GMP105 Digital Barometric Pressure Sensor

General Introduction

GMP105 is a digital barometric pressure sensor especially designed for applications requiring waterproof, highly-precision pressure measurement like altimeter / barometer system in portable devices, such as bike navigation system, wearable devices, for outdoor activities. It is both a pressure and temperature sensor housed in a compact 3.3×3.3×2.1mm^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 0.01°C. The pressure sensor has a wide operating range from 300 to 1100hPa that covers all surface elevations on earth.

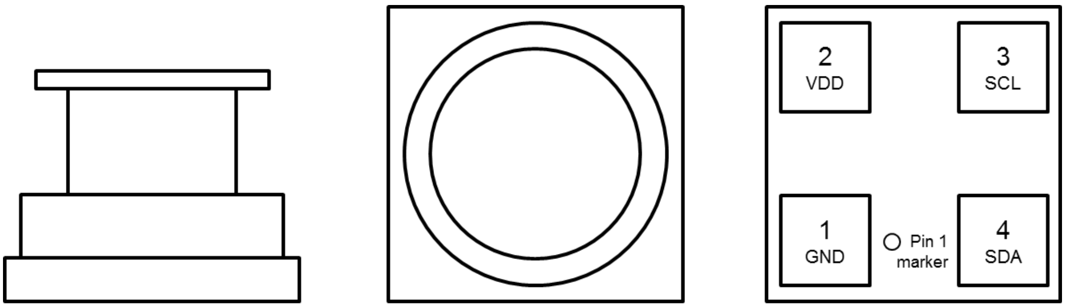
GMP105 can detect absolute barometric pressure with highly accuracy. The maximum altitude resolution can be up to less than 30cm. Several operation options further offer large window for user optimization on the power consumption, resolution and filter performance.

Features

- Operation range:
  - Pressure: 300~1100hPa (Absolute)
- Temperature: -40~+85°C
- Built-in 24-bit ADC:
  - Pressure resolution: up to 0.18 Pa
  - Temperature resolution: up to 0.01°C
- Digital interface:
  - I2C: standard and fast modes
- Calibrated P and T data output, no need for user calibration
- Supply voltage:
  - VDD 1.8V~5.5V
- Power Consumption:
  - Standby ~ 1uA
- RoHS-compliance package:
  - LGA-4L with metal tube
  - Footprint 3.3×3.3mm^2, height 2.1mm

Applications

Altimetry and barometry, GPS applications, and activity tracking for outdoor activities.



Side View **Top View** **Bottom View**

Specifications

Table 1: Pin Descriptions

Pin#	Name	Description
1	GND	Ground pin
2	VDD	Core circuit power supply in
3	SCL	SCL clock pin
4	SDA	SDA data I/O pin

Table 2: Specification

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Operation voltage	VDD		1.8	—	5.5	V
Temperature range	Ta		-40	25	+85	°C
Pressure range	P		300	—	1100	hPa
Operation current OSR=256 OSR=1024 OSR=4096 OSR=8192 (default) OSR=16384 OSR=32768	IDD	VDD = 3.3V 20Hz P+T conversion	—	 TBD TBD TBD TBD TBD TBD	—	uA
Standby current	IDDSD	Mode[1:0]=2'b00	—	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
Offset temperature coefficient	TCO		—	TBD	—	Pa/K
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	-0.5	6.5	V
Signal input voltage	VIS	-0.3	VDD + 0.3	V
Pressure	PMAX	0	20000	hPa
Storage temperature	TST	-40	+125	°C
ESD	HBM	—	±2	kV

Block Diagram and Connection

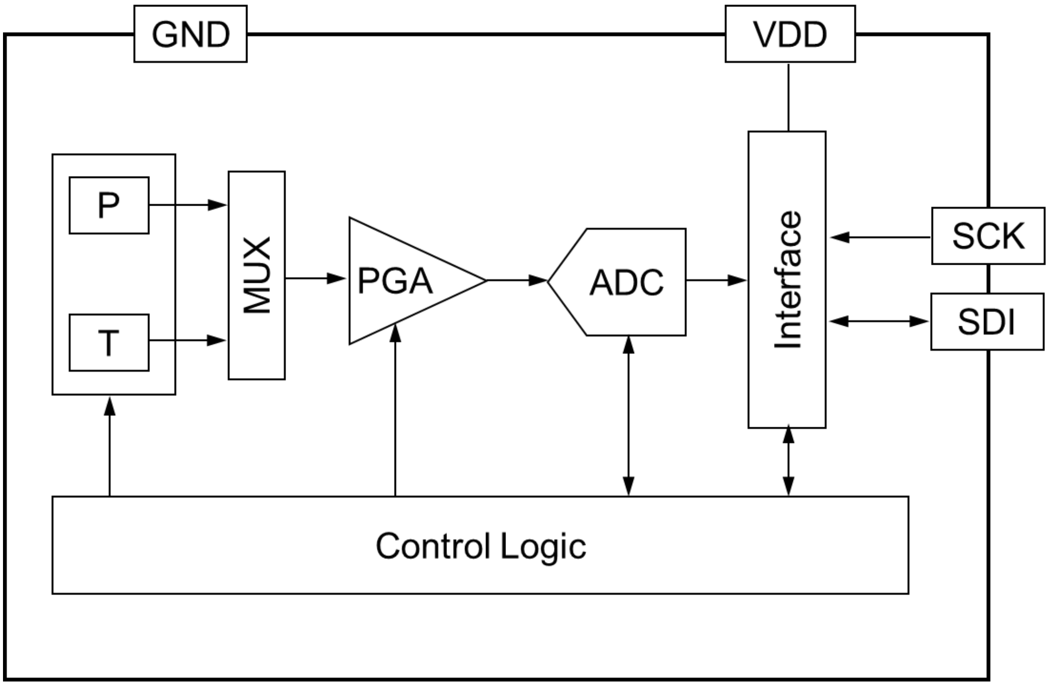


Figure 1: GMP105 Block Diagram

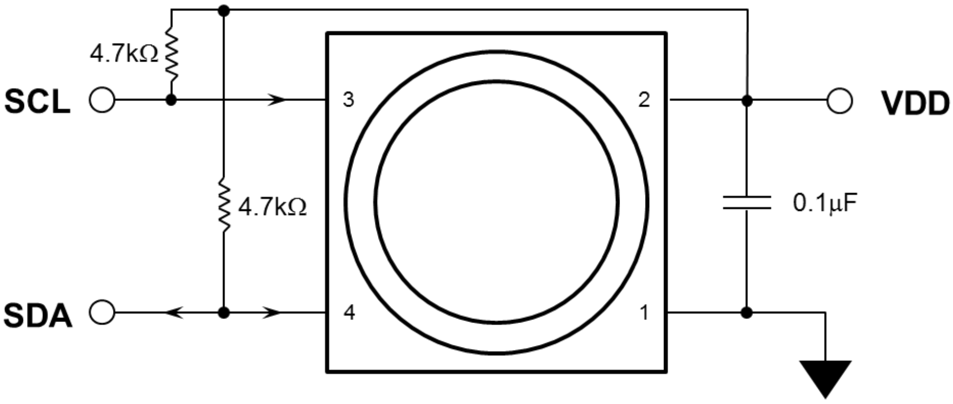


Figure 2: GMP105 I2C Connection Example

Functional Description

Power Management

GMP105 has only one power supply pin: VDD that serves as the major power supply pin for all internal analog and digital functional blocks, and it 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 GMP105 will transit to continuous mode.

Reset Functions

GMP105 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 (11h) to 0xB6 will trigger the device soft reset by resetting all register to default values.

Initialization

GMP105 will automatically initialize to continuous mode upon power-up after POR. The temperature and pressure data are immediately available without any further configuration. For mode other than continuous mode, see "Power Modes" section for details. For further resolution configuration, see "Noise and Resolution" section for description.

Power Modes

GMP105 offers three power modes, standby, force and continuous mode, by setting the 09h[1:0] (Mode[1:0]) bits, see 09h register description for more detail.

The transitions between different modes are illustrated in Figure 3.

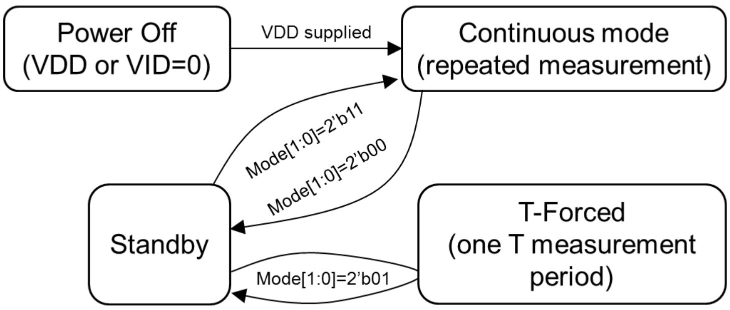


Figure 3: Mode transactions diagram

- Standby mode

GMP105 will enter standby mode by setting 09h[1:0] (Mode[1:0]) bits to 2'b00. In this mode, data measurement stops and the power consumption is at the minimum. Nevertheless all registers are still accessible for configuration.

- Force mode

GMP105 will enter force mode by setting 09h[1:0] (Mode[1:0]) bits to 2'b01. In force mode, GMP105 will take one-time temperature and pressure measurement and returns to standby mode automatically. The measurement results can then be obtained from the temperature and pressure data registers (02h~07h). Users need to set to force mode again for another measurement. The timing diagram of the force mode is illustrated in the following Figure 4.

Below summarized the force mode operation for single shot measurement:

1. Set to the Force mode by setting 09h[1:0] (Mode[1:0]) bits to 2'b01.
2. Check 08h[2] (DRDY) bit and wait until its value is set. The measurement results are available in the data registers (02h~07h) when DRDY = 1'b1.
3. Read the measurement results from data registers (02h~07h).
4. Divide the pressure data by 16 to get pressure in Pa.
5. Divide the temperature data by 100 to get temperature in Celsius degree.

In force mode, temperature or pressure measurement can be skipped by setting OSRCIC_T[2:0] or OSRCIC_P[2:0] bits to 3'b000 respectively. By setting OSRCIC_P[2:0]=3'b000 to disable pressure measurement, GMP105 can be used in pure temperature measurement. Likewise by setting OSRCIC_T[2:0]=3'b000 to disable temperature measurement, GMP105 can be used in pure pressure measurement.

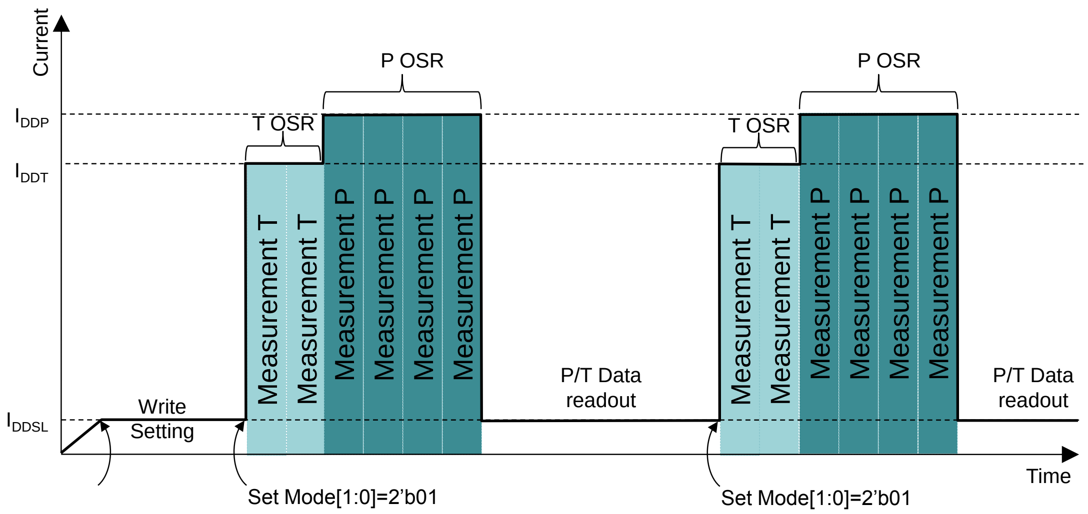


Figure 4: Force mode timing diagram

- Continuous mode

GMP105 will enter force mode by setting 09h[1:0] (Mode[1:0]) bits to 2'b11. In continuous mode, GMP105 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 0Ah register. The device will not get back to standby mode until manually set 09h[1:0] (Mode[1:0]) bits to 2'b00. The measurement results can be obtained from the data registers (02h~07h). The timing diagram of the continuous mode is illustrated in the following Figure 5.

Below summarized the continuous mode setup steps:

1. Set the sleep time interval by setting Standby_Time[3:0] bits of 0Ah register.
2. Set to the continuous mode by setting 09h[1:0] (Mode[1:0]) bits to 2'b11.

After reading data registers (02h~07h), users divide the temperature data by 100 to get temperature in Celsius degree. Likewise pressure in Pa can be calculated by dividing the pressure data by 16.

In continuous mode, temperature or pressure measurement can be skipped by setting OSRCIC_T[2:0] or OSRCIC_P[2:0] bits to 3'b000 respectively. By setting OSRCIC_P[2:0]=3'b000 to disable pressure measurement, GMP105 can be used in pure temperature measurement. Likewise by setting OSRCIC_T[2:0]=3'b000 to disable temperature measurement, GMP105 can be used in pure pressure measurement.

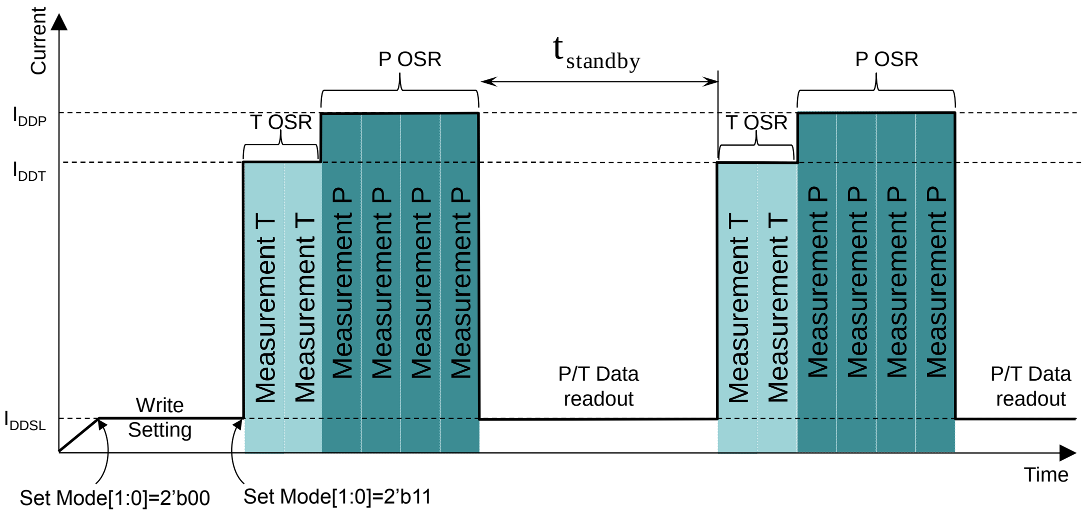


Figure 5: Continuous mode timing diagram

Noise and Resolution

GMP105 provide OSR (Over-Sampling Ratio) configuration to meet various situation of resolution and response time requirement. For high resolution application, users can increase the OSR for better resolution accompanied with typically longer conversion time. So the maximum data rate is lowered. On the other hand for faster response application, users can decrease the OSR for faster conversion time with typically lower resolution. So the ENOB (Effective Number of Bit) is lowered.

The OSR can be configured by the OSRCIC_X and OSRFIR_X (X be T or P) register bits for temperature and pressure measurement respectively. The overall OSR is calculated by multiplication of the factors defined by OSRCIC_X and OSRFIR_X (X be T or P). For example in the case of OSRCIC_X=3'b001 and OSRFIR_X=3'b001, the OSR = 64 (from CIC) × 2 (from FIR) = 128. See respective register bits description for factor definitions. Table 4 below summarized the OSR and resolution configuration.

Table 4: OSR, conversion time and resolution

OSR	Conversion Time (ms)	Typical Resolution (ENOB)
128	0.4	14
512	TBD	15
1024	TBD	16
2048	3.1	17
4096	5.5	18
8192	TBD	19
16384	TBD	19.4
32768	TBD	19.7
65536	78	20

User Register Map

Table 5: 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>02h</td><td>TEMPH</td><td colspan="8">Temperature[23:16]</td><td>R</td><td>NA</td></tr>
<tr><td>03h</td><td>TEMPM</td><td colspan="8">Temperature[15:8]</td><td>R</td><td>NA</td></tr>
<tr><td>04h</td><td>TEMPL</td><td colspan="8">Temperature[7:0]</td><td>R</td><td>NA</td></tr>
<tr><td>05h</td><td>PRESSH</td><td colspan="8">Pressure [23:16]</td><td>R</td><td>NA</td></tr>
<tr><td>06h</td><td>PRESSM</td><td colspan="8">Pressure [15:8]</td><td>R</td><td>NA</td></tr>
<tr><td>07h</td><td>PRESSL</td><td colspan="8">Pressure [7:0]</td><td>R</td><td>NA</td></tr>
<tr><td>08h</td><td>STATUS</td><td colspan="5">Reserved</td><td>DRDY</td><td colspan="2">Reserved</td><td>R</td><td>NA</td></tr>
<tr><td>09h</td><td>CTRL1</td><td colspan="3">OSRCIC_T[2:0]</td><td colspan="3">OSRCIC_P[2:0]</td><td colspan="2">Mode[1:0]</td><td>RW</td><td>0x93</td></tr>
<tr><td>0Ah</td><td>CTRL2</td><td colspan="4">Reserved</td><td colspan="4">Standby_Time[3:0]</td><td>RW</td><td>0x10</td></tr>
<tr><td>0Bh</td><td>CTRL3</td><td colspan="2">Reserved</td><td colspan="3">OSRFIR_T[2:0]</td><td colspan="3">Reserved</td><td>RW</td><td>0x08</td></tr>
<tr><td>0Dh</td><td>CTRL4</td><td colspan="2">Reserved</td><td colspan="3">OSRFIR_P[2:0]</td><td colspan="3">IIR_P[2:0]</td><td>RW</td><td>0x20</td></tr>
<tr><td>0Fh</td><td>CTRL5</td><td colspan="8">Reserved</td><td>RW</td><td>0x02</td></tr>
<tr><td>11h</td><td>RESET</td><td colspan="8">Reset[7:0]</td><td>W</td><td>NA</td></tr>
</table>

Note: Registers not described above are reserved. It is advised not to access the reserved registers to avoid any unexpected consequences.

Description of Registers

Register 02h~04h: Temperature Data Registers

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
02h	TEMPH	Temperature[23:16]								R	NA
03h	TEMPM	Temperature[15:8]								R	NA
04h	TEMPL	Temperature[7:0]								R	NA

The temperature 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 temperature data output is calibrated and has sensitivity of 100 LSB/℃. The central value (0x00) stands for 0℃. Thus the Celsius temperature can be converted from the temperature reading by the following formula:

$$T\,(^\circ\mathrm{C}) = \frac{\mathrm{Temperatur\ e}[23:0]}{100}$$

Register 05h~07h: Pressure Data Registers

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
05h	PRESSH	Pressure [23:16]								R	NA
06h	PRESSM	Pressure [15:8]								R	NA
07h	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 calibrated and has sensitivity of 16 LSB/Pa. The central value (0x00) stands for 0 Pa. Thus the pressure in Pa, P(Pa), can be converted from the pressure reading by the following formula:

$$P\,(\mathrm{Pa}) = \frac{\mathrm{Pressure}[23:0]}{16}$$

Register 08h: STATUS Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
08h	STATUS	Reserved					DRDY	Reserved		R	NA

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

1'b0 once data registers are read.

Register 09h: CTRL1 Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
09h	CTRL1	OSRCIC_T[2:0]			OSRCIC_P[2:0]			Mode[1:0]		RW	0x93

Mode[1:0] control the sensor power mode. Available setting is summarized in the following table. See the "Functional Description" section for details of the operation modes.

Mode[1:0]	Power Mode
2'b00	Standby mode
2'b01	Force mode (one measurement)
2'b10	Reserved
2'b11	Continuous mode

OSRCIC_P[2:0] selects the OSR factor for the pressure data conversion as summarized in the following table. See Noise and Resolution section in Functional Description for usage description.

OSRCIC_P[2:0]	OSR Factor, CIC
3'b000	Skip pressure measurement
3'b001	64x
3'b010	128x
3'b011	256x
3'b100	512x
Others	Reserved

OSRCIC_T[2:0] selects the OSR factor for the temperature data conversion as summarized in the following table. See Noise and Resolution section in Functional Description for usage description.

OSRCIC_T[2:0]	OSR Factor, CIC
3'b000	Skip temperature measurement
3'b001	64x
3'b010	128x
3'b011	256x
3'b100	512x
Others	Reserved

Register 0Ah: CTRL2 Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
0Ah	CTRL2	Reserved				Standby_Time[3:0]				RW	0x10

Standby_Time[3:0] control the standby interval between periodic conversions in the continuous mode, see Figure 7 for illustration.

Standby_Time[3:0]	**Standby Time (ms)**
4'b0000	0.5
4'b0001	62.5
4'b0010	125
4'b0011	250
4'b0100	500
4'b0101	1000
4'b0110	2000
4'b0111	4000
4'b1000	0
4'b1001	0.2
4'b1010	1
4'b1011	2
4'b1100	4
4'b1101	8
4'b1110	16
4'b1111	32

Register 0Bh: CTRL3 Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
0Bh	CTRL3	Reserved		OSRFIR_T[2:0]			Reserved			RW	0x08

OSRFIR_T[2:0] controls the temperature OSR factor as summarized in the following table. See Noise and Resolution section in Functional Description for usage description.

OSRFIR_T[2:0]	**OSR Factor, FIR**
3'b000	1x
3'b001	2x
3'b010	4x
3'b011	8x
3'b100	16x

3'b101	32x
3'b110	64x
3'b111	128x

Register 0Dh: CTRL4 Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
0Dh	CTRL4	Reserved		OSRFIR_P[2:0]			IIR_P[2:0]			RW	0x20

IIR_P[2:0] controls the pressure IIR filter order as summarized in the following table:

IIR_P[2:0]	**Pressure IIR order**
3'b000	IIR off
3'b001	2
3'b010	4
3'b011	8
3'b100	16
Others	Reserved

OSRFIR_P[2:0] controls the pressure OSR factor as summarized in the following table. See Noise and Resolution section in Functional Description for usage description.

OSRFIR_P[2:0]	**OSR Factor, FIR**
3'b000	1x
3'b001	2x
3'b010	4x
3'b011	8x
3'b100	16x
3'b101	32x
3'b110	64x
3'b111	128x

Register 11h: RESET Register

Addr.	Name	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Access	Default
11h	RESET	Reset[7:0]								W	NA

Set RESET register (11h) to 0xB6 to trigger the device soft reset. All register values will be reset to default. The Reset[7:0] bits will automatically return to 0x00 when the soft reset complete.

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 GMP105 and master with clock rate up to 400kHz.

The 7-bit device slave address is defined as 0x76.

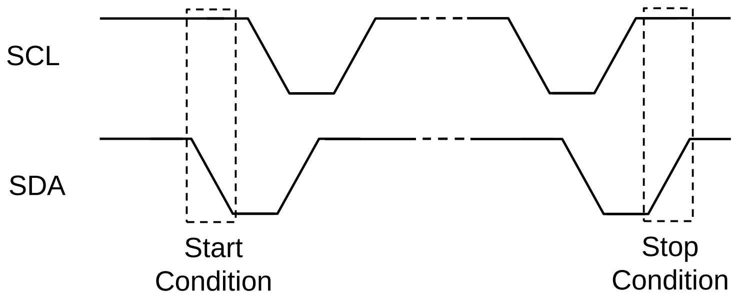
The I2C bus takes master clock through SCL pin and exchanges serial data via SDA. SDA is a bidirectional (input/output) connection. Both are open-drain connection and must be connected externally to VDD via a pull-up resistor. The I2C interface supports multiple auto-read only. When doing multiple read, the internal I2C address pointer will automatically increase by 1 for the next access. While doing multiple write, the address pointer will not automatically increase and must be specified one by one.

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.

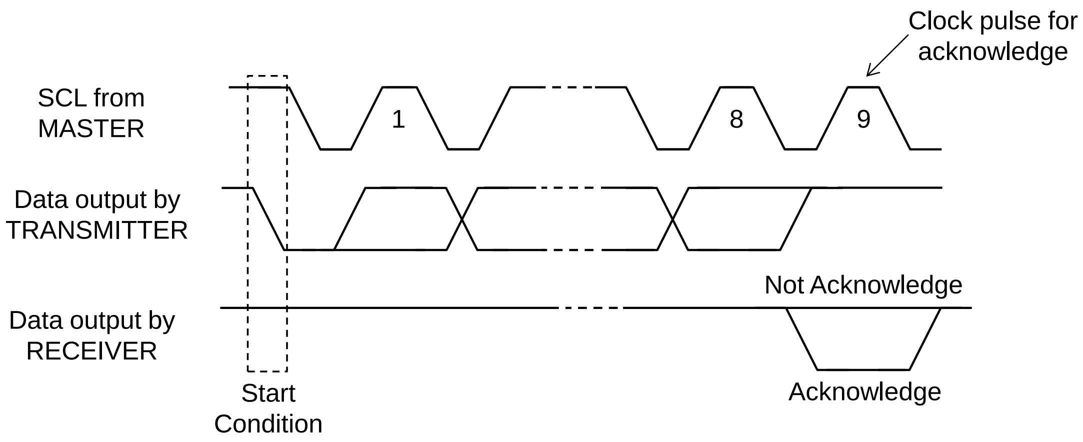
Data transfer begins by bus master indicating a start condition (ST) of a falling edge on SDA when SCL is high. The master terminates transmission and frees the bus by issuing a STOP condition (SP). Stop condition is a rising edge on SDA while SCL is high. The bus remains active if a repeated START (SR)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

Figure 6: I2C START and STOP condition



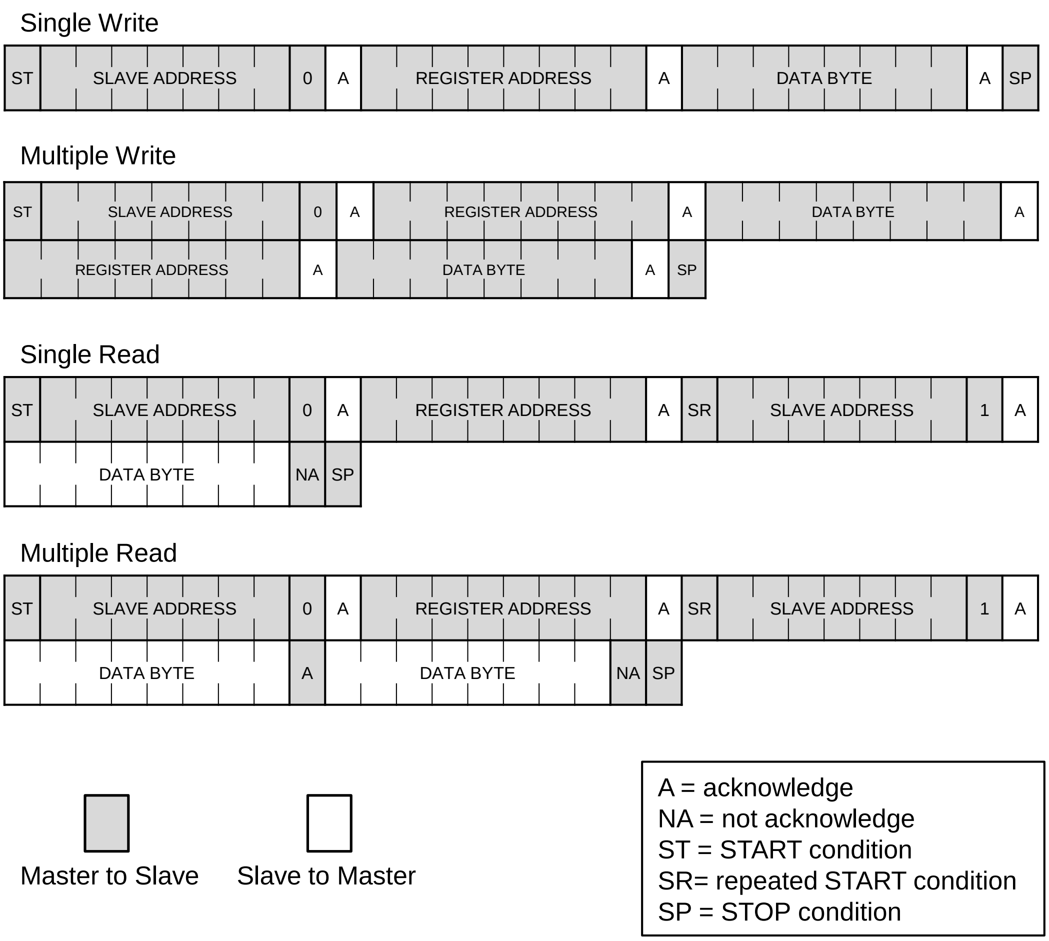
After a start condition (ST), the 7-bit slave address + RW bit must be sent by master. If the slave address does not match with GMP105, there is no acknowledge and the following data transfer will not affect GMP105. If the slave address corresponds to GMP105, it will acknowledge by pulling SDA to low 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 GMP105 acknowledge. Figure 7 illustrates the acknowledge signal sequence.

Figure 7: Acknowledge signal sequence



A write to GMP105 includes transmission of a START condition, the slave address with R/W bit=1'b0, subsequent one or more byte pairs of register address and register data to write, and finally a STOP condition. "Single Write" and "Multiple Write" in Figure 8 illustrates the frame format of single and multiple write to GMP105 respectively.

Figure 8: I2C access format: standard and fast mode



A read from GMP105 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. GMP105 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 8 illustrates the frame format for reading single or multiple byte from GMP105.

I2C Specifications

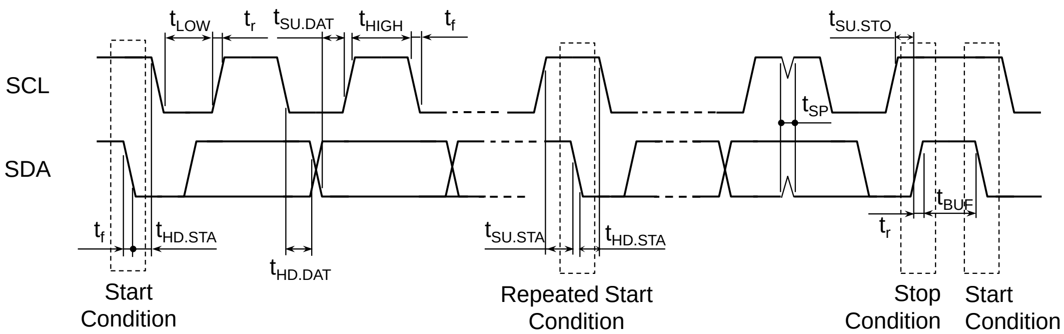
Table 6: I2C Timing Specification: Standard Mode

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 7: 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 9: I2C Timing Diagram: Standard and Fast Mode



Package

Outline Dimension

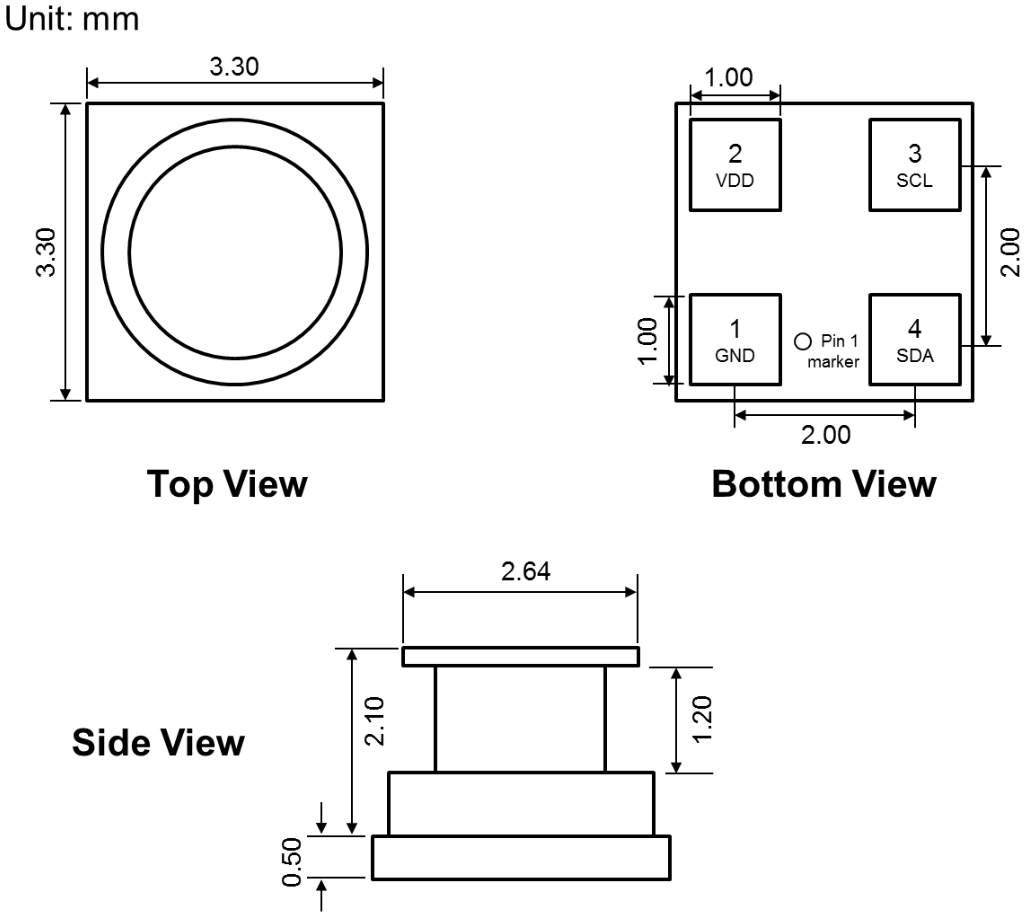


Figure 10: Package Outline Dimension

Recommended PCB Foot Print Layout

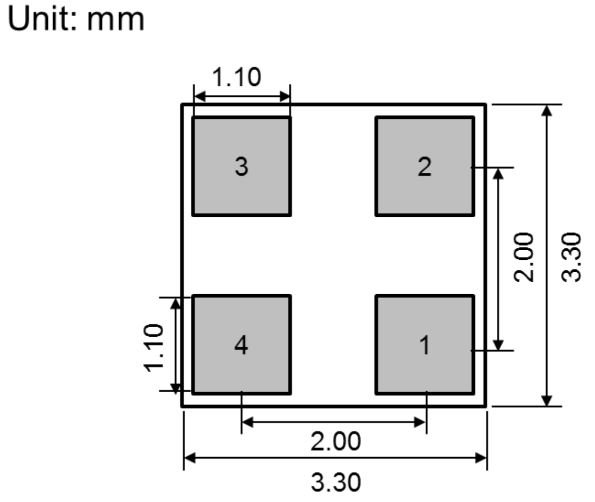


Figure 11: Layout Recommendation for PCB Land Pad

RoHS Compliance

GMEMS LGA with metal tube 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

GMP105 package MSL rating is Level 3.

Document History and Modification

Revision No.	Description	Date
V0.1	Preliminary first release	2018/5/8