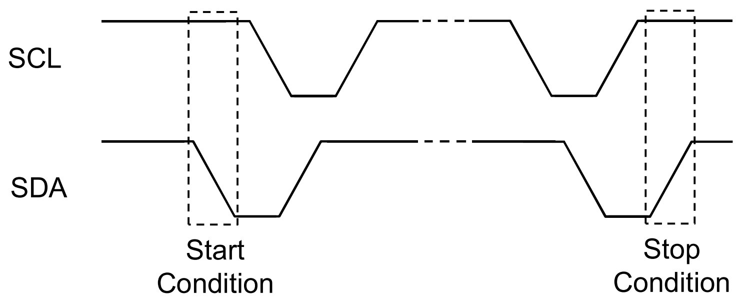
The I2C bus takes master clock through SCL pin and exchanges serial data via SDA. SDA is a bidirectional (input/output) connection. Both are open-drain connection and must be connected externally to VID via a pull-up resistor. The I2C interface supports multiple read and write. When using multiple read/write, 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.

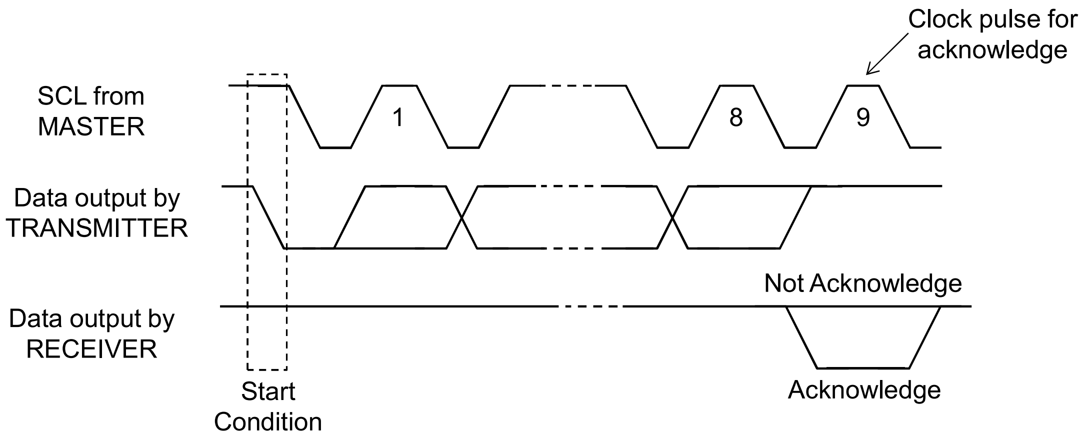
Data transfer begins by bus master indicating a start condition (ST) of a falling edge on SDA when SCL is high. The master terminates transmission and frees the bus by issuing a STOP condition (SP). Stop condition is a rising edge on SDA while SCL is high. The bus remains active if a repeated START (SR) condition is generated instead of a STOP condition. Figure 9 illustrates the START and STOP condition.

Figure 9: I2C START and STOP condition



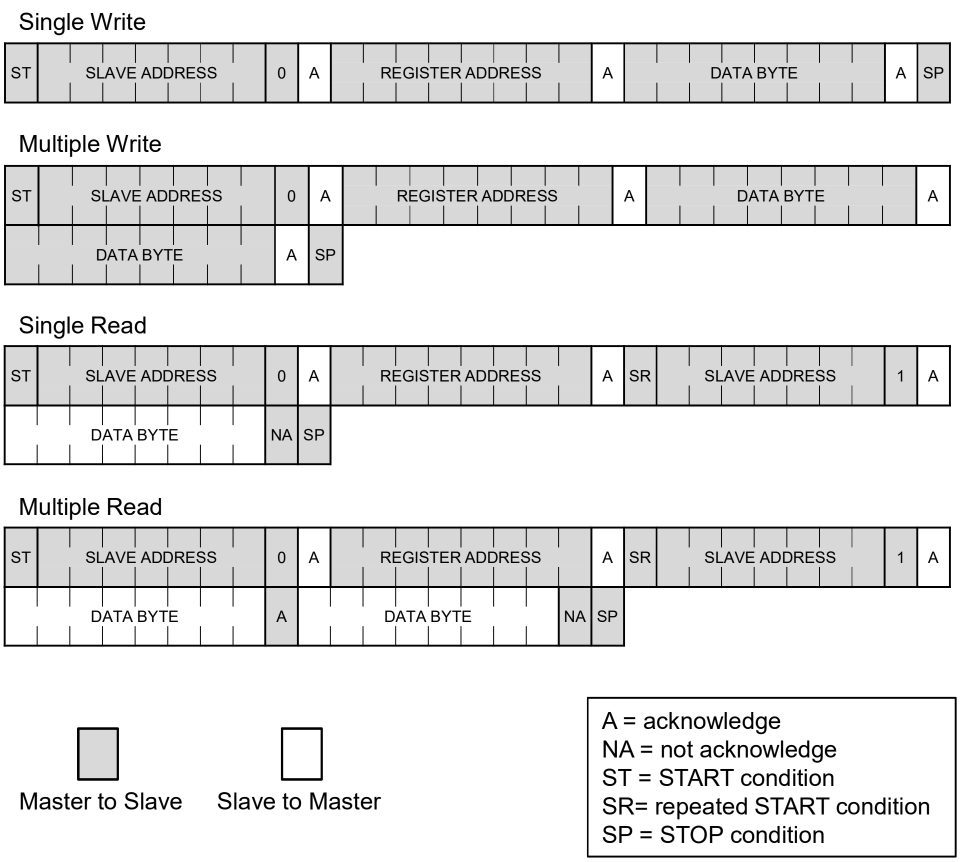

After a start condition (ST), the 7-bit slave address + RW bit must be sent by master. If the slave address does not match with GMP102N, there is no acknowledge and the following data transfer will not affect GMP102N. If the slave address corresponds to GMP102N, it will acknowledge by pulling SDA to 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 GMP102N acknowledge. Figure 10 illustrates the acknowledge signal sequence.

Figure 10: Acknowledge signal sequence




A write to GMP102N 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 11 illustrates the frame format of single and multiple write to GMP102N respectively.

Figure 11: I2C access format: standard and fast mode




A read from GMP102N 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. GMP102N acknowledge receipt of the read operation command by pulling SDA low during the 9th 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 11 illustrates the frame format for reading single or multiple byte from GMP102N.

## I2C Specifications

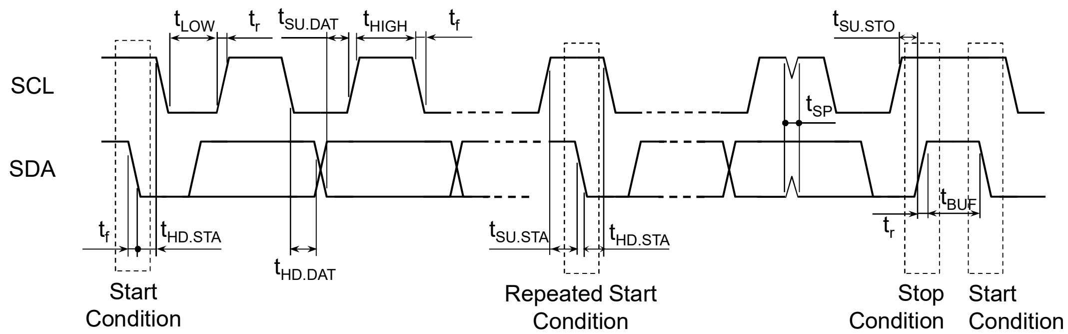
Table 5: I2C Timing Specification: Standard Mode

| 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 12: I2C Timing Diagram: Standard and Fast Mode



# Digital Interface: SPI

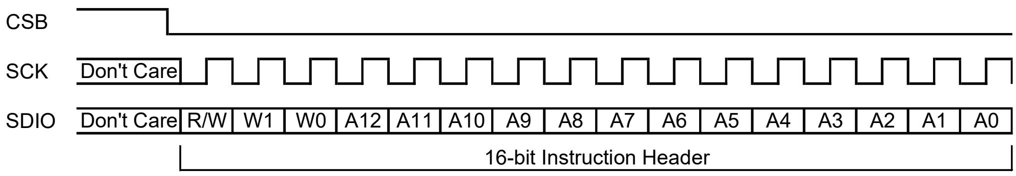
## SPI Interface General Description

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 13. The instruction phase is divided into several bit fields.

Figure 13: 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.

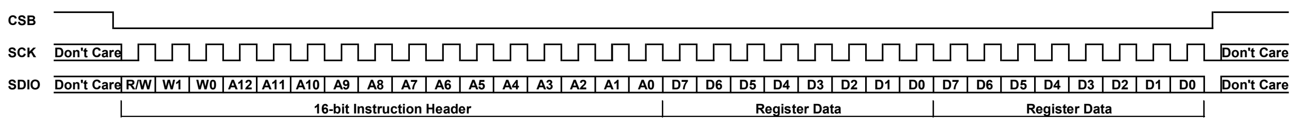
Table 7: W1/W0 settings

| 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 14 illustrates the timing for transferring two bytes.

Figure 14: SPI access timing

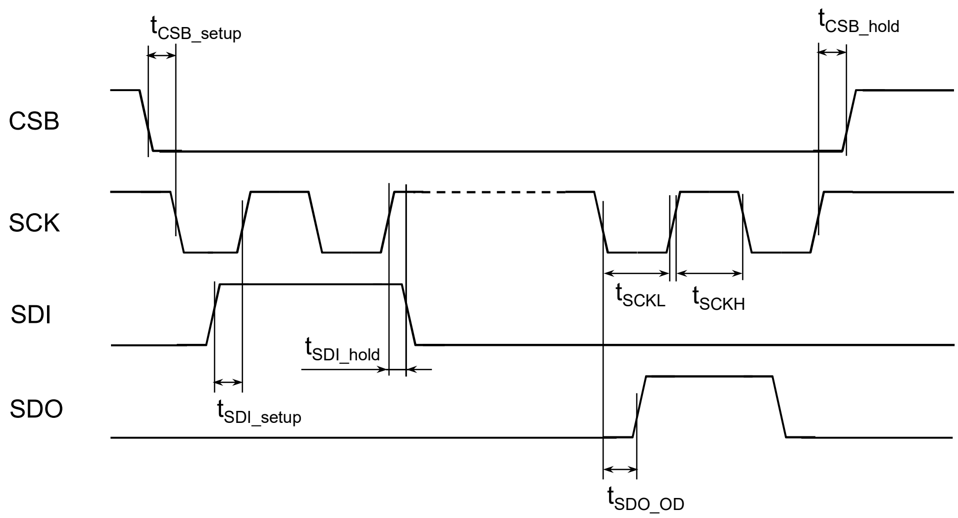


SPI Specification

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)<br>40 (250pF) | ns |
| CSB setup time | $t_{CSB\_setup}$ | 20 | — | ns |
| CSB hold time | $t_{CSB\_hold}$ | 40 | — | ns |

Figure 15: SPI Timing Diagram



# Package

## Outline Dimension

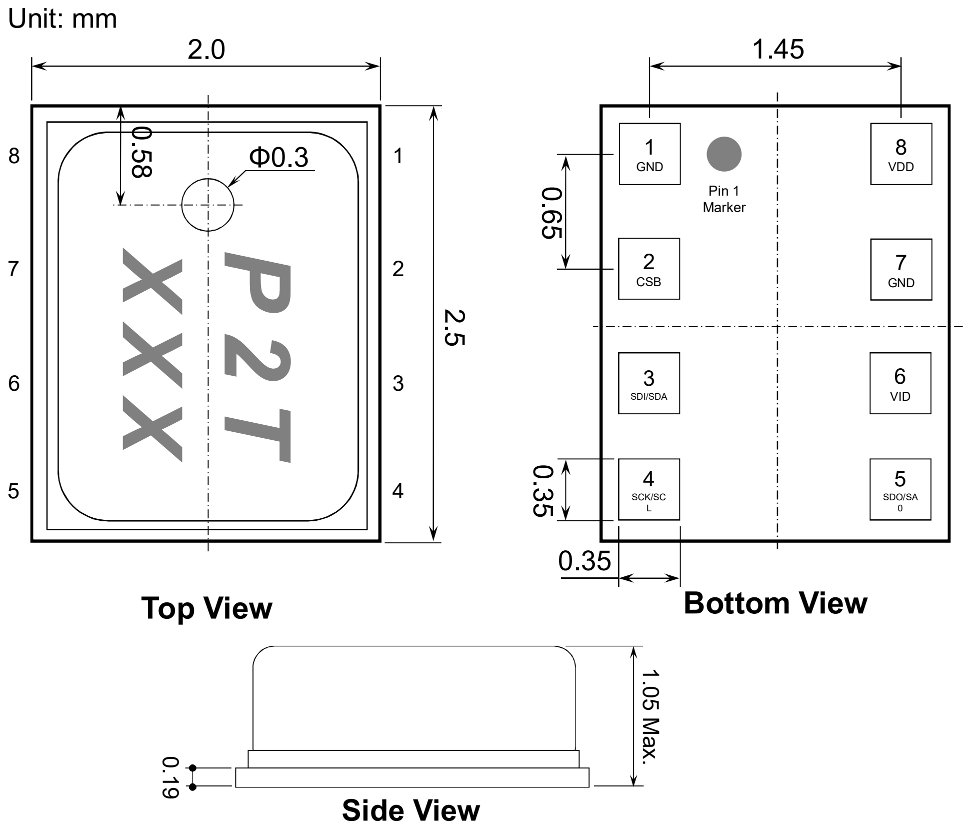



Figure 16: Package Outline Dimension

## Recommended PCB Foot Print Layout

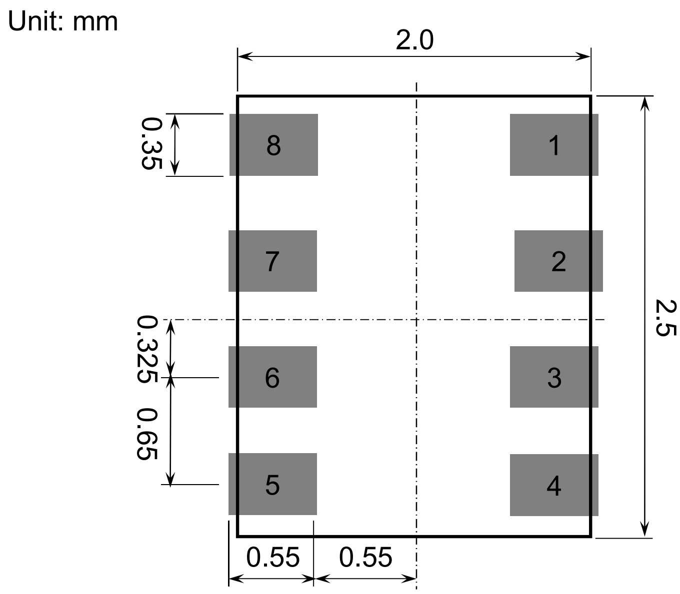



Figure 17: Layout Recommendation for PCB Land Pad

## RoHS Compliance

GMP102N package is 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

GMP102N package MSL rating is Level 3.

Document History and Modification

| Revision No. | Description | Date |
|---|---|---|
| V0.1 | Preliminary first release | 2019/3/22 |
| V0.2 | Update vent hole position | 2019/4/17 |
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