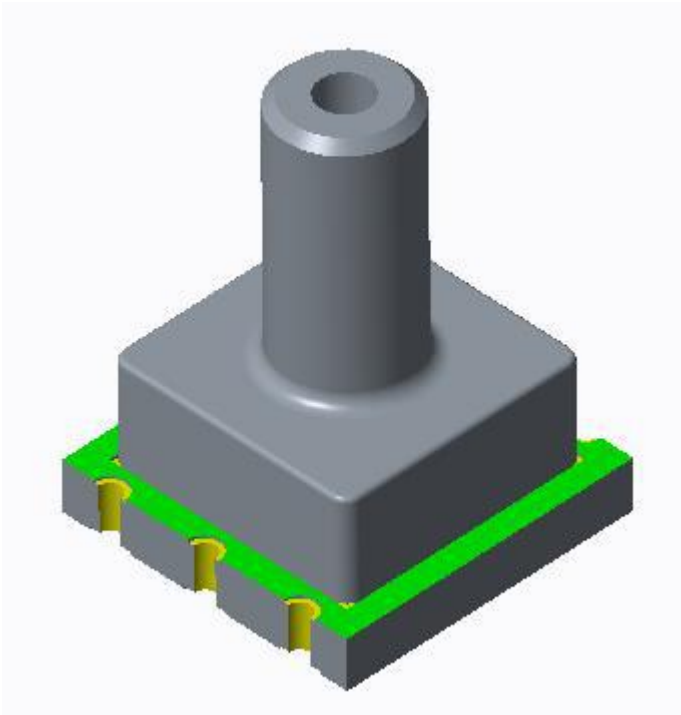
SP01-017

Quick connection pressure sensor

Pb-free, halogen-free and RoHS compliant



Restricted

1. Security warning

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2. Publication history

Version	Date	Description	Author	Approved
1.0	2020.02.28	New design	Faye	Devin

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1. Introduction

The SP01-017 is a quick connection pressure sensor with a high accuracy and a low current consumption. The SP01-017 is both a pressure and a temperature sensor. The pressure sensor element is based on a capacitive sensing principle which guarantees a high precision during temperature changes.

The pressure and temperature sensor elements are measured by a 24-bit ΣΔ ADC. Measurement results can be accessed over I2C, with an optional configurable interrupt and a result FIFO capable of holding 32 pressure and/or temperature measurements.

Each SP01-017 contains dedicated fuse locations to allow for individual calibration of each unit and storing of calibration coefficients. These coefficients are used in the application to convert the measurement results to high accuracy pressure and temperature values.

Key features The SP01-017 contains a FIFO which can store up to 32 measurements. By using the FIFO, the host processor can remain in a sleep mode for a longer period of time between readouts, reducing the overall system power consumption. Sensor measurements and calibration coefficients are available through the serial I2C interface.

- Pressure range: 300 ... 2500hPa
- Temperature Range: -40…+85°C
- Supply voltage: 1.7 ... 3.6V (VDD), 1.2 ... 3.6V (VDDIO)
- Relative accuracy: typ. ±0.06hPa
- Absolute accuracy: typ. ±1hPa
- Temperature accuracy: typ. ± 1.0°C
- Pressure temperature sensitivity: typ. 1.0Pa/K @ 1000hPa
- Measurement time: Typical: 27.6 ms for standard mode (16x). Minimum: 3.6 ms for low precision mode
- Average current consumption: 1.7 µA for pressure measurement, 2 µA for temperature measurement @1Hz sampling rate, Standby: <1 µA.
- I2C interface, Embedded 24-bit ADC
- FIFO: Stores latest 32 pressure or temperature measurements
- Pb-free, halogen-free and RoHS compliant

Typical applications

- Wearable devices
- Altimeter and barometer for portable devices
- Enhancement of GPS navigation (dead-reckoning, slope detection, etc.)
- In- and out-door navigation
- Weather station equipment
- Vertical velocity indication (rise/sink speed)

Specific notes

Particles can influence the performance of the pressure sensor, we strongly recommend you to introduce special measures to avoid deposition of particles on the coating gel or screen particles after assembly as the assembly process is considered to be the main root cause for particle generation.

2. Test condition

Table 1: Test condition

Standard Conditions	Temperature	Humidity	Air pressure
Environment conditions	-40°C…+85°C	25%RH…75%RH	300hPa…2500hPa
Basic test conditions	+25°C	60%RH…70%RH	300hPa…2500hPa

3. Absolute maximum ratings

Table 2: Absolute maximum ratings

Parameter	Condition	Min	Max	Units
Storage temperature		-40	+125	°C
Supply Voltage	All pins		+4	V
Voltage at all IO Pins	All pins		+4	V
ESD rating	JESD22-A114	-2	+2	kV
Overpressure			10000	hPa

4. Electrical characteristics

VDD = 1.8V, VDDIO=1.8V, T=25°C, unless otherwise noted.

Table 3: Operating conditions, output signal characteristics

Parameter	Symbol	Condition		Min	Typ.(1)	Max	Units
Operating temperature	T_a	Operational		-40	25	85	°C
		Full accuracy			25	65	°C
Operating Pressure	P_a			300		2500	hPa
Supply voltage	VDD			1.7		3.6	V
Interface supply voltage	VDDIO			1.2		3.6	V
Supply current (with 1 measurement per second.)	I_{dd}	1 Hz	Low power mode		5		µA
			Standard mode		15		
			High precision mode		40		
Note: The current consumption depends on both pressure measurement precision and rate. Please refer to the Pressure Configuration (PRS_CFG) register description for an overview of the current consumption in different combinations of measurement precision and rate.							
Peak current	I_{peak}	During pressure measurement			345		µA
		During temperature measurement			280		µA
Standby current	I_{std}				1		µA
Relative accuracy pressure	P_{rel}	800…1050hPa +25…+40°C			±0.06		hPa
Absolute accuracy pressure	P_{abs}	300...2500hPa +10…+65°C			±1.0		hPa
Noise in pressure	P_{noise}	Low power mode			4.0		Pa RMS
		Standard mode			2.0		
		High precision mode			1.0		
Note: Pressure noise is measured as the average standard deviation. Please refer to the Pressure Configuration (PRS_CFG) register description for all precision mode options.							
Offset temperature coefficient	TCO	1000hPa +25…+40°C			±1.0		Pa/K
Absolute accuracy temperature	T_{abs}	0…+65°C			±1.0		°C
Pressure measurement rate	f_P			1		128	Hz
Temperature measurement rate	f_T			1		64	Hz

Pressure measurement time	t	Low power mode		8.8		ms
		Standard mode		32.8		
		High precision mode		119.2		
Note: The pressure measurement time (and thus the maximum rate) depends on the pressure measurement precision. Please refer to the Pressure Configuration (PRS_CFG) register description for an overview of the possible combinations of measurement precision and rate.						
Solder drift(2)		Drift measured 96 hours after reflow.		±1.0		hPa
Long term stability		12 months		±1.0		hPa
Supply voltage ramp-up time	t_{vddup}	Time for supply voltage to reach 90% of final value	0.001		5	ms
Serial data clock	f_{I2C}	For I2C			3.4	MHz
Power supply rejection	P_{psr}	50mVpp sine wave, sweep from 100Hz to 5MHz			TBD	PaRMS
Time to sensor ready	T_{Sensor_rdy}	The SENSOR_RDY bit in the Measurement Configuration register will be set when the sensor is ready		8		ms

Note: (1) Typical specifications are not guaranteed; (2) Device might drift out of spec after soldering reflow or when it is exposed to extreme temperature conditions but it is expected to return back into limits spec after 96h and completely recover after 168h.

5. Operation

5.1 Operating Modes

The barometer unit supports 3 different modes of operation: Standby, Command, and Background mode.

- **Standby Mode**
  - Default mode after power on or reset. No measurements are performed.
  - All registers and compensation coefficients are accessible.
- **Command Mode**
  - One pressure and/or temperature measurement is performed according to the selected precision.
  - The sensor will return to Standby Mode when the measurement is finished, and the measurement result will be available in the dedicated result registers or FIFO output registers.
  - The FIFO can be used when the sensor is in Command Mode. Several measurements can be requested before reading data back from the FIFO.

- **Background Mode**
  - Pressure and/or temperature measurements are performed continuously according to the selected measurement precision and rate. The temperature measurement is performed immediately after the pressure measurement.
  - After each measurement is completed, the result will be available in the dedicated result registers if the FIFO is disabled. If the FIFO is enabled it will be added to the FIFO.
  - The FIFO can be used to store 32 measurement results and minimize the number of times the sensor must be accessed to read out the results. Using background mode and FIFO streaming mode, the barometer unit measures continuously and the most recent 32 measurements can be read at any time.
  - The FIFO behavior can be configured to either stop-on-full mode, which stops recording data once the FIFO is full, or to streaming mode, which will continue recording data once the FIFO is full, deleting the oldest data each time a new measurement is recorded.

Note: *Operation mode and measurement type are set in the Sensor Operating Mode and Status (MEAS_CFG) register.*

5.2 Measurement Precision and Rate

Different applications require different measurement precision and measurement rates. The barometer unit measurement precision and rate (in background mode) can be configured to match the requirements of the application in which it is being used. This reduces current consumption of the sensor and the system.

In order to achieve a higher precision, the barometer unit will read the sensor multiple times (oversampling), and combine the readings into one result. This increases the current consumption and the measurement time, which again reduces the maximum measurement rate.

The measurement precision, rate and time is set in the *Pressure Configuration (PRS_CFG)* and *Temperature Configuration (TEMP_CFG)* registers. The register descriptions contain information about the current consumption and the possible combinations of measurement precision, time, and rate.

Please note that the pressure sensor is temperature dependent. Temperature measurements must be made together with the pressure measurements in order to compensate for the temperature dependency. This reduces the maximum pressure measurement rate, *since:* $\boldsymbol{Rate_{temperature} * Time_{temperature} + Rate_{pressure} * Time_{pressure} < 1\ second}$. *Measurement Settings and Use Case Examples* contains a table with examples of combinations of pressure and temperature precision and rates for different use cases.

5.3 Sensor Interface

The SP01-017 measurement data, calibration coefficients, Product ID and configuration registers can be accessed through both the I2C serial interfaces.

I2C interface

- The sensor's default interface.
- The sensor's address is *0x77*.

The basic timing is shown in the diagram below:

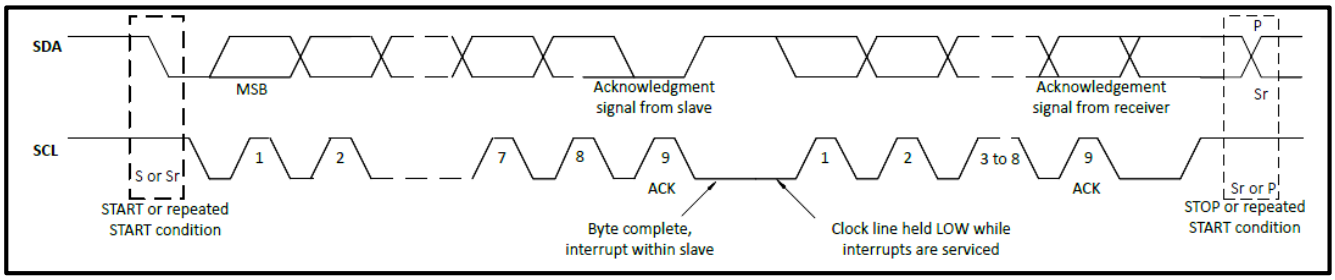


Figure 1: I2C timing diagram

In one access, without a stop command, incremental read (address is auto increment) and auto-incremental write are supported. The read and write access is shown below:

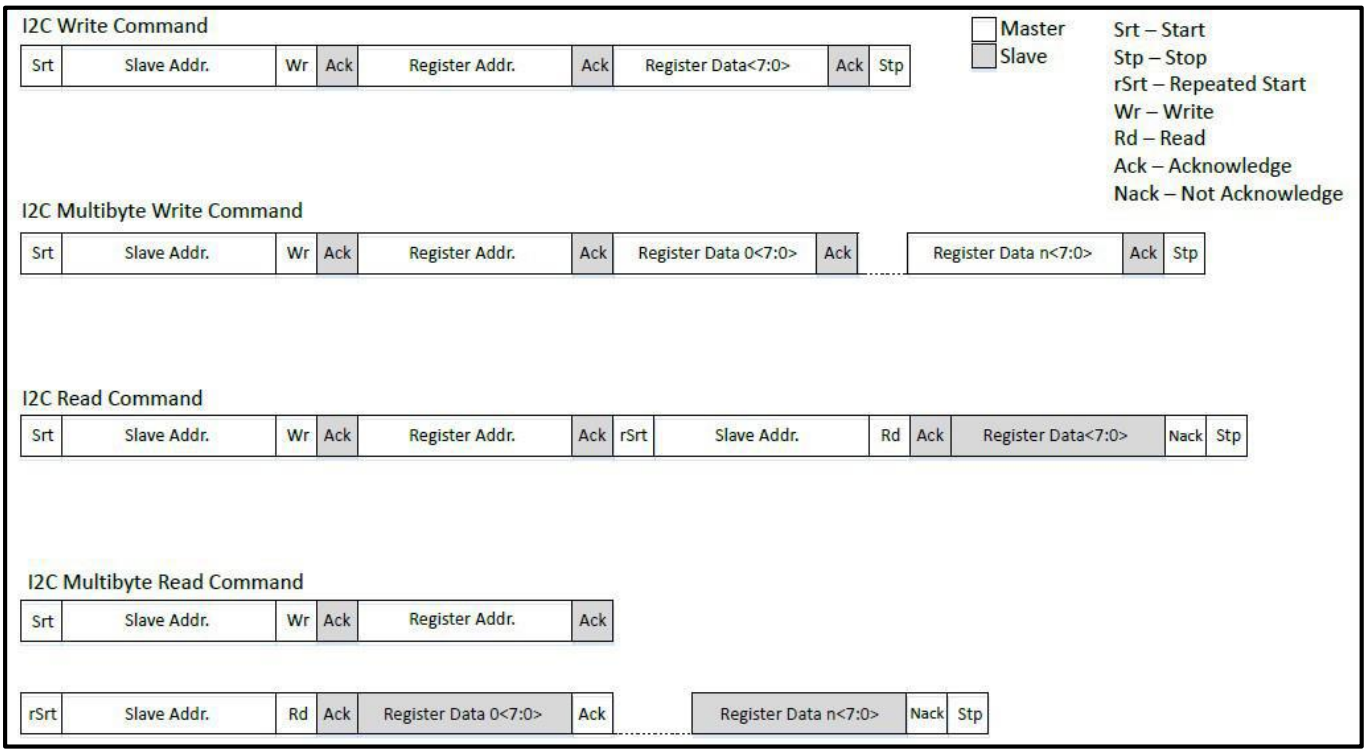


Figure 2: I2C write and read commands

5.4 FIFO Operation

The SP01-017 FIFO can store up to the last 32 measurements of pressure and/or temperature. This reduces the overall system power consumption as the host processor does not need to continuously poll data from the sensor but can go into standby mode for longer periods of time.

The FIFO can store any combination of pressure and temperature results, according to the background mode measurement rate settings.

The least significant bit of the FIFO measurement result register PSR_B0 is used to indicate whether the measurement is a pressure or temperature result. The least significant bit is set to:

- '1' if the result is a pressure measurement.

- '0' if it is a temperature measurement.

Note: The sensor uses 24 bits to store the measurement result, which is more than is necessary to cover the full dynamic range of the pressure sensor. Using the least significant bit to label the measurement type does not affect the precision of the result.

The FIFO can be enabled in the CFG_REG. The data from the FIFO is read out from PSR_B2, PSR_B1 and PSR_B0 regardless of whether the result in the FIFO is a temperature or a pressure measurement.

When a measurement has been read, the FIFO will automatically increment and place the next result in the data register. The FIFO empty bit is set in *FIFO Status (FIFO_STS)* register when the FIFO is empty, in this case all FIFO reads return 0x800000.

If the FIFO is full, the FIFO interrupt Full/WM bit in the FIFO_STS register is set. If the Interrupt select [3:0] bits in the CFG_REG register are set to 0x08, an interrupt will also be generated when the FIFO is full.

If the FIFO watermark interrupt is configured by setting the Interrupt select [3:0] bits in the CFG_REG register to 0x04, the FIFO will generate an interrupt when the number of pressure and temperature results stored in the FIFO equals the configured watermark level.

The FIFO can be configured to one of two behaviors when full:

- FIFO stops recording new measurement results when full.
- FIFO continues recording new measurement results when full, overwriting the oldest measurement.

This behavior can be configured by setting the FIFO Stop on full bit in the CFG_REG register. Setting this bit to 0 will enable streaming mode, setting to 1 will enable stop-on-full mode.

Attention: It is recommended not to poll the FIFO full flag bit in register INT STS faster once every 375 µs, as it is not updated immediately. Similarly the FIFO full status bit in register FIFO_STS should only be polled once every 250 µs.

5.5 Calibration and Measurement Compensation

The barometer unit is a calibrated sensor and contains calibration coefficients. These are used in the application (for instance by the host processor) to compensate the measurement results for sensor non-linearity's.

The sections that follow, describe how to calculate the compensated results and convert them into Pa and °C values.

5.5.1 How to calculate compensated pressure values

After starting the measurements, the latest pressure and temperature raw data will be available as 24-bit 2's complement numbers in their respective result registers if the FIFO is disabled: PSR_B2 to PSR_B0, and TMP_B2 to TMP_B0.

If the FIFO is enabled, all measurement results will be stored in registers PSR_B2 to PSR_B0. In this case, the register value will update to the next result stored in the FIFO after each read. The least significant bit of PSR_B0 will read "1" if the measurement is a pressure reading, or "0" if the measurement is a temperature reading. When all of the FIFO values have been read, the result register will be set to 0x800000.

When the FIFO is disabled, reading the result register will not affect the register value, it will only be

updated when a new measurement is completed.

All measurement data can be read in a single command using auto-increment read.

To calculate the pressure reading, it is necessary to first read and parse the calibration coefficient registers from addresses 0x26 to 0x39. These values only need to be read and parsed once for each device, they are fused in memory and will not change during operation. The method to generate the *Calibration Coefficients* values is described in the Calibration coefficients section of this document.

The pressure values stored in the result registers must be scaled according to the oversampling rate. The numbers in the registers must be divided by kP before they are used in the pressure reading calculation formula. The kP values for each oversampling option can be found in *Oversampling rate: kP*.

1. **Deriving the scaled pressure and temperature values**

   $\mathbf{Pres_{SCALED}} = Pres_{RAW} / kP$

   $Temp_X = Temp_{RAW} / 1048576$

   $\mathbf{Temp_{SCALED}} = (8.5 \times Temp_X) / (1 + 8.8 \times Temp_X)$

   Where:

   • $Pres_{RAW}$ is the 24 bit, 2's complement number read from the pressure output registers or FIFO

   • $Temp_{RAW}$ is the 24 bit, 2's complement number read from the temperature output registers or FIFO

2. **Pressure output calculation**

   $\mathbf{Pres_{CALIBRATED}} = C00 + [C10 \times Pres_{SCALED}] + [C01 \times Temp_{SCALED}] + [C20 \times Pres_{SCALED}^2] + [C02 \times Temp_{SCALED}^2] + [C30 \times Pres_{SCALED}^3] + [C11 \times Pres_{SCALED} \times Temp_{SCALED}] + [C12 \times Pres_{SCALED} \times Temp_{SCALED}^2] + [C21 \times Pres_{SCALED}^2 \times Temp_{SCALED}]$

   Where: C00, C10, C01, C20, C02, C30, C11, C12 and C21 are the calibration coefficients read from registers 0x26 to 0x39.

5.5.2 How to calculate compensated temperature values

In order to calculate temperature output values in °C, it is first necessary to calculate two coefficients, **A'** and **B'**.

These coefficients are calculated from values stored in the calibration coefficients registers, and do not change. These two coefficients can be calculated once on device start up and then stored in memory to be used in all future high accuracy temperature measurements.

The steps required to calculate A' and B' are below, calculation constants can be found in *Table 5*.

1. **Read T_Vbe, T_dVbe and T_gain:**

   These parameters are read directly from the calibration coefficient registers 0x20 to 0x22. These three values are in 2's complement.

2. **Calculate V_{BE}, ΔV_{BE} and A_{ADC}:**

   These values are calculated directly from the calibration coefficient values:

   - V_{BE} = **T_Vbe** × 1.05031E-4 + 0.463232422
   - ΔV_{BE} = **T_dVbe** × 1.25885E-5 + 0.04027621
   - A_{ADC} = **T_gain** × 8.4375E-5 + 0.675

3. **Calculate V_{BE_CAL} and ΔV_{BE_CAL}:**
   - $V_{BE\_CAL} = V_{BE} / A_{ADC}$
   - $\Delta V_{BE\_CAL} = \Delta V_{BE} / A_{ADC}$
4. **Calculate calibration Temperature T_{CALIB}:**
   - $T_{CALIB} = A_0 \times \Delta V_{BE\_CAL} - 273.15$
5. **Calculate $V_{BE\_CAL}(T_{REF})$, the V_{BE} value at reference temperature T_{REF}:**
   - $V_{BE\_CAL}(T_{REF}) = V_{BE\_CAL} - (T_{CALIB} - T_{REF}) \times (T_{C\_VBE})$
6. **Calculate k_{PTAT} correction coefficient:**
   - $k_{PTAT} = [V_{BE\_TARGET}(T_{REF}) - V_{BE\_CAL}(T_{REF})] \times k_{PTAT\_CORNER} + k_{PTAT\_CURVATURE}$
7. **Calculate A' and B' coefficients:**
   - **A'** $= A_0 \times (V_{BE\_CAL} + \alpha \times \Delta V_{BE\_CAL}) \times (1 + k_{PTAT})$
   - **B'** $= -273.15 \times (1 + k_{PTAT}) - k_{PTAT} \times T_{CALIB}$

Once the A' and B' coefficients have been calculated once, they can be stored in the host system and used for all future high accuracy temperature calculations for the barometer unit.

The calculation of high accuracy temperature readings using A' and B' is a four step process, shown below.

1. Read out temperature result T_{RAW} from registers TMP_B2 to TMP_B0 or FIFO, if enabled.
2. Scale the temperature measurement:
   - $T_{CAL} = T_{RAW} / 1048576$
3. Calculate μ coefficient:
   - $\mu = T_{CAL} / (1 + \alpha \times T_{CAL})$
4. Calculate **T_{OUT}**:
   - **T_{OUT}** $= (A' \times \mu) + B'$

5.5.3 Oversampling rate: kP

When calculating the pressure measurement from the output register value, it is necessary to include a calculation factor called kP. The value of kP changes depending on the oversampling rate selected for the measurement. The table below lists the oversampling rates and the respective kP values.

Table 4: kP values associated with each oversampling rate

Bit Field Value	Oversampling Rate	Scale Factor (kP)
000	1 (single)	262144
001	2 times (Low Power)	786432
010	4 times	1835008
011	8 times	3932160
100	16 times (Standard)	126976
101	32 times	258048
110	64 times (High Precision)	520192
111	128 times	1044480

5.5.4 A' and B' calculation constants

The following table lists all of the coefficients required to calculate the A' and B' coefficients.

Table 5: A' and B' calculation constants

Name	Unit	Value
T_{REF}	°C	27
$V_{BE\_TARGET}(T_{REF})$	V	0.687027
α	-	9.45
T_{C_VBE}	V	-1.735E-3
k_{PTAT_CORNER}	-	-0.8
$k_{PTAT\_CURVATURE}$	-	0.039
A_0	K	5030

5.6 Applications

The example application circuits below demonstrate the connection of the I2C serial interface.

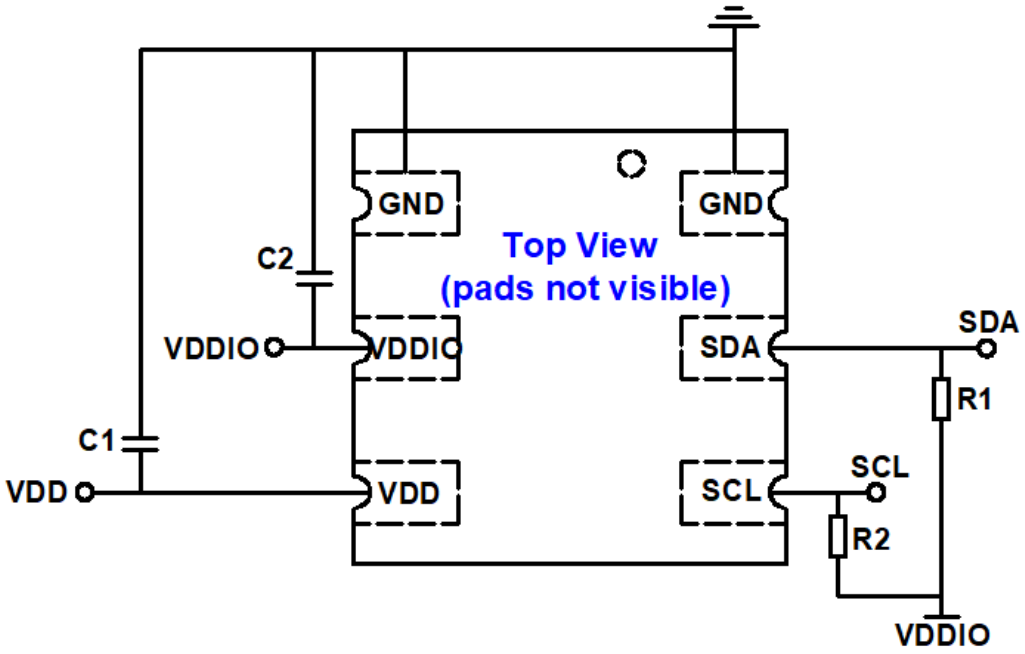


Figure 3: Application circuit example using the I2C serial interface

Table 6: Component Values

Component	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Pull-up/down Resistor	R1, R2			10	kΩ	
Supply Blocking Capacitor	C1, C2	100	100		nF	The blocking capacitors should be placed as close to the package pins as possible.

6. Register Map

The SP01-017 user registers are listed and described below. The calibration coefficient registers can be found in the Calibration coefficients section.

Table 7: Register Map

Register Name	Addr.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset Value
PSR_B2	0x00	Pressure measurement MSB <23:16>								0x80
PSR_B1	0x01	Pressure measurement LSB <15:8>								0x00
PSR_B0	0x02	Pressure measurement XLSB <7:0>								0x00
TMP_B2	0x03	Temperature measurement MSB <23:16>								0x80
TMP_B1	0x04	Temperature measurement LSB <15:8>								0x00
TMP_B0	0x05	Temperature measurement XLSB <7:0>								0x00
PSR_CFG	0x06	-	Pressure measurement rate [2:0]			-	Pressure measurement resolution [2:0]			0x00
TEMP_CFG	0x07	Must be set to 1	Temperature measurement rate [2:0]			-	Temperature measurement resolution [2:0]			0x80
MEAS_CFG	0x08	Init. complete	Cont. mode flag	Temp. data ready	Press. data ready	-	Measurement control [2:0]			0x00
CFG_REG	0x09	Interrupt select [3:0]				Interrupt polarity	FIFO Stop on full	FIFO enable	SPI mode	0x00
INT STS	0x0A	-	-	-	-	-	FIFO interrupt Full / WM	Temp. interrupt	Press. interrupt	0x00
WM_CFG	0x0B	-	-	-	Watermark level[4:0]					0x1F
FIFO_STS	0x0C	FIFO fill level[5:0]						FIFO Full / WM	FIFO empty	0x00
RESET	0x0D	FIFO flush	-	-	-	Soft reset[3:0]				0x00
PROD_ID	0x1D	Revision ID[3:0]				Product ID[3:0]				0x1A

Attention: To ensure correct functionality, registers not listed in this register map must not be accessed.

7. Register Description

7.1 PSR_B2

Register containing most significant byte of the pressure measurement result.

Address: 0x00

Reset Value: 0x80

Table 8: PSR_B2 register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PSR23	PSR22	PSR21	PSR20	PSR19	PSR18	PSR17	PSR16

Table 9: PSR_B2 bit fields

Bit Name	Bits	Type	Description
Pressure measurement MSB <23:16>	<7:0>	R	Pressure measurement result bits 23 to 16.

7.2 PSR_B1

Register containing middle byte of the pressure measurement result.

Address: 0x01

Reset Value: 0x00

Table 10: PSR_B1 register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PSR15	PSR14	PSR13	PSR12	PSR11	PSR10	PSR9	PSR8

Table 11: PSR_B1 bit fields

Bit Name	Bits	Type	Description
Pressure measurement LSB	<7:0>	R	Pressure measurement result bits 15 to 8.

7.3 PSR_B0

Register containing least significant byte of the pressure measurement result.

Address: 0x02

Reset Value: 0x00

Table 12: PSR_B0 register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PSR7	PSR6	PSR5	PSR4	PSR3	PSR2	PSR1	PSR0

Table 13: PSR_B0 bit fields

Bit Name	Bits	Type	Description
Pressure measurement XLSB <7:0>	<7:0>	R	Pressure measurement result bits 7 to 0.

7.4 TMP_B2

Register containing most significant byte of the temperature measurement result.

Address: 0x03

Reset Value: 0x80

Table 14: TMP_B2 register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TMP23	TMP22	TMP21	TMP20	TMP19	TMP18	TMP17	TMP16

Table 15: TMP_B2 bit fields

Bit Name	Bits	Type	Description
Temperature measurement MSB <23:16>	<7:0>	R	Temperature measurement result bits 23 to 16.

7.5 TMP_B1

Register containing middle byte of the temperature measurement result.

Address: 0x04

Reset Value: 0x00

Table 16: TMP_B1 register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TMP15	TMP14	TMP13	TMP12	TMP11	TMP10	TMP9	TMP8

Table 17: TMP_B1 bit fields

Bit Name	Bits	Type	Description
Temperature measurement LSB <15:8>	<7:0>	R	Temperature measurement result bits 15 to 8.

7.6 TMP_B0

Register containing least significant byte of the temperature measurement result.

Address: 0x05

Reset Value: 0x00

Table 18: TMP_B0 register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TMP7	TMP6	TMP5	TMP4	TMP3	TMP2	TMP1	TMP0

Table 19: TMP_B0 bit fields

Bit Name	Bits	Type	Description
Temperature measurement XLSB <7:0>	<7:0>	R	Temperature measurement result bits 7 to 0.

7.7 PSR_CFG

Configuration register for pressure measurement. Pressure or stress measurements can be enabled. Pressure measurement rate and resolution can be modified.

Address: 0x06

Reset Value: 0x00

Table 20: PSR_CFG register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	Pressure measurement rate[2:0]			-	Pressure measurement resolution[2:0]		

Table 21: PSR_CFG bit fields

Bit Name	Bits	Type	Description
Pressure measurement rate[2:0]	<6:4>	RW	Pressure measurement rate: • 000 - 1 sample/sec • 001 - 2 samples/sec • 010 - 4 samples/sec • 011 - 8 samples/sec • 100 - 16 samples/sec • 101 - 32 samples/sec • 110 - 64 samples/sec • 111 - 128 samples/sec
Pressure measurement resolution[2:0]	<2:0>	RW	Pressure measurement resolution (Pressure oversampling rate): • 000 - 256 samples - 1x decimation • 001 - 512 samples - 2x decimation (low power) • 010 - 1024 samples - 4x decimation • 011 - 2048 samples - 8x decimation • 100 - 4096 samples - 16x decimation (standard) • 101 - 8192 samples - 32x decimation • 110 - 16384 samples - 64x decimation (high precision) • 111 - 32768 samples - 128x decimation

Table 22: Precision (PaRMS) and pressure measurement time (ms) versus oversampling rate

Oversampling (PSR_CFG[3:0])	1x (0000)	2x (0001)	4x (0010)	8x (0011)	16x (0100)	32x (0101)	64x (0110)	128x (0111)
Measurement time	3.6	5.2	8.4	14.8	27.6	53.2	104.4	206.8
Precision	5		2.5		1.2	0.9	0.5	

Table 23: Estimated current consumption (µA)

Oversampling (PSR_CFG[3:0])	1x (0000)	2x (0001)	4x (0010)	8x (0011)	16x (0100)	32x (0101)	64x (0110)	128x (0111)
Measurements pr sec. (PM_RATE([2:0])								
1 (000)	2.1	2.7	3.8	6.1	11	20	38	75
2 (001)								
4 (010)								
8 (011)	*Note: The current consumption can be calculated as the Measurement Rate * Current Consumption of 1 measurement per. sec.*							n.a.
16 (100)							n.a.	n.a.
32 (101)						n.a.	n.a.	n.a.
64 (110)					n.a.	n.a.	n.a.	n.a.
128 (111)			n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Note: The table shows the possible combinations of Pressure Measurement Rate and oversampling when no temperature measurements are performed. When temperature measurements are performed the possible combinations are limited to $Rate_{temperature}$ *x Measurement* $Time_{temperature}$ *+* $Rate_{pressure}$ *x Measurement* $Time_{pressure} < 1$ *second.*

Temperature measurement time versus temperature oversampling rate is similar to pressure measurement time versus pressure oversampling rate.

7.8 TEMP_CFG

Configuration register for temperature measurements. Temperature measurement rate and resolution can be modified.

Address: 0x07

Reset Value: 0x00

Table 24: TEMP_CFG register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Must be set to 1	Temperature measurement rate [2:0]			-	Temperature measurement resolution [2:0]		

Table 25: TEMP_CFG bit fields

Bit Name	Bits	Type	Description
Must be set to 1	<7>	RW	*Warning: This bit **must** be set to '1' to configure the temperature measurement correctly. If this bit is not set, the temperature and pressure measurements will not function correctly.*

Temperature measurement rate [2:0]	<6:4>	RW	Temperature measurement rate: • 000 - 1 sample/sec • 001 - 2 samples/sec • 010 - 4 samples/sec • 011 - 8 samples/sec • 100 - 16 samples/sec • 101 - 32 samples/sec • 110 - 64 samples/sec
Temperature measurement resolution [2:0]	<2:0>	RW	Temperature measurement resolution: • 000 - 256 samples - 1x decimation • 001 - 512 samples - 2x decimation • 010 - 1024 samples - 4x decimation • 011 - 2048 samples - 8x decimation • 100 - 4096 samples - 16x decimation • 101 - 8192 samples - 32x decimation • 110 - 16384 samples - 64x decimation • 111 - 32768 samples - 128x decimation

Table 26: Temperature measurement time (ms) versus oversampling rate

Oversampling (TEMP_CFG[2:0])	Single (000)	2 times (001)	4 times (010)	8 times (011)	16 times (100)	32 times (101)	64 times (110)
Measurement time (ms)	5.2	8.4	14.8	27.6	53.2	104.4	206.8

7.9 MEAS_CFG

Configuration register for general measurement settings.

Address: 0x08

Reset Value: 0x00

Table 27: MEAS_CFG register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Init. complete	Cont. mode flag	Temp. data ready	Press. data ready	-	Measurement control [2:0]		

Table 28: MEAS_CFG bit fields

Bit Name	Bits	Type	Description
Init. complete	<7>	R	Status bit set when initialization procedure is complete.
Cont. mode flag	<6>	R	Status bit set when SP01-017 is in continuous measurement mode.
Temp. data ready	<5>	R	Status bit set when new temperature measurement data is available. Cleared when register 0x05 is read.
Press. data ready	<4>	R	Status bit set when new pressure measurement data is available. Cleared when register 0x02 is read.
Measurement control [2:0]	<2:0>	RW	Configuration register controlling measurement mode: • 000 - Idle / Stop Background • 001 - Pressure Measurement • 010 - Temperature Measurement • 011 - Pressure and Temperature Measurement one shot • 100 - Idle / Stop Background • 101 - Continuous Pressure Measurement • 110 - Continuous Temperature Measurement • 111 - Continuous Pressure and Temperature Measurement

7.10 CFG_REG

Interrupt, SPI mode and FIFO configuration register.

Address: 0x09

Reset Value: 0x00

Table29: CFG_REG register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Interrupt select[3:0]				Interrupt polarity	FIFO Stop on full	FIFO enable	SPI mode

Table 30: CFG_REG bit fields

Bit Name	Bits	Type	Description
Interrupt select[3:0]	<7:4>	RW	Select interrupt source: • 0000 - no interrupt enabled • 0001 - Pressure Interrupt enabled • 0010 - Temperature Interrupt enabled • 0011 - Pressure & Temperature Interrupt enabled • 0100- FIFO Watermark Interrupt enabled • 1000- FIFO FULL Interrupt enabled All other settings are invalid. Interrupt pin (SDO pin) is cleared when the Interrupt Status Register (0x0A) is read.
Interrupt polarity	<3>	RW	Interrupt active polarity: • 0 - Active low • 1 - Active high *Note: Interrupt can only be output when the SP01-017 is in I2C or 3-wire SPI modes.*
FIFO Stop on full	<2>	RW	Configures FIFO behavior when full: • 0 - FIFO in streaming mode. When full, oldest data is overwritten as new data is available. • 1 - FIFO in stop on full mode. When full, old data is retained, new data is not stored.
FIFO enable	<1>	RW	Enables pressure and temperature result FIFO: • 0 - FIFO is disabled. Old results are not stored. Pressure and temperature results stored in respective results registers. • 1 - FIFO is enabled. Results are read from result registers 0x00 - 0x02. Up to 32 results can be stored.
SPI mode	<0>	RW	Configures the SPI protocol used: • 0 - 4-wire SPI interface. • 1 - 3-wire SPI interface

7.11 INT STS

Register reflecting the current status of the SP01-017 interrupt sources. All bits are clear on read.

Address: 0x0A

Reset Value: 0x00

Table 31: INT STS register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	-	FIFO interrupt Full / WM	Temp. interrupt	Press. interrupt

Note: The interrupt pin, and this register itself are cleared when this register is read.

Table 32: INT STS bit fields

Bit Name	Bits	Type	Description
FIFO interrupt Full / WM	<3>	R	This bit is set when FIFO is full or when FIFO reaches watermark level. Source depends on setting in CFG_REG register. *Note: This bit should not be polled faster than once per 375µs.*
Temp. interrupt	<2>	R	This bit is set when new temperature data is available.
Press. interrupt	<1>	R	This bit is set when new pressure data is available.

7.12 WM_CFG

FIFO watermark level configuration register.

Address: 0x0B

Reset Value: 0x1F

Table 33: WM_CFG register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	Watermark level[4:0]				

Table 34: WM_CFG bit fields

Bit Name	Bits	Type	Description
Watermark level[4:0]	<4:0>	RW	Configures number of measurement results which must be in the FIFO to trigger the FIFO watermark interrupt. • 0x00 - Interrupt generated when FIFO contains 1 unread measurement result. • 0x1F - Interrupt generated when FIFO contains 32 unread measurement results.

7.13 FIFO_STS

FIFO status register, reflecting FIFO fill and watermark status.

Address: 0x0C

Reset Value: 0x00

Table 35: FIFO_STS register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FIFO fill level[5:0]						FIFO Full / WM	FIFO empty

Table 36: FIFO_STS bit fields

Bit Name	Bits	Type	Description
FIFO fill level[5:0]	<7:2>	R	This bit field contains the number of pressure and/or temperature measurements currently stored in the measurement results FIFO.
FIFO Full / WM	<1>	R	This bit is set when FIFO is full or when FIFO reaches watermark level. Source depends on setting in WM_CFG register. *Note: This bit is updated every 250 µs.*
FIFO empty	<0>	R	This bit is set when the FIFO is empty. • 0 – FIFO currently contains data • 1 - FIFO does not currently contain data *Note: This bit is updated every 250 µs.*

7.14 RESET

Reset register allows soft reset of the SP01-017, and flushing of the measurement results FIFO.

Address: 0x0D

Reset Value: 0x00

Table 37: RESET register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FIFO flush	-	-	-	Soft reset[3:0]			

Table 38: RESET bit fields

Bit Name	Bits	Type	Description
FIFO flush	<7>	W	Setting this bit to 1 clears all data in the measurement results FIFO.
Soft reset[3:0]	<3:0>	W	Two soft reset options are available, depending on the value sent to this bit field. • 0b1000: Reset configuration registers without eFuse refresh. Duration ~0.7ms. • 0b1001: Full reset. Similar to power-on-reset, all registers are reset and eFuse refresh is carried out. Duration ~3ms. *Note: Only the listed values should be written to the soft reset bit field. Writing incorrect values may result in unexpected behavior.*

7.15 PROD_ID

Product ID register storing product and revision information.

Address: 0x1D

Reset Value: 0x1A

Table 39: PROD_ID register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Revision ID[3:0]				Product ID[3:0]			

Table 40: PROD_ID bit fields

Bit Name	Bits	Type	Description
Revision ID[3:0]	<7:4>	R	SP01-017 revision number, incremented on metal and silicon revisions.
Product ID[3:0]	<3:0>	R	SP01-017 product ID number. Always set to 0x1A.

8. Calibration coefficients

The SP01-017 register map contains a number of one time programmable fuse registers which are intended to be used to store calibration coefficients, which are individually calculated and are used in the calculation of pressure and temperature measurements.

The three temperature measurement coefficients should be stored across three registers at addresses 0x20 to 0x22. These coefficients must be used to accurately convert the temperature measurement value stored in the results registers TMP_B0 to TMP_B2 into a temperature value in °C.

Pressure calibration coefficients should be stored in register addresses 0x26 to 0x39. These coefficients must be used in the calculation of pressure measurement results to eliminate any measurement non-linearity's caused by temperature changes.

Table 41: SP01-017 Temperature Calculation Coefficients

Register Name	Addr.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
T_GAIN_COEFF	0x20	T_gain <7:0>							
T_dVBE_COEFF	0x21	T_dVbe<6:0>							T_Vbe<0>
T_VBE_COEFF	0x22	T_Vbe<8:1>							

Table 42: SP01-017 Pressure Measurement Calibration Coefficients

Register Name	Addr.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
COEFF_REG_1	0x26	C00 <19:12>							
COEFF_REG_2	0x27	C00 <11:4>							
COEFF_REG_3	0x28	C00 <3:0>				C10 <19:16>			
COEFF_REG_4	0x29	C10 <15:8>							
COEFF_REG_5	0x2A	C10 <7:0>							
COEFF_REG_6	0x2B	C01 <19:12							
COEFF_REG_7	0x2C	C01 <11:4							
COEFF_REG_8	0x2D	C01 <3:0>				C02 <19:6>			
COEFF_REG_9	0x2E	C02 <15:8>							
COEFF_REG_10	0x2F	C02 <7:0>							
COEFF_REG_11	0x30	-	C20<14:8>						
COEFF_REG_12	0x31	C20 <7:0>							
COEFF_REG_13	0x32	-				C30 <11:8>			
COEFF_REG_14	0x33	C30 <7:0>							
COEFF_REG_15	0x34	C11 <16:9>							
COEFF_REG_16	0x35	C11 <8:1>							
COEFF_REG_17	0x36	C11 <0>	C12 <16:10>						
COEFF_REG_18	0x37	C12 <9:2>							
COEFF_REG_19	0x38	C12 <1:0>		C21 <13:8>					
COEFF_REG_20	0x39	C21 <7:0>							

8.1 Coefficient number formats

The six temperature calculation coefficients use the following number formats:

Table 43: SP01-017 temperature calculation coefficients number format

Coefficient	Format
T_gain	8 bits, 2's complement
T_dVbe	7 bits, 2's complement
T_Vbe	9 bits, 2's complement

The pressure measurement calibration coefficients use the following number formats:

Table 44: SP01-017 pressure measurement calibration coefficients number formats

Coefficient	Format
C00	20 bit, 2's complement
C01	20 bit, 2's complement
C02	20 bit, 2's complement
C10	20 bit, 2's complement
C11	17 bit, 2's complement
C12	17 bit, 2's complement
C20	15 bit, 2's complement
C21	14 bit, 2's complement
C30	12 bit, 2's complement

9. Mechanical characteristics

9.1 Pin configuration

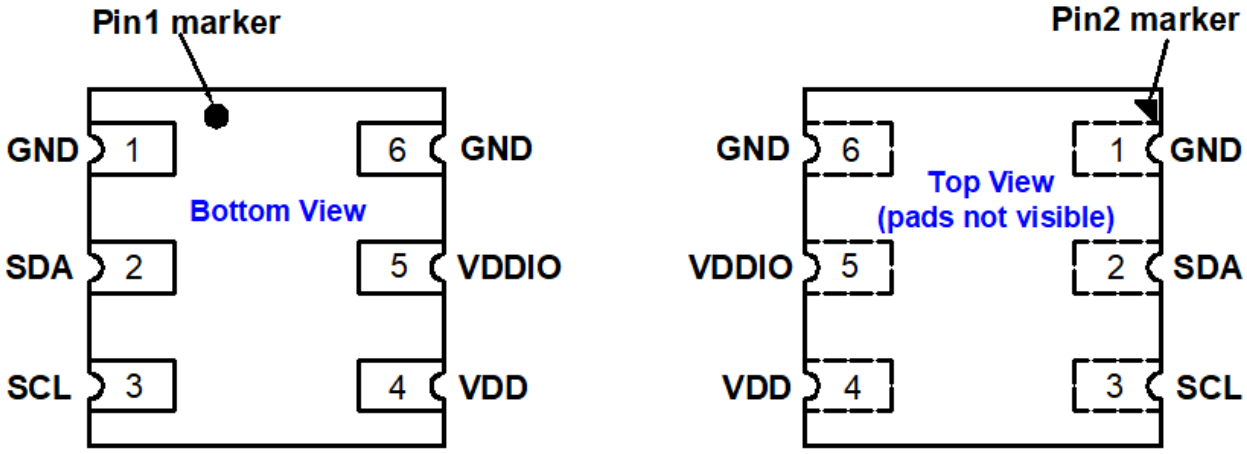


Figure 4: Layout pin configuration SP01-017 (bottom view and top view)

Table 45: Pin configuration of SP01-017

Pin	Name	I2C
1	GND	Ground
2	SDA	Serial data in/OUT
3	SCL	Serial Clock
4	VDD	Supply voltage for analog blocks
5	VDDIO	Digital supply voltage for blocks and I/O interface
6	GND	Ground

9.2 Outline dimensions

The sensor is a 6-pin metal housing LGA 6.0 (±0.15) × 6.0 (±0.15) × 7.8 (±0.15) mm^3 package. Its dimensions are depicted in Figure 5.

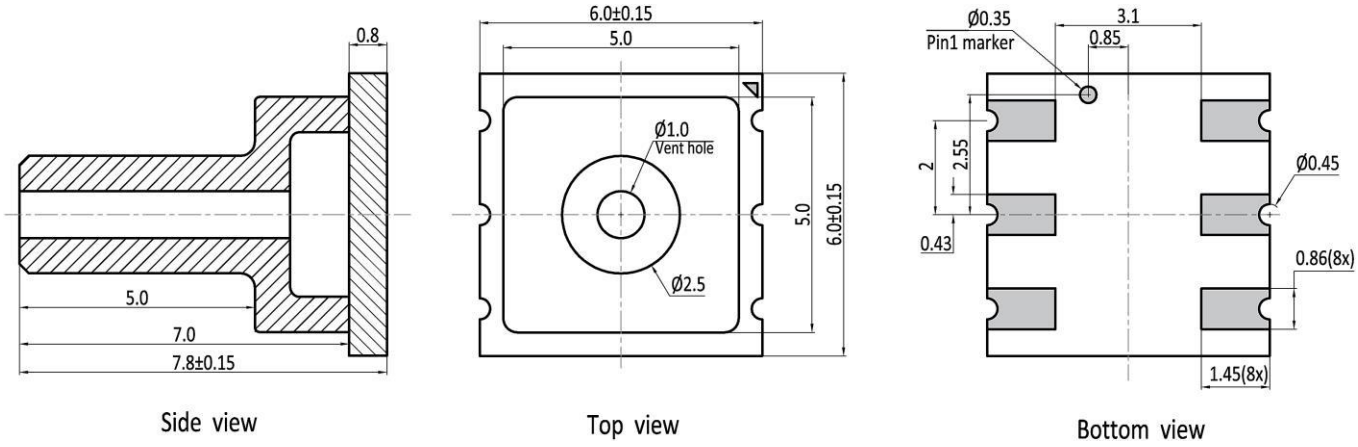


Figure 5: SP01-017 outline and mechanical data

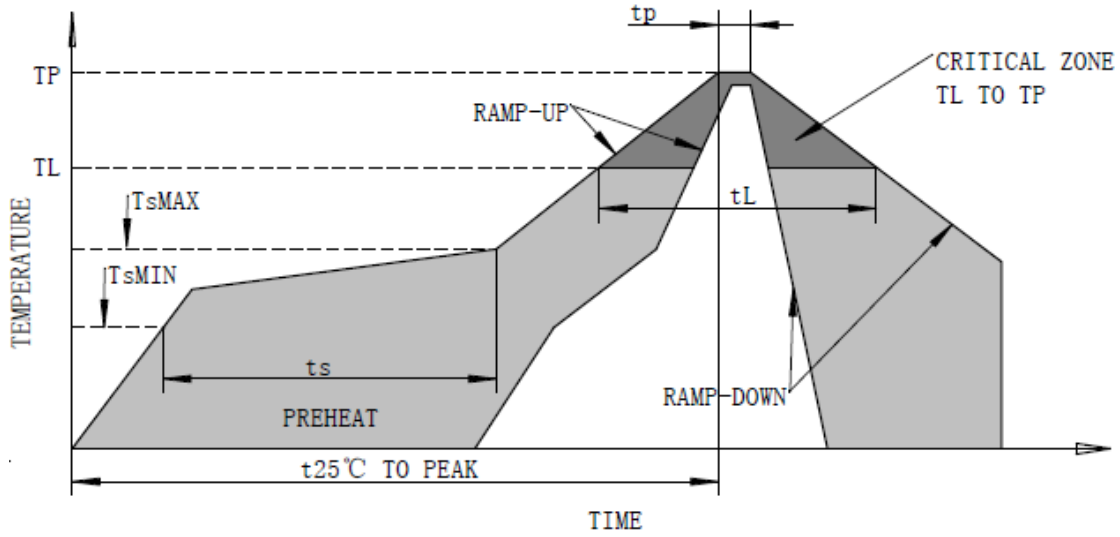
Note: General tolerances are ±0.05mm.

10. Storage and transportation

- Keep in warehouse with less than 75% humidity and without sudden temperature change, acid air, any other harmful air or strong magnetic field.
- The MEMS pressure sensor with normal pack can be transported by ordinary conveyances. Please protect products against moist, shock, sunburn and pressure during transportation.
- Storage Temperature Range：-40°C～+125°C
- Operating Temperature Range：-40°C～+85°C

11. Soldering recommendation

Recommended solder reflow for flex board:



Profile Feature	Pb-Free Assembly
Average ramp-up rate(TsMAX to TP)	2°C /seconds max
Preheat -Temperature Min.(TsMIN) -Temperature Max.(TsMAX) -Time(TsMIN to TsMAX)(Ts)	 130°C 200°C 90～110 seconds
Time maintained above: -Temperature(TL) -Time(tL)	 217°C 50～60 seconds
Ramp time of Ts to TL	15-25 seconds
Time 25°C to peak temperature	300 seconds max
Peak temperature(TP)	235-240 °C
Ramp-down rate (peak to 217°C)	2～4°C /seconds