Data sheet

BMP280
Digital Pressure Sensor

Bosch Sensortec

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BMP280: Data sheet

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BMP280

DIGITAL PRESSURE SENSOR

Key parameters

- Pressure range — 300 ... 1100 hPa (equiv. to +9000…-500 m above/below sea level)
- Package — 8-pin LGA metal-lid; Footprint : 2.0 × 2.5 mm², height: 0.95 mm
- Relative accuracy (700 ... 900hPa @25°C) — ±0.12 hPa, equiv. to ±1 m
- Absolute accuracy (950 ...1050 hPa, 0 ...+40 °C) — typ. ±1 hPa
- Temperature coefficient offset (25 ... 40°C @900hPa) — 1.5 Pa/K, equiv. to 12.6 cm/K
- Digital interfaces — I²C (up to 3.4 MHz); SPI (3 and 4 wire, up to 10 MHz)
- Current consumption — 2.7µA @ 1 Hz sampling rate
- Temperature range — -40 ... +85 °C
- RoHS compliant, halogen-free
- MSL 1

Typical applications

- Enhancement of GPS navigation
  (e.g. time-to-first-fix improvement, dead-reckoning, slope detection)
- Indoor navigation (floor detection, elevator detection)
- Outdoor navigation, leisure and sports applications
- Weather forecast
- Vertical velocity indication (e.g. rise/sink speed)

Target devices

- Handsets such as mobile phones, tablet PCs, GPS devices
- Navigation systems
- Home weather stations
- Flying toys
- Watches

General Description

Robert Bosch is the world market leader for pressure sensors in automotive and consumer applications. Bosch's proprietary APSM (Advanced Porous Silicon Membrane) MEMS manufacturing process is fully CMOS compatible and allows a hermetic sealing of the cavity in an all silicon process. The BMP280 is based on Bosch's proven Piezo-resistive pressure sensor technology featuring high EMC robustness, high accuracy and linearity and long term stability.

The BMP280 is an absolute barometric pressure sensor especially designed for mobile applications. The sensor module is housed in an extremely compact 8-pin metal-lid LGA package with a footprint of only 2.0 × 2.5 mm^2 and 0.95 mm package height. Its small dimensions and its low power consumption of 2.7 µA @1Hz allow the implementation in battery driven devices such as mobile phones, GPS modules or watches.

As the successor to the widely adopted BMP180, the BMP280 delivers high performance in all applications that require precise pressure measurement. The BMP280 operates at lower noise, supports new filter modes and an SPI interface within a footprint 63% smaller than the BMP180.

The emerging applications of indoor navigation, fitness as well as GPS refinement require a high relative accuracy and a low TCO at the same time. BMP180 and BMP280 are perfectly suitable for applications like floor detection since both sensors feature excellent relative accuracy is ±0.12 hPa, which is equivalent to ±1 m difference in altitude. The very low offset temperature coefficient (TCO) of 1.5 Pa/K translates to a temperature drift of only 12.6 cm/K.
Please contact your regional Bosch Sensortec partner for more information about software packages enhancing the calculation of the altitude given by the BMP280 pressure reading.

Table 1: Comparison between BMP180 and BMP280

Parameter	BMP180	BMP280
Footprint	3.6 × 3.8 mm	2.0 × 2.5 mm
Minimum V_{DD}	1.80 V	1.71 V
Minimum V_{DDIO}	1.62 V	1.20 V
Current consumption @3 Pa RMS noise	12 µA	2.7 µA
RMS Noise	3 Pa	1.3 Pa
Pressure resolution	1 Pa	0.16 Pa
Temperature resolution	0.1°C	0.01°C
Interfaces	I²C	I²C & SPI (3 and 4 wire, mode '00' and '11')
Measurement modes	Only P or T, forced	P&T, forced or periodic
Measurement rate	up to 120 Hz	up to 157 Hz
Filter options	None	Five bandwidths

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1. Specification

If not stated otherwise,

- All values are valid over the full voltage range
- All minimum/maximum values are given for the full accuracy temperature range
- Minimum/maximum values of drifts, offsets and temperature coefficients are ±3σ values over lifetime
- Typical values of currents and state machine timings are determined at 25 °C
- Minimum/maximum values of currents are determined using corner lots over complete temperature range
- Minimum/maximum values of state machine timings are determined using corner lots over 0…+65 °C temperature range

The specification tables are split into pressure and temperature part of BMP280

Table 2: Parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Units
Operating temperature range	T_A	operational	-40	25	+85	°C
		full accuracy	0		+65	
Operating pressure range	P	full accuracy	300		1100	hPa
Sensor supply voltage	V_{DD}	ripple max. 50mVpp	1.71	1.8	3.6	V
Interface supply voltage	V_{DDIO}		1.2	1.8	3.6	V
Supply current	$I_{DD,LP}$	1 Hz forced mode, pressure and temperature, lowest power		2.8	4.2	µA
Peak current	I_{peak}	during pressure measurement		720	1120	µA
Current at temperature measurement	I_{DDT}			325		µA
Sleep current[1]	I_{DDSL}	25 °C		0.1	0.3	µA
Standby current (inactive period of normal mode) [2]	I_{DDSB}	25 °C		0.2	0.5	µA
Relative accuracy pressure V_{DD} = 3.3V	A_{rel}	700 ... 900hPa 25 . . . 40 °C		±0.12		hPa
				±1.0		m

[1] Typical value at VDD = VDDIO = 1.8 V, maximal value at VDD = VDDIO = 3.6 V.

[2] Typical value at VDD = VDDIO = 1.8 V, maximal value at VDD = VDDIO = 3.6 V.

Offset temperature coefficient	TCO	900hPa 25 . . . 40 °C		±1.5		Pa/K
				12.6		cm/K
Absolute accuracy pressure	A^P_{ext}	300 . . 1100 hPa -20 . . . 0 °C		±1.7		hPa
	A^P_{full}	300 . . . 1100 hPa 0 . . . 65 °C		±1.0		hPa
Resolution of output data in ultra high resolution mode	R^P	Pressure		0.0016		hPa
	R^T	Temperature		0.01		°C
Noise in pressure	$V_{p,full}$	Full bandwidth, ultra high resolution See chapter 3.5		1.3		Pa
				11		cm
	$V_{p,filtered}$	Lowest bandwidth, ultra high resolution See chapter 3.5		0.2		Pa
				1.7		cm
Absolute accuracy temperature[3]	A^T	@ 25 °C		±0.5		°C
		0 . . . +65 °C		±1.0		°C
PSRR (DC)	PSRR	full V_{DD} range			±0.005	Pa/mV
Long term stability[4]	ΔP_{stab}	12 months		±1.0		hPa
Solder drifts		Minimum solder height 50 µm	-0.5		+2	hPa
Start-up time	$t_{startup}$	Time to first communication after both V_{DD} > 1.58V and V_{DDIO} > 0.65V			2	ms
Possible sampling rate	f_{sample}	*osrs_t* = *osrs_p* = 1; See chapter 3.8	157	182	tbd[5]	Hz
Standby time accuracy	$\Delta t_{standby}$			±5	±25	%

[3] Temperature measured by the internal temperature sensor. This temperature value depends on the PCB temperature, sensor element self-heating and ambient temperature and is typically above ambient temperature.
[4] Long term stability is specified in the full accuracy operating pressure range 0 ... 65°C
[5] Depends on application case, please contact Application Engineer for further questions

2. Absolute maximum ratings

The absolute maximum ratings are provided in Table 3.

Table 3: Absolute maximum ratings

Parameter	Condition	Min	Max	Unit
Voltage at any supply pin	V_{DD} and V_{DDIO} Pin	-0.3	4.25	V
Voltage at any interface pin		-0.3	V_{DDIO} + 0.3	V
Storage Temperature	≤ 65% rel. H.	-45	+85	°C
Pressure		0	20 000	hPa
ESD	HBM, at any Pin		±2	kV
	CDM		±500	V
	Machine model		±200	V

3. Functional description

BMP280由一个压阻式压力传感元件和一个混合信号专用集成电路组成。ASIC执行A/D转换，并通过数字接口提供转换结果和传感器特定补偿数据。

BMP280为设计人员提供了最高的灵活性，通过从大量可能的传感器设置组合中进行选择，可以适应有关精度、测量时间和功耗的要求。

BMP280可在三种功率模式下运行(见3.6章):

- sleep mode
- normal mode
- forced mode

在睡眠模式下，不执行任何测量。正常模式包括主动测量周期和非主动待机周期之间的自动永久循环。在强制模式下，只执行一次测量。测量完成后，传感器返回睡眠模式。

一组过采样设置可从超低功率到超高分辨率设置，以适应传感器的目标应用。这些设置是预定义的压力测量过采样和温度测量过采样的组合。压力和温度测量过采样可独立选择0 ~ 16次过采样(见3.3.1和3.3.2章):

- Temperature measurement
- Ultra low power
- Low power
- Standard resolution
- High resolution
- Ultra high resolution

BMP280配备了内置IIR滤波器，以最大限度地减少由于砰的门或窗造成的输出数据的短期干扰。过滤系数取值范围为0 (off) ~ 16。

为了简化设备使用并减少功率模式、过采样率和过滤器设置的大量可能组合，Bosch Sensortec为智能手机、移动气象站或飞行玩具的常见用例提供了一套经过验证的建议(见3.4章):

- Handheld device low-power (e.g. smart phones running Android)
- Handheld device dynamic (e.g. smart phones running Android)
- Weather monitoring (setting with lowest power consumption)
- Elevator / floor change detection
- Drop detection
- Indoor navigation

3.1 Block diagram

Figure 1 shows a simplified block diagram of the BMP280:

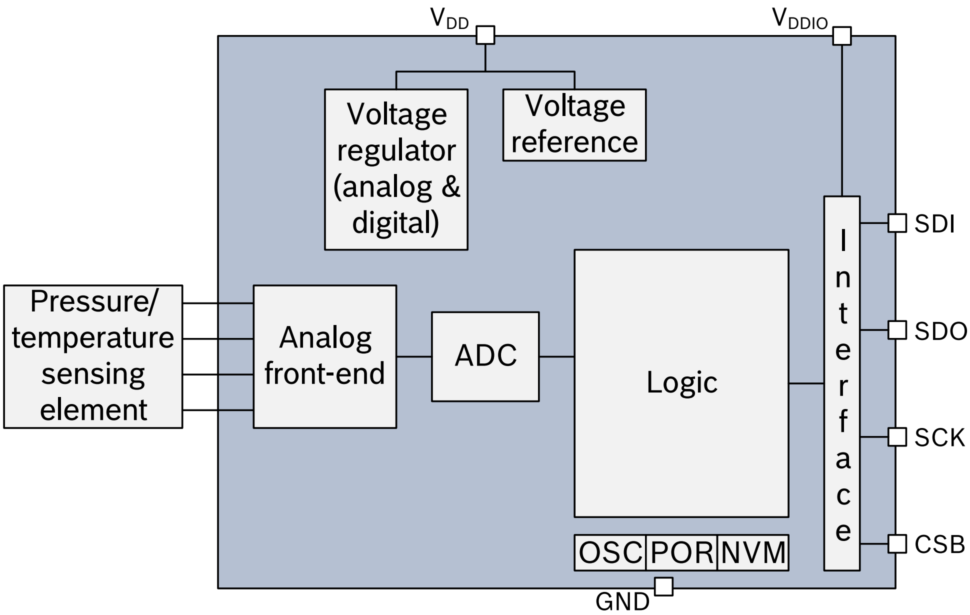

Figure 1: Block diagram of BMP280

3.2 Power management

BMP280有两个独立的电源引脚

- V_{DD} 是所有内部模拟和数字功能模块的主要电源
- V_{DDIO} 是一个单独的电源引脚，用于数字接口的供电

通电复位发生器在通电顺序后复位逻辑电路和寄存器值。提高VDD和VDDIO水平的斜率和顺序没有限制。上电后，传感器进入休眠状态(参见3.6.1)。

警告。当VDDIO关闭时，将任何接口引脚(SDI, SDO, SCK或CSB)保持在逻辑高电平，由于通过ESD保护二极管的电流过大，可能会永久损坏设备。

如果提供了VDDIO，但不提供VDD，则接口引脚保持在高z电平。因此，在BMP280 VDD供应建立之前，总线已经可以自由使用。

3.3 Measurement flow

BMP280测量周期包括可选过采样的温度和压力测量。测量结束后，数据通过一个可选的IIR滤波器，消除短期压力波动(例如摔门引起的)。流程如下图所示。

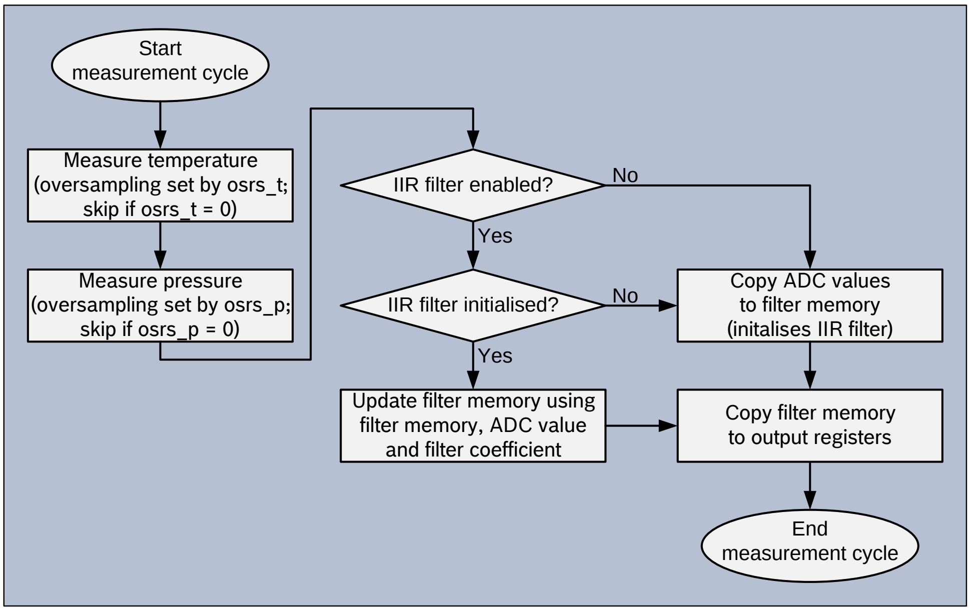

Figure 2: BMP280 measurement cycle

上面图表的各个块将在下面的子章节中详细说明。

3.3.1 Pressure measurement

可以启用或跳过压力测量。如果使用BMP280作为温度传感器，跳过测量可能是有用的。当启用时，存在几个过采样选项。每个过采样步骤都会降低噪声，并将输出分辨率提高1位，这些分辨率存储在XLSB数据寄存器0xF9中。启用/禁用测量和过采样设置是通过控制寄存器0xF4中的osrs_p[2:0]位选择的。

Table 4: *osrs_p* settings

Oversampling setting	Pressure oversampling	Typical pressure resolution	Recommended temperature oversampling
Pressure measurement skipped	Skipped (output set to 0x80000)	–	As needed
Ultra low power	×1	16 bit / 2.62 Pa	×1
Low power	×2	17 bit / 1.31 Pa	×1
Standard resolution	×4	18 bit / 0.66 Pa	×1
High resolution	×8	19 bit / 0.33 Pa	×1
Ultra high resolution	×16	20 bit / 0.16 Pa	×2

为了找到osrs_p的合适设置，请参考第3.4章。

3.3.2 Temperature measurement

可启用或跳过温度测量。跳过测量可以非常快速地测量压力。当启用时，存在几个过采样选项。每个过采样步骤都会降低噪声并将输出分辨率提高一位，这将存储在XLSB数据寄存器0xFC中。通过控制寄存器0xF4中的osrs_t[2:0]位选择启用/禁用温度测量和过采样设置。

Table 5: *osrs_t* settings

osrs_t[2:0]	Temperature oversampling	Typical temperature resolution
000	Skipped (output set to 0x80000)	–
001	×1	16 bit / 0.0050 °C
010	×2	17 bit / 0.0025 °C
011	×4	18 bit / 0.0012 °C
100	×8	19 bit / 0.0006 °C
101, 110, 111	×16	20 bit / 0.0003 °C

建议将osrs_t的值基于osrs_p的选择值，如表4所示。×2以上的温度过采样是可能的，但不会显著提高压力输出的精度。这是因为补偿压力值的噪声更多地取决于原始压力而不是原始温度噪声。遵循推荐的设置将产生最佳的噪声功率比。

3.3.3 IIR filter

环境压力受到许多短期变化的影响，例如，由于砰的一声门或窗，或风吹进传感器。为了抑制输出数据中的这些干扰，而不引起额外的接口流量和处理器工作负载，BMP280具有一个内部IIR滤波器。它有效地降低了输出信号的带宽6。下一个测量步骤的输出是使用以下公式进行滤波：

$$data\_filtered = \frac{data\_filtered\_old \cdot (filter\_coefficient - 1) + data\_ADC}{filter\_coefficient},$$

其中data_filtered_old是来自前一次采集的数据，data_ADC是来自IIR滤波前ADC的数据。

IIR过滤器可以使用控制寄存器0xF5中的过滤器[2:0]位进行配置，并具有以下选项：

[6] Since most pressure sensors do not sample continuously, filtering can suffer from signals with a frequency higher than the sampling rate of the sensor. E.g. environmental fluctuations caused by windows being opened and closed might have a frequency <5 Hz. Consequently, a sampling rate of ODR = 10 Hz is sufficient to obey the Nyquist theorem.

Table 6: *filter* settings

Filter coefficient	Samples to reach ≥75 % of step response
Filter off	1
2	2
4	5
8	11
16	22

为了找到合适的过滤器设置，请参阅第3.4章。

当写入寄存器过滤器时，过滤器被重置。下一个值将通过筛选器并作为筛选器的初始内存值。如果跳过温度或压力测量，即使输出寄存器设置为0x80000，相应的滤波器内存也将保持不变。当重新启用先前跳过的测量时，将使用上次未跳过测量时的过滤器内存对输出进行筛选。

3.4 Filter selection

为了选择最佳设置，建议使用以下用例：

Table 7: Recommended filter settings based on use cases

Use case	Mode	Over-sampling setting	osrs_p	osrs_t	IIR filter coeff. (see 3.3.3)	I_{DD} [µA] (see 3.7)	ODR [Hz] (see 3.8.2)	RMS Noise [cm] (see 3.5)
handheld device low-power (e.g. Android)	Normal	Ultra high resolution	×16	×2	4	247	10.0	4.0
handheld device dynamic (e.g. Android)	Normal	Standard resolution	×4	×1	16	577	83.3	2.4
Weather monitoring (lowest power)	Forced	Ultra low power	×1	×1	Off	0.14	1/60	26.4
Elevator / floor change detection	Normal	Standard resolution	×4	×1	4	50.9	7.3	6.4
Drop detection	Normal	Low power	×2	×1	Off	509	125	20.8
Indoor navigation	Normal	Ultra high resolution	×16	×2	16	650	26.3	1.6

3.5 Noise

噪声取决于选择的过采样和滤波器设置。所述值是在受控压力环境下确定的，并基于以最高采样速度采集的32个连续测量点的平均标准偏差。这是为了从噪声测量中排除长期漂移所必需的。

Table 8: Noise in pressure

Typical RMS noise in pressure [Pa]					
Oversampling setting	**IIR filter coefficient**				
	off	**2**	**4**	**8**	**16**
Ultra low power	3.3	1.9	1.2	0.9	0.4
Low power	2.6	1.5	1.0	0.6	0.4
Standard resolution	2.1	1.2	0.8	0.5	0.3
High resolution	1.6	1.0	0.6	0.4	0.2
Ultra high resolution	1.3	0.8	0.5	0.4	0.2

Table 9: Noise in temperature

Typical RMS noise in temperature [°C]	
Temperature oversampling	**IIR filter off**
oversampling ×1	0.005
oversampling ×2	0.004
oversampling ×4	0.003
oversampling ×8	0.003
oversampling ×16	0.002

3.6 Power modes

BMP280提供三种电源模式:休眠模式，强制模式和正常模式。这些可以使用控制寄存器0xF4中的模式[1:0]位进行选择。

Table 10: *mode* settings

***mode*[1:0]**	**Mode**
00	Sleep mode
01 and 10	Forced mode
11	Normal mode

3.6.1 Sleep mode

开机复位后，默认设置为休眠模式。在睡眠模式下，不执行任何测量，并且功耗(IDDSM)处于最小值。所有寄存器都是可访问的;芯片id和补偿系数可以读取。

3.6.2 Forced mode

在强制模式下，根据选定的测量和过滤器选项执行单个测量。当测量完成时，传感器返回睡眠模式，测量结果可以从数据寄存器获得。下一次测量时，需要再次选择强制模式。这类似于BMP180操作。对于采样率要求较低或需要主机同步的应用，建议使用强制模式。

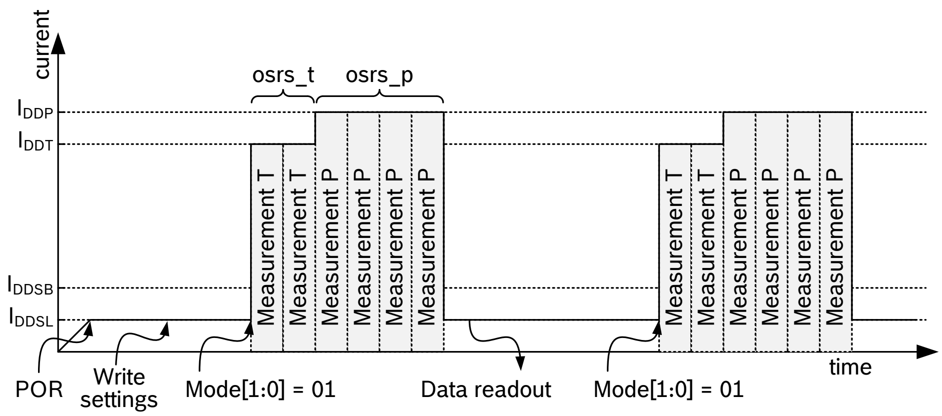

Figure 3: Forced mode timing diagram

3.6.3 Normal mode

正常模式在一个(活动)测量周期和一个(非活动)待机周期之间连续循环，待机周期的时间由tstandby定义。待机周期(IDDSB)电流略大于休眠模式。在设置模式、测量和筛选选项之后，可以从数据寄存器获得最后的测量结果，而不需要进一步的写访问。当使用IIR滤波器时，建议使用正常模式，对于需要过滤短期干扰(例如吹入传感器)的应用非常有用。

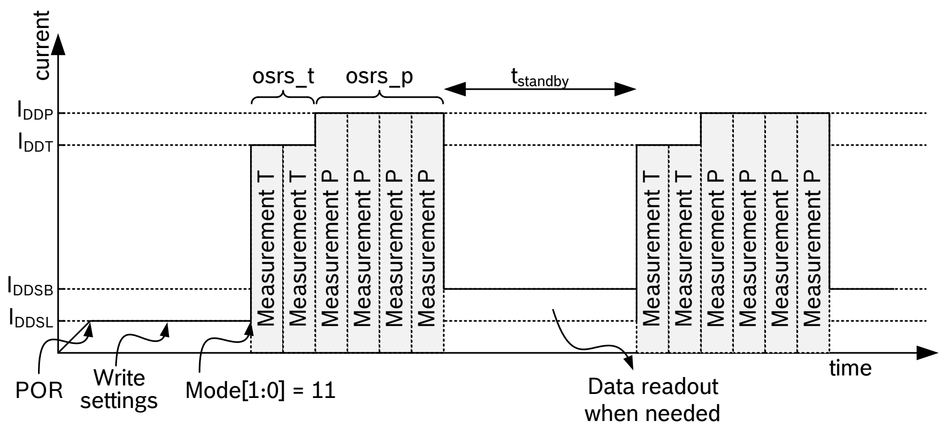

Figure 4: Normal mode timing diagram

备用时间由控制寄存器0xF5的t_sb[2:0]位的内容决定，如下表所示：

Table 11: *t_sb* settings

***t_sb*[1:0]**	**$t_{standby}$ [ms]**
000	0.5
001	62.5
010	125
011	250
100	500
101	1000
110	2000
111	4000

3.6.4模式转换图

支持的模式转换如下所示。如果设备当前正在进行测量，则模式切换命令的执行将被延迟到当前运行的测量周期结束。后续的模式更改命令将被忽略，直到执行最后一个模式更改命令。除了下面所示的模式转换外，其他模式转换都是为了稳定性而测试的，但不代表设备的推荐使用。

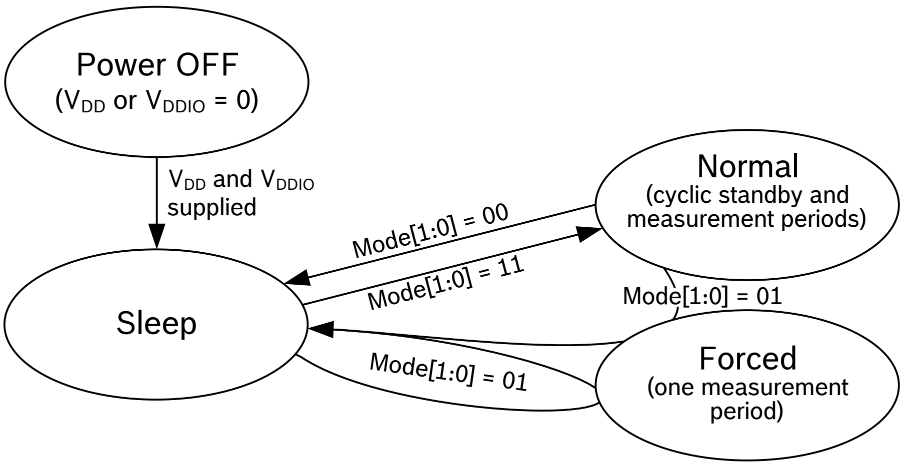

Figure 5: Mode transition diagram

3.7电流消耗

当前消耗取决于ODR和过采样设置。下面给出的值被标准化到ODR为1Hz。在给定ODR下的实际消耗量可以通过将表12中的消耗量与使用的ODR相乘来计算。实际ODR由用户设置强制测量的频率或过采样和表14中正常模式下的tstandby设置定义。

Table 12: Current consumption

Oversampling setting	Pressure oversampling	Temperature oversampling	I_{DD} [µA] @ 1 Hz forced mode	
			Typ	Max
Ultra low power	×1	×1	2.74	4.16
Low power	×2	×1	4.17	6.27
Standard resolution	×4	×1	7.02	10.50
High resolution	×8	×1	12.7	18.95
Ultra high resolution	×16	×2	24.8	36.85

3.8测量时序

在强制模式下执行测量的速率取决于过采样设置osrs_t和osrs_p。它们在正常模式下执行的速率取决于过采样设置设置osrs_t和osrs_p以及待机时间tstandby。在下表中，只给出建议的osrs组合的odr结果。

3.8.1测量时间

下表说明了基于所选过采样设置的典型和最大测量时间。最小可达频率由最大测量时间决定。

Table 13: measurement time

Oversampling setting	Pressure oversampling	Temperature oversampling	Measurement time [ms]		Measurement rate [Hz]	
			Typ	Max	Typ	Min
Ultra low power	×1	×1	5.5	6.4	181.8	155.6
Low power	×2	×1	7.5	8.7	133.3	114.6
Standard resolution	×4	×1	11.5	13.3	87.0	75.0
High resolution	×8	×1	19.5	22.5	51.3	44.4
Ultra high resolution	×16	×2	37.5	43.2	26.7	23.1

3.8.2正常模式下的测量速率

下表解释了基于过采样设置和tstandby，在正常模式下可以预期的测量速率。

Table 14: typical output data Rate (ODR) in normal mode [Hz]

Oversampling setting	$t_{standby}$ [ms]							
	0.5	62.5	125	250	500	1000	2000	4000
Ultra low power	166.67	14.71	7.66	3.91	1.98	0.99	0.50	0.25
Low power	125.00	14.29	7.55	3.88	1.97	0.99	0.50	0.25
Standard resolution	83.33	13.51	7.33	3.82	1.96	0.99	0.50	0.25
High resolution	50.00	12.20	6.92	3.71	1.92	0.98	0.50	0.25
Ultra high resolution	26.32	10.00	6.15	3.48	1.86	0.96	0.49	0.25

Table 15: Sensor timing according to recommended settings (based on use cases)

Use case	Mode	Over-sampling setting	osrs_p	osrs_t	IIR filter coeff. (see 3.3.3)	Timing	ODR [Hz] (see 3.8.2)	BW [Hz] (see 3.3.3)
handheld device low-power (e.g. Android)	Normal	Ultra high resolution	×16	×2	4	$t_{standby}$ = 62.5 ms	10.0	0.92
handheld device dynamic (e.g. Android)	Normal	Standard resolution	×4	×1	16	$t_{standby}$ = 0.5 ms	83.3	1.75
Weather monitoring (lowest power)	Forced	Ultra low power	×1	×1	Off	1/min	1/60	full
Elevator / floor change detection	Normal	Standard resolution	×4	×1	4	$t_{standby}$ = 125 ms	7.3	0.67
Drop detection	Normal	Low power	×2	×1	Off	$t_{standby}$ = 0.5 ms	125	full
Indoor navigation	Normal	Ultra high resolution	×16	×2	16	$t_{standby}$ = 0.5 ms	26.3	0.55

3.9数据读出

要在转换后读取数据，强烈建议使用突发读取，而不是逐个寻址每个寄存器。这将防止属于不同测量的字节可能发生混淆，并减少接口流量。数据读取是通过从0xF7到0xFC开始突发读取来完成的。压力和温度数据都以无符号的20位格式读取。强烈建议使用博世提供的BMP280 API

Sensortec，用于读出和补偿。关于内存映射和接口的详细信息，请分别参考第3.12章和第5章。

强制模式下数据读出的计时应确保最大测量时间(见3.8.1章)得到尊重。在正常模式下，读取可以以与预期数据输出速率相似的速度完成(见3.8.2章)。读取"ut" 和"up" 值后，需要使用存储在设备中的补偿参数计算实际压力和温度。该程序在3.11章中详细说明。

3.10数据寄存器阴影

在正常模式下，测量计时不一定与读出同步。这意味着，当用户读取前一次测量的结果时，新的测量结果可能可用。在这种情况下，为了保证数据的一致性，将执行阴影。只有当所有的数据寄存器都在一次突发读取时，阴影才会起作用。因此，如果用户没有将数据读出与测量周期同步，则必须使用突发读取。使用多个独立的read命令可能导致数据不一致。

如果一个新的测量已经完成，并且数据寄存器仍在被读取，那么新的测量结果将被传输到影子数据寄存器中。一旦用户结束突发读取，影子寄存器的内容就被传输到数据寄存器中，即使没有读取所有的数据寄存器。因此，只有在使用单个突发读取命令时，才能保证跨多个数据寄存器的读取在一个测量周期内是一致的。在SPI情况下，由CSB引脚的上升边缘标记突发读取的结束，或在I2C情况下由停止条件的识别标记。在突发读取结束后，所有用户数据寄存器都被立即更新。

3.11输出补偿

BMP280输出由ADC输出值组成。然而，每个传感元件表现不同，实际压力和温度必须使用一组校准参数来计算。3.11.3中推荐的计算方法采用定点算法。在诸如Matlab™或LabVIEW™这样的高级语言中，定点代码可能得不到很好的支持。在这种情况下，可以使用附录8.1中的浮点代码作为替代。对于8位微控制器，可变大小可能是有限的。在这种情况下，在附录8.2中给出了一个简化的32位整数码。

3.11.1计算要求

下表显示了在GCC优化级别为-O2的32位Cortex-M3微控制器上进行补偿计算所需的时钟周期数。该控制器不包含浮点单元，因此所有浮点计算都是模拟的。浮点数只推荐用于有FPU的PC应用。

Table 16: Computational requirements for compensation formulas

Compensation of	Number of clock cycles (ARM Cortex-M3)		
	32 bit integer	64 bit integer	Double precision
Temperature	~46	–	~2400 [7]
Pressure	~112 [8]	~1400	~5400 [7]

3.11.2微调参数读出

微调参数在生产过程中被编程到设备的非易失性存储器(NVM)中，客户不能更改。每个补偿字都是存储在two补码中的16位有符号或无符号整数值。由于内存被组织成8位字，必须总是将两个字组合起来以表示补偿字。8位寄存器命名为calib00…calib25，存储在内存地址0x88…0xA1。对应的补偿词dig_t#表示与温度补偿相关的值，dig_p#表示与压力补偿相关的值。映射如表17所示。

Table 17: Compensation parameter storage, naming and data type

Register Address LSB / MSB	Register content	Data type
0x88 / 0x89	dig_T1	unsigned short
0x8A / 0x8B	dig_T2	signed short
0x8C / 0x8D	dig_T3	signed short
0x8E / 0x8F	dig_P1	unsigned short
0x90 / 0x91	dig_P2	signed short
0x92 / 0x93	dig_P3	signed short
0x94 / 0x95	dig_P4	signed short
0x96 / 0x97	dig_P5	signed short
0x98 / 0x99	dig_P6	signed short
0x9A / 0x9B	dig_P7	signed short
0x9C / 0x9D	dig_P8	signed short
0x9E / 0x9F	dig_P9	signed short
0xA0 / 0xA1	reserved	reserved

3.11.3补偿公式

请注意，强烈建议使用Bosch Sensortec提供的API来执行读取和补偿。如果不希望这样做，可以应用下面的代码，但风险由用户承担。压力和温度值都应以20位正格式接收，存储在32位有符号整数中。

[7] Use only recommended for high-level programming languages like Matlab™ or LabVIEW™
[8] Use only recommended for 8-bit micro controllers

变量t_fine(带符号的32位)将精细分辨率温度值传递给压力补偿公式，并可以作为全局变量实现。数据类型"BMP280_S32_t" 应该定义一个32位有符号整型变量类型，通常可以定义为"长符号整型"。数据类型"BMP280_U32_t" 应该定义一个32位无符号整型变量类型，通常可以定义为"long unsigned int"。为了获得最好的计算精度，需要64位整数支持。

如果这是不可能的您的平台，请参阅附录8.2的32位替代方案。

数据类型"BMP280_S64_t" 应该定义一个64位有符号整型变量类型

支持平台可以定义为"long long signed int"。本规范的修订版本为1.1版。

```
// Returns temperature in DegC, resolution is 0.01 DegC. Output value of "5123" equals 51.23 DegC.
// t_fine carries fine temperature as global value
BMP280_S32_t t_fine;
BMP280_S32_t bmp280_compensate_T_int32(BMP280_S32_t adc_T)
{
   BMP280_S32_t var1, var2, T;
   var1  = ((((adc_T>>3) - ((BMP280_S32_t)dig_T1<<1))) * ((BMP280_S32_t)dig_T2)) >> 11;
   var2  = (((((adc_T>>4) - ((BMP280_S32_t)dig_T1)) * ((adc_T>>4) - ((BMP280_S32_t)dig_T1))) >> 12) *
      ((BMP280_S32_t)dig_T3)) >> 14;
   t_fine = var1 + var2;
   T  = (t_fine * 5 + 128) >> 8;
   return T;
}
""_
// Returns pressure in Pa as unsigned 32 bit integer in Q24.8 format (24 integer bits and 8 fractional bits).
// Output value of "24674867" represents 24674867/256 = 96386.2 Pa = 963.862 hPa
BMP280_U32_t bmp280_compensate_P_int64(BMP280_S32_t adc_P)
{
   BMP280_S64_t var1, var2, p;
   var1 = ((BMP280_S64_t)t_fine) - 128000;
   var2 = var1 * var1 * (BMP280_S64_t)dig_P6;
   var2 = var2 + ((var1*(BMP280_S64_t)dig_P5)<<17);
   var2 = var2 + (((BMP280_S64_t)dig_P4)<<35);
   var1 = ((var1 * var1 * (BMP280_S64_t)dig_P3)>>8) + ((var1 * (BMP280_S64_t)dig_P2)<<12);
   var1 = (((((BMP280_S64_t)1)<<47)+var1))*((BMP280_S64_t)dig_P1)>>33;
   if (var1 == 0)
   {
      return 0; // avoid exception caused by division by zero
   }
   p = 1048576-adc_P;
   p = (((p<<31)-var2)*3125)/var1;
   var1 = (((BMP280_S64_t)dig_P9) * (p>>13) * (p>>13)) >> 25;
   var2 = (((BMP280_S64_t)dig_P8) * p) >> 19;
   p = ((p + var1 + var2) >> 8) + (((BMP280_S64_t)dig_P7)<<4);
   return (BMP280_U32_t)p;
```

3.12计算压力和温度

下图是压力和温度测量的详细算法。

该算法可从Bosch Sensortec和其销售和分销合作伙伴处作为参考C源代码("BMP28x_ API")提供给客户。

详情请与您的博世Sensortec代表联系。

Calculation of pressure and temperature for BMP280

Sample trimming values

Register Address (LSB / MSB)	Name	Value	Type
0x88 / 0x89	dig_T1	27504	unsigned short
0x8A / 0x8B	dig_T2	26435	short
0x8C / 0x8D	dig_T3	-1000	short
0x8E / 0x8F	dig_P1	36477	unsigned short
0x90 / 0x91	dig_P2	-10685	short
0x92 / 0x93	dig_P3	3024	short
0x94 / 0x95	dig_P4	2855	short
0x96 / 0x97	dig_P5	140	short
0x98 / 0x99	dig_P6	-7	short
0x9A / 0x9B	dig_P7	15500	short
0x9C / 0x9D	dig_P8	-14600	short
0x9E / 0x9F	dig_P9	6000	short
0xA0 / 0xA1			

Sample measurement values

Register Address (MSB / LSB / XLSB)	Name	Value	Type	
0xF7 / 0xF8 / 0xF9[7:4]	UT [20 bit]	519888	signed long (*)	(*) Value is always positive, even though the compensation functions expect a signed integer as input
0xFA / 0xFB / 0xFC[7:4]	UP [20 bit]	415148	signed long (*)	(*) Value is always positive, even though the compensation functions expect a signed integer as input

var1 =	128793,1787		var1 = (((double)adc_T)/16384.0 - ((double)dig_T1)/1024.0) * ((double)dig_T2);
var2 =	-370,8917052		var2 = ((((double)adc_T)/131072.0 - ((double)dig_T1)/8192.0) * (((double)adc_T)/131072.0 - ((double) dig_T1)/8192.0)) * ((double)dig_T3);
tfine =	128422		t_fine = (BMP280_S32_t)(var1 + var2);
T =	**25,08**	***Temperature [°C]***	T = (var1 + var2) / 5120.0;
integer result (**):	**2508**	***Temperature [1/100 °C]***	

var1 =	211,1435029		var1 = ((double)t_fine/2.0) - 64000.0;
var2 =	-9,523652701		var2 = var1 * var1 * ((double)dig_P6) / 32768.0;
var2 =	59110,65716		var2 = var2 + var1 * ((double)dig_P5) * 2.0;
var2 =	187120057,7		var2 = (var2/4.0)+(((double)dig_P4) * 65536.0);
var1 =	-4,302618389		var1 = (((double)dig_P3) * var1 * var1 / 524288.0 + ((double)dig_P2) * var1) / 524288.0;
var1 =	36472,21037		var1 = (1.0 + var1 / 32768.0)*((double)dig_P1);
p =	633428		p = 1048576.0 - (double)adc_P;
p =	100717,8456		p = (p - (var2 / 4096.0)) * 6250.0 / var1;
var1 =	28342,24444		var1 = ((double)dig_P9) * p * p / 2147483648.0;
var2 =	-44875,50492		var2 = p * ((double)dig_P8) / 32768.0;
p =	**100653,27**	***Pressure [Pa]***	p = p + (var1 + var2 + ((double)dig_P7)) / 16.0;
int32 result (**):	**100653**	***Pressure [Pa]***	
int64 result (**):	**25767236**	***Pressure [1/256 Pa]***	

(**) The actual result of the integer calculation may deviate slightly from the values shown here due to integer calculation rounding errors

4. 全局内存映射和寄存器描述

4.1总则

与设备的所有通信都是通过对寄存器的读写来完成的。寄存器的宽度为8位。有几个被保留的寄存器;它们不应该被写入，读取时也不保证有特定的值。关于界面的详细介绍，请参见第5章。

4.2内存映射

下面的表18给出了内存映射。没有显示保留寄存器。

Table 18: Memory map

Register Name	Address	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Reset state
temp_xlsb	0xFC	temp_xlsb<7:4>				0	0	0	0	0x00
temp_lsb	0xFB	temp_lsb<7:0>								0x00
temp_msb	0xFA	temp_msb<7:0>								0x80
press_xlsb	0xF9	press_xlsb<7:4>				0	0	0	0	0x00
press_lsb	0xF8	press_lsb<7:0>								0x00
press_msb	0xF7	press_msb<7:0>								0x80
config	0xF5	t_sb[2:0]			filter[2:0]				spi3w_en[0]	0x00
ctrl_meas	0xF4	osrs_t[2:0]			osrs_p[2:0]			mode[1:0]		0x00
status	0xF3					measuring[0]			im_update[0]	0x00
reset	0xE0	reset[7:0]								0x00
id	0xD0	chip_id[7:0]								0x58
calib25...calib00	0xA1…0x88	calibration data								individual

Registers:	**Reserved registers**	Calibration data	**Control registers**	**Data registers**	**Status registers**	**Revision**	**Reset**
Type:	**do not write**	read only	**read / write**	**read only**	**read only**	**read only**	**write only**

4.3寄存器描述

4.3.1寄存器0xD0 " id "

“id” 寄存器包含芯片识别号chip_id[7:0]，它是0x58。这个数字可以在设备完成上电复位后立即读取。

4.3.2寄存器0xE0 " reset "

“重置” 寄存器包含软重置词reset[7:0]。如果将值0xB6写入寄存器，则使用完整的power-on-reset过程重置设备。写入0xB6以外的其他值没有效果。读取值总是0x00。

4.3.3寄存器0xF3“status”

“状态”寄存器包含两个比特，表示设备的状态。

Table 19: Register 0xF3 *“status”*

Register 0xF3 *“status”*	Name	Description
Bit 3	measuring[0]	Automatically set to ‘1’ whenever a conversion is running and back to ‘0’ when the results have been transferred to the data registers.
Bit 0	im_update[0]	Automatically set to ‘1’ when the NVM data are being copied to image registers and back to ‘0’ when the copying is done. The data are copied at power-on-reset and before every conversion.

4.3.4寄存器0xF4 "ctrl_meas "

“ctrl_meas” 寄存器设置设备的数据采集选项。

Table 20: Register 0xF4 *“ctrl_meas”*

Register 0xF4 *“ctrl_meas”*	Name	Description
Bit 7, 6, 5	osrs_t[2:0]	Controls oversampling of temperature data. See chapter 3.3.2 for details.
Bit 4, 3, 2	osrs_p[2:0]	Controls oversampling of pressure data. See chapter 3.3.1 for details.
Bit 1, 0	mode[1:0]	Controls the power mode of the device. See chapter 3.6 for details.

Table 21: register settings *osrs_p*

osrs_p[2:0]	Pressure oversampling
000	Skipped (output set to 0x80000)
001	oversampling ×1
010	oversampling ×2
011	oversampling ×4
100	oversampling ×8
101, Others	oversampling ×16

Table 22: register settings *osrs_t*

***osrs_t*[2:0]**	**Temperature oversampling**
000	Skipped (output set to 0x80000)
001	oversampling ×1
010	oversampling ×2
011	oversampling ×4
100	oversampling ×8
101, 110, 111	oversampling ×16

4.3.5寄存器0xF5 " config "

“config” 寄存器设置设备的速率、过滤器和接口选项。在正常模式下对config寄存器的写入可能会被忽略。在睡眠模式下，写操作不会被忽略。

Table 23: Register 0xF5 *“config”*

Register 0xF5 *“config”*	**Name**	**Description**
Bit 7, 6, 5	t_sb[2:0]	Controls inactive duration $t_{standby}$ in normal mode. See chapter 3.6.3 for details.
Bit 4, 3, 2	filter[2:0]	Controls the time constant of the IIR filter. See chapter 3.3.3 for details.
Bit 0	spi3w_en[0]	Enables 3-wire SPI interface when set to ‘1’. See chapter 5.3 for details.

4.3.6 Register 0xF7…0xF9 "press "(_msb ， _lsb， _xlsb)

“压力”寄存器包含原始压力测量输出数据[19:0]。如何从设备上读取压力和温度信息，请参考3.9章。

Table 24: Register 0xF7 … 0xF9 *“press”*

Register 0xF7-0xF9 *“press”*	**Name**	**Description**
0xF7	press_msb[7:0]	Contains the MSB part up[19:12] of the raw pressure measurement output data.
0xF8	press_lsb[7:0]	Contains the LSB part up[11:4] of the raw pressure measurement output data.
0xF9 (bit 7, 6, 5, 4)	press_xlsb[3:0]	Contains the XLSB part up[3:0] of the raw pressure measurement output data. Contents depend on temperature resolution, see table 5.

4.3.7寄存器0xFA…0xFC "temp "(_msb ， _lsb， _xlsb)

"temp" 寄存器包含原始温度测量输出数据ut[19:0]。有关如何从设备中读取压力和温度信息的详细信息，请参阅第3.9章。

Table 25: Register 0xFA … 0xFC *"temp"*

Register 0xF7-0xF9 *"press"*	**Name**	**Description**
0xFA	temp_msb[7:0]	Contains the MSB part ut[19:12] of the raw temperature measurement output data.
0xFB	temp_lsb[7:0]	Contains the LSB part ut[11:4] of the raw temperature measurement output data.
0xFC (bit 7, 6, 5, 4)	temp_xlsb[3:0]	Contains the XLSB part ut[3:0] of the raw temperature measurement output data. Contents depend on pressure resolution, see Table 4.

5. 数字接口

BMP280支持I C和SPI数字接口;它充当两个协议的从服务器。I C接口支持标准、快速和高速模式。SPI接口支持4线制和3线制配置中的SPI模式' 00 ' (CPOL = CPHA = ' 0 ')和模式' 11 ' (CPOL = CPHA = ' 1 ')。

支持以下事务:

- 单字节写入
- 多字节写入(使用寄存器地址和寄存器数据对)
- 单字节读取
- 多字节读取(使用一个自动递增的寄存器地址)

5.1接口选择

接口选择根据CSB(芯片选择)状态自动完成。如果CSB连接到VDDIO，则I²C接口处于激活状态。如果CSB下拉，则SPI接口被激活。CSB下拉一次后(无论是否发生任何时钟周期)，I²C接口将被禁用，直到下一次上电复位。这样做是为了避免无意中将SPI流量解码为I²C数据到另一个slave。由于通电复位仅在同时建立VDD和VDDIO时执行，因此不存在由于所使用的通电顺序而导致错误协议检测的风险。但是，如果要使用I²C并且CSB没有直接连接到VDDIO，而是通过可编程引脚连接，则必须确保该引脚在设备上电复位期间已经输出VDDIO电平。如果不是这种情况，设备将被锁定在SPI模式而不响应I²C命令。

5.2 I²C接口

I 2C从接口兼容飞利浦I 2C规范2.1版。详细时间参见表27。支持所有模式(标准、快速、高速)。SDA和SCL并不是纯粹的开漏。两个衬垫都包含到VDDIO和GND的ESD保护二极管。由于器件不进行时钟拉伸，因此SCL结构是一个没有损耗能力的高阻输入。

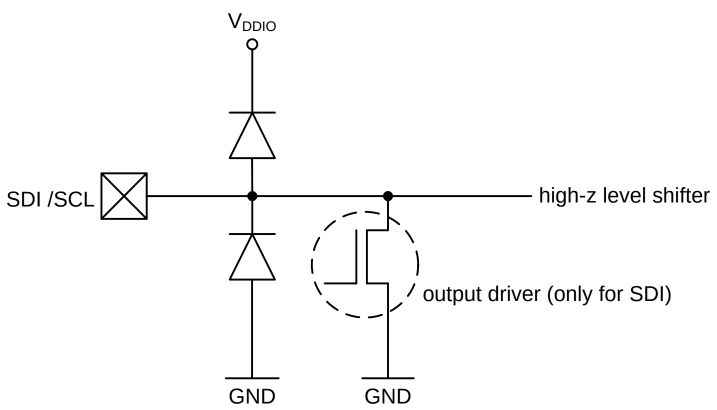

Figure 6: SDI/SCK ESD drawing

7位设备地址为111011x。6位MSB是固定的。最后一位可以通过SDO值更改，并且可以在操作过程中更改。将SDO连接到GND导致从地址1110110 (0x76);将其连接到VDDIO会导致从地址1110111 (0x77)，这是相同的

作为BMP180的I²C地址。SDO引脚不能保持浮动状态;如果保持浮动，I²C地址将是未定义的。

I C接口使用以下引脚:

- SCK: serial clock (SCL)
- SDI: data (SDA)
- SDO: Slave address LSB (GND = '0', V_{DDIO} = '1')

CSB必须连接到VDDIO才能选择I²C接口。SDI是双向开放漏地:它必须通过一个上拉电阻从外部连接到VDDIO。有关连接说明，请参阅第6章。

在I C协议图中使用以下缩写:

- S Start
- P Stop
- ACKS Acknowledge by slave
- ACKM Acknowledge by master
- NACKM Not acknowledge by master

5.2.1 I²C写

写入是通过以写模式发送从地址(RW = ' 0 ')来完成的，结果是从地址111011X0 (' X '由SDO引脚的状态决定。然后主机发送成对的寄存器地址和寄存器数据。事务由一个停止条件结束。如图7所示。

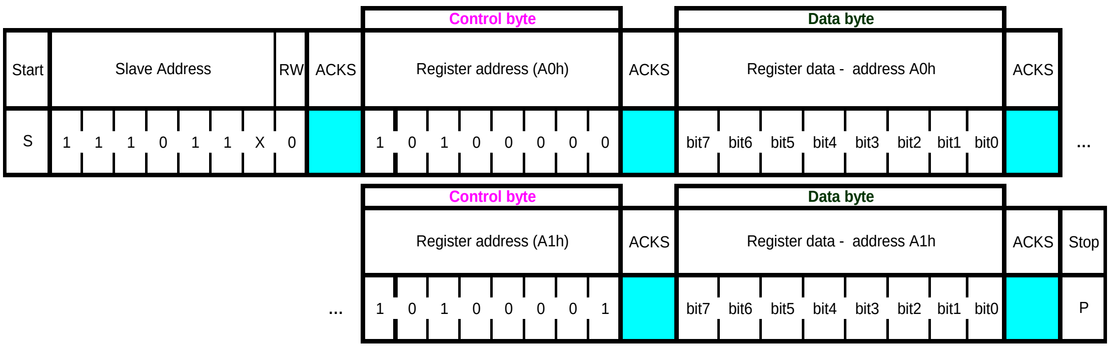

Figure 7: I²C multiple byte write (not auto-incremented)

5.2.2 I²C读取

为了能够读取寄存器，首先必须以写模式发送寄存器地址(从地址111011X0)。然后必须生成停止或重复启动条件。在此之后，从机以读模式(RW = ' 1 ')在地址111011X1寻址，之后从机从自动递增的寄存器地址发送数据，直到出现NOACKM和停止条件。图8描述了这一点，其中从寄存器0xF6和0xF7读取两个字节。

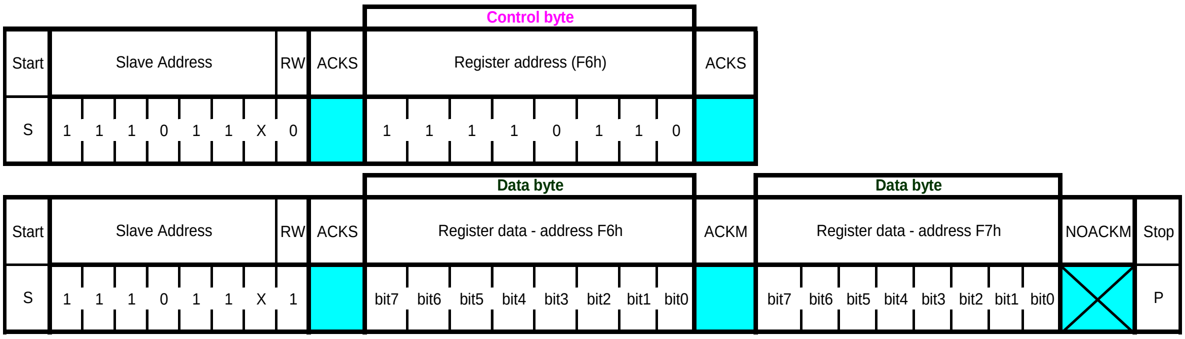

Figure 8: I²C multiple byte read

5.3 SPI接口

SPI接口兼容SPI模式’ 00 ’ (CPOL = CPHA = ’ 0 ’)和模式’ 11 ’ (CPOL = CPHA = ’ 1 ’)。模式’ 00 ’和’ 11 ’之间的自动选择是由CSB下降沿后的SCK值决定的。

SPI接口有4线制和3线制两种模式。两者的协议是一样的。通过将’ 1 ’设置为寄存器spi3w_en来选择3线模式。pad SDI作为数据板，采用三线制。

SPI接口使用以下引脚:

- CSB: chip select, active low
- SCK: serial clock
- SDI: serial data input; data input/output in 3-wire mode
- SDO: serial data output; hi-Z in 3-wire mode

有关连接说明，请参阅第6章。

CSB是主动低，并有一个集成的上拉电阻。SDI上的数据在SCK上升沿被设备锁存，SDO在SCK下降沿被更改。CSB低时通信开始，CSB高时通信停止;在CSB上的这些转换过程中，SCK必须是稳定的。SPI协议如图9所示。有关时间细节，请参阅表28。

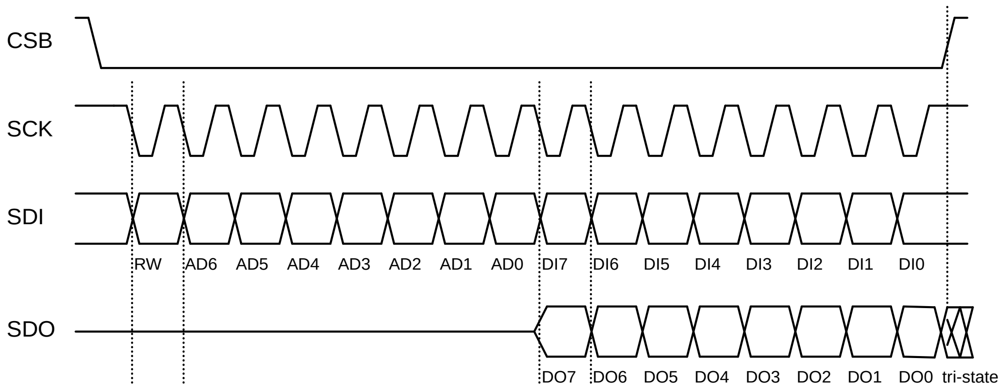

Figure 9: SPI protocol (shown for mode ‘11’ in 4-wire configuration)

在SPI模式下，只有7位寄存器地址被使用;寄存器地址的MSB不被使用，而是被一个读/写位(RW = ' 0 '表示写，RW = ' 1 '表示读)取代。
例如:address 0xF7通过SPI寄存器地址0x77访问。对于写访问，传输字节0x77，对于读访问，传输字节0xF7。

5.3.1 SPI写入

写入是通过降低CSB和发送对控制字节和寄存器数据来完成的。控制字节由SPI寄存器地址(=没有比特7的完整寄存器地址)和写入命令(bit7 = RW = ’ 0 ’)组成。可以在不引发CSB的情况下编写若干对。该事务由一个募集CSB结束。SPI写协议如图10所示。

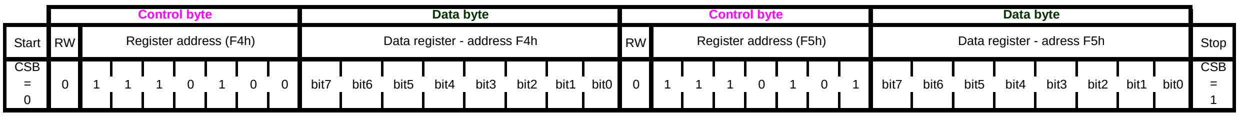

Figure 10: SPI multiple byte write (not auto-incremented)

5.3.2 SPI读取

读取通过降低CSB并首先发送一个控制字节来完成。控制字节由SPI寄存器地址(=没有第7位的完整寄存器地址)和读取命令(第7位= RW = ’ 1 ’)组成。写入控制字节后，数据从SDO引脚(三线模式下的SDI)发送出去;寄存器地址会自动递增。SPI读取协议如图11所示。

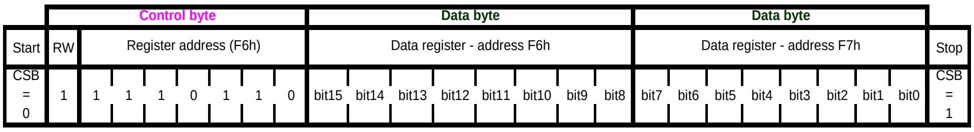

Figure 11: SPI multiple byte read

5.4接口参数规范

5.4.1接口通用参数

一般接口参数见表26。

Table 26: interface parameters

Parameter	Symbol	Condition	Min	Typ	Max	Units
Input – low level	Vil_si	V_{DDIO}=1.2V to 3.6V			0.2 * V_{DDIO}	V
Input – high level	Vih_si	V_{DDIO}=1.2V to 3.6V	0.8 * V_{DDIO}			V
Output – low level for I2C	Vol_SDI	V_{DDIO}=1.62V, iol=3 mA			0.2 * V_{DDIO}	V
Output – low level for I2C	Vol_SDI_1.2	V_{DDIO}=1.20V, iol=3 mA			0.23 * V_{DDIO}	V
Output – low level	Vol_SDO	V_{DDIO}=1.62V, iol=1 mA			0.2 * V_{DDIO}	V
Output – low level	Vol_SDO_1.2	V_{DDIO}=1.20V, iol=1 mA			0.23 * V_{DDIO}	V
Output – high level	Voh	V_{DDIO}=1.62V, ioh=1 mA (SDO, SDI)	0.8 * V_{DDIO}			V
Output – high level	Voh_1.2	V_{DDIO}=1.2V, ioh=1 mA (SDO, SDI)	0.6 * V_{DDIO}			V
Pull-up resistor	Rpull	Internal pull-up resistance to V_{DDIO}	70	120	190	kΩ
I²C bus load capacitor	Cb	On SDI and SCK			400	pF

5.4.2 I²C时序

对于I²C计时，使用以下缩写：

- “S&F mode” = standard and fast mode
- “HS mode” = high speed mode
- Cb = bus capacitance on SDA line

所有其他命名参考I²C规范2.1(2000年1月)。

I C时序图示于

图12。表27给出了相应的值。

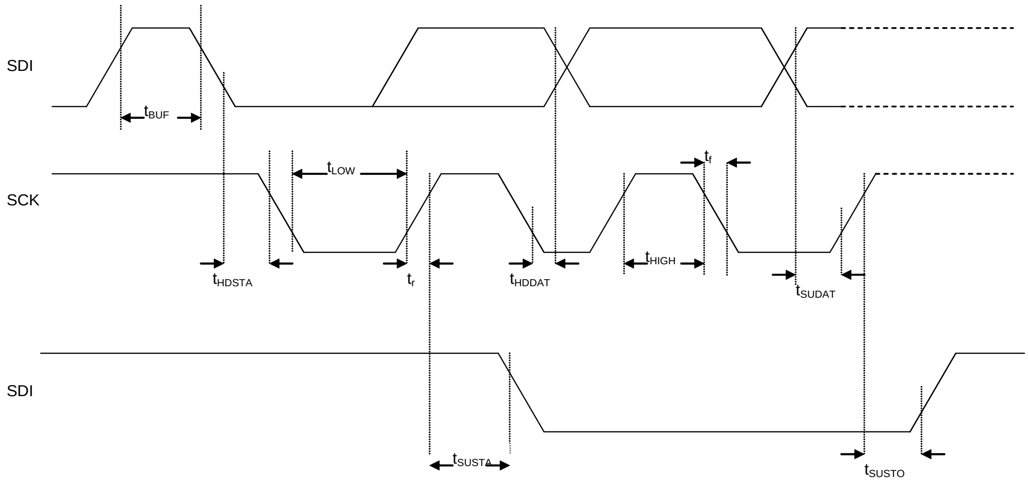

Figure 12: I²C timing diagram

Table 27: I²C timings

Parameter	Symbol	Condition	Min	Typ	Max	Units
SDI setup time	$t_{SU;DAT}$	S&F Mode HS mode	160 30			ns ns
SDI hold time	$t_{HD;DAT}$	S&F Mode, Cb≤100 pF S&F Mode, Cb≤400 pF HS mode, Cb≤100 pF HS mode, Cb≤400 pF	80 90 18 24		 115 150	ns ns ns ns
SCK low pulse	t_{LOW}	HS mode, Cb≤100 pF V_{DDIO} = 1.62 V	160			ns
SCK low pulse	t_{LOW}	HS mode, Cb≤100 pF V_{DDIO} = 1.2 V	210			ns

上述I2C特定时间对应于以下内部增加延迟:

- SDI和SCK输入之间的输入延迟:在标准和快速模式下，SDI的延迟通常比SCK多100纳秒，在高速模式下，通常比SCK多20纳秒。
- 从SCK下降沿到SDI输出传播的输出延迟在标准和快速模式下通常为140 ns，在高速模式下通常为70 ns。

5.4.3 SPI定时

SPI时序图如图13所示，而对应的值则在表28中给出。所有定时都适用于4线和3线SPI。

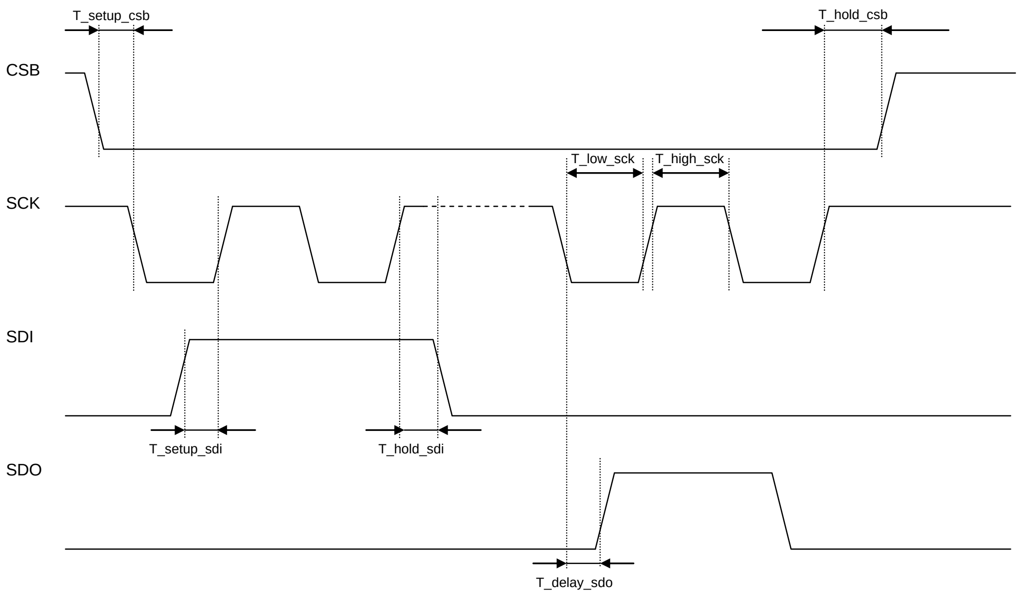

Figure 13: SPI timing diagram

Table 28: SPI timings

Parameter	Symbol	Condition	Min	Typ	Max	Units
SPI clock input frequency	F_spi		0		10	MHz
SCK low pulse	T_low_sck		20			ns
SCK high pulse	T_high_sck		20			ns
SDI setup time	T_setup_sdi		20			ns
SDI hold time	T_hold_sdi		20			ns
SDO output delay	T_delay_sdo	25pF load, V_{DDIO}=1.6V min			30	ns
SDO output delay	T_delay_sdo	25pF load, V_{DDIO}=1.2V min			40	ns
CSB setup time	T_setup_csb		20			ns
CSB hold time	T_hold_csb		20			ns

6. Pin-out and connection diagram

6.1 Pin-out

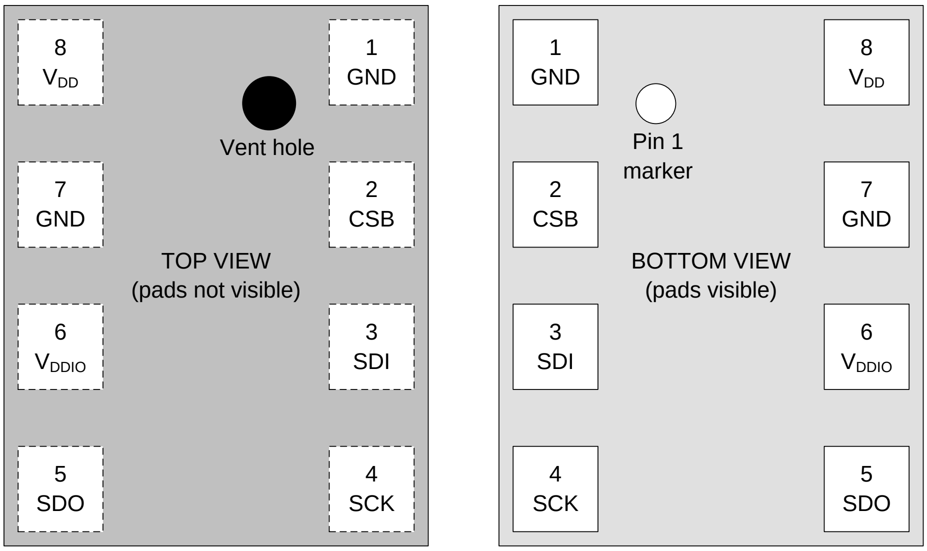

Figure 14: Pin-out top and bottom view

Table 29: Pin description

Pin	Name	I/O Type	Description	Connect to		
				SPI 4W	**SPI 3W**	**I²C**
1	GND	Supply	Ground	GND		
2	CSB	In	Chip select	CSB	CSB	V_{DDIO}
3	SDI	In/Out	Serial data input	SDI	SDI/SDO	SDA
4	SCK	In	Serial clock input	SCK	SCK	SCL
5	SDO	In/Out	Serial data output	SDO	DNC	GND for default address
6	V_{DDIO}	Supply	Digital interface supply	V_{DDIO}		
7	GND	Supply	Ground	GND		
8	V_{DD}	Supply	Analog supply	V_{DD}		

6.2 Connection diagram 4-wire SPI

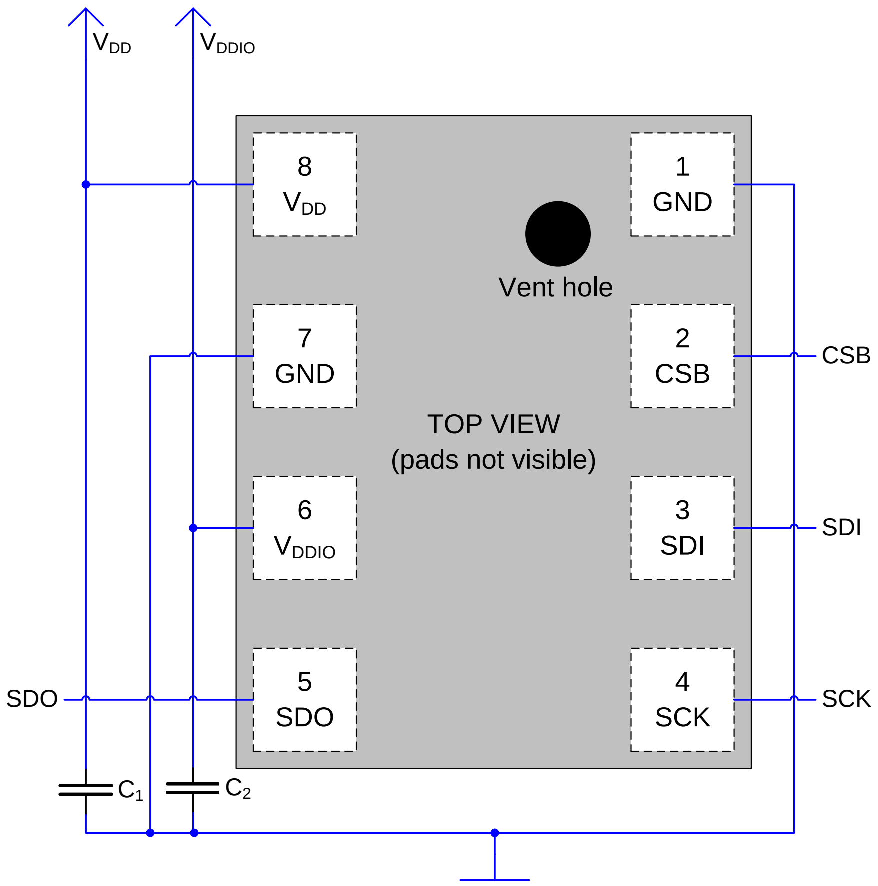

Figure 15: 4-wire SPI connection diagram (Pin1 marking indicated)

Note: the recommended value for C_1, C_2 is 100 nF.

6.3 Connection diagram 3-wire SPI

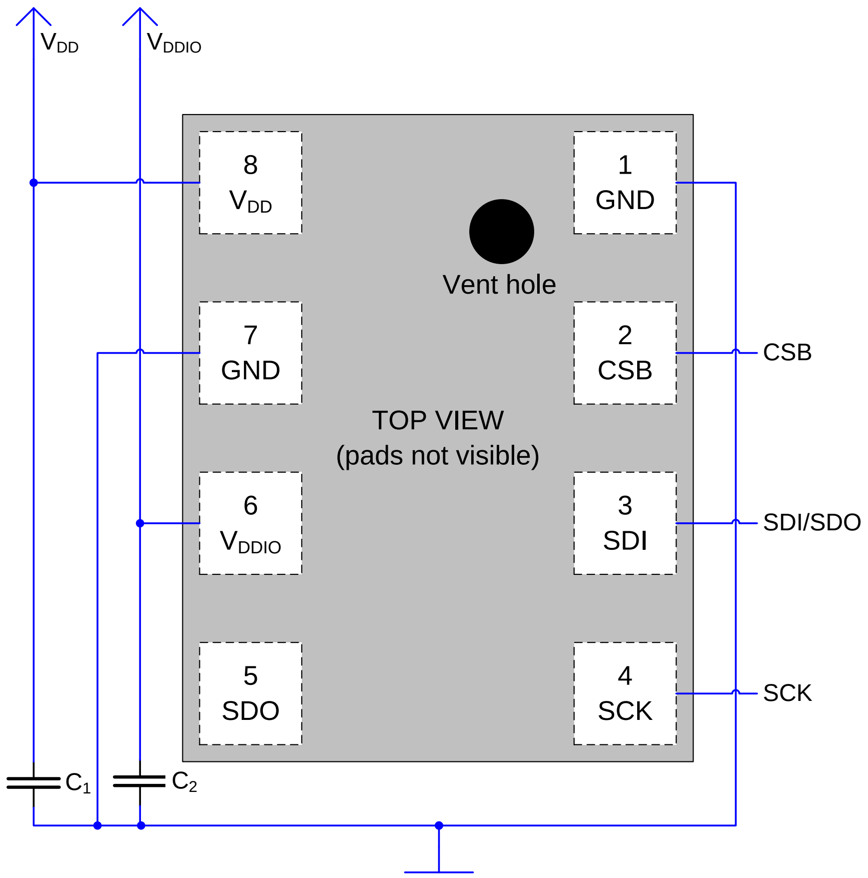

Figure 16: 3-wire SPI connection diagram (Pin1 marking indicated)

Note: the recommended value for C_1, C_2 is 100 nF.

6.4 Connection diagram I²C

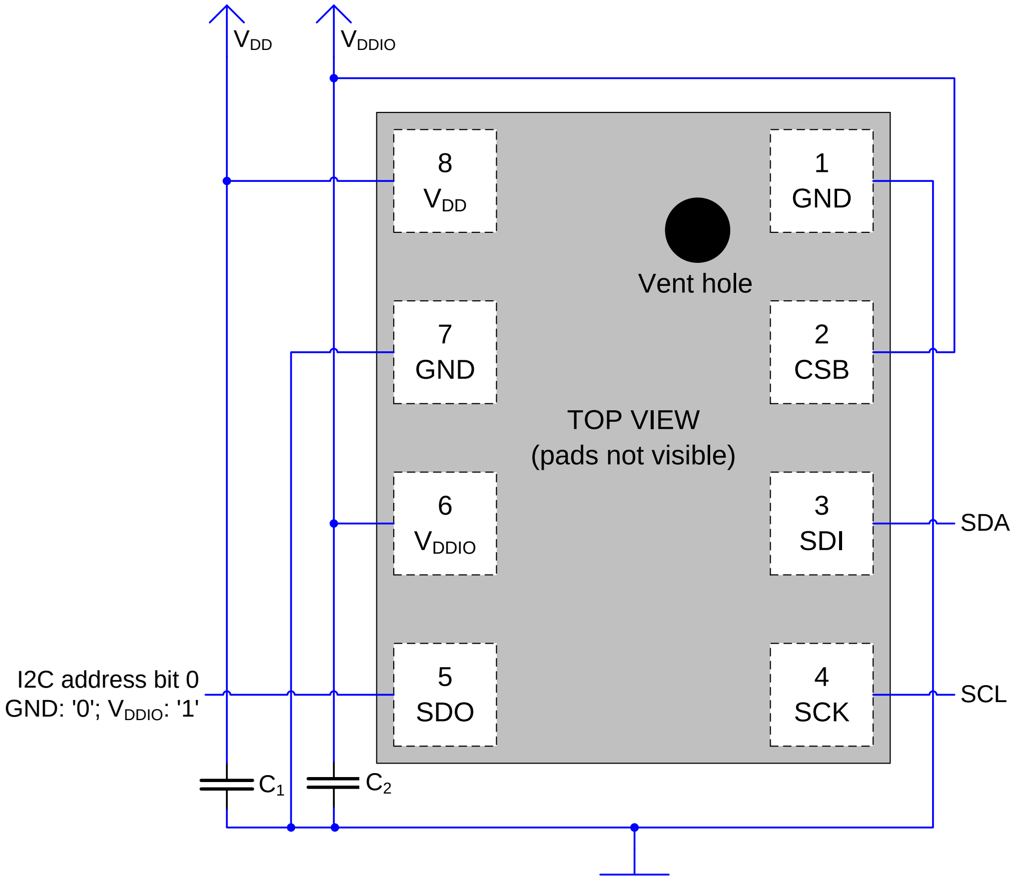

Figure 17: I²C connection diagram (Pin1 marking indicated)

Notes:

- The recommended value for C_1, C_2 is 100 nF.
- A direct connection between CSB and V_{DDIO} is recommended. If CSB is detected as low during startup, the interface will be locked into SPI mode. See chapter 5.1.

7. Package, reel and environment

7.1 Outline dimensions

The sensor housing is an 8-pin metal-lid LGA 2.0 × 2.5× 0.95 mm^3 package. Its dimensions are depicted in Figure 18.

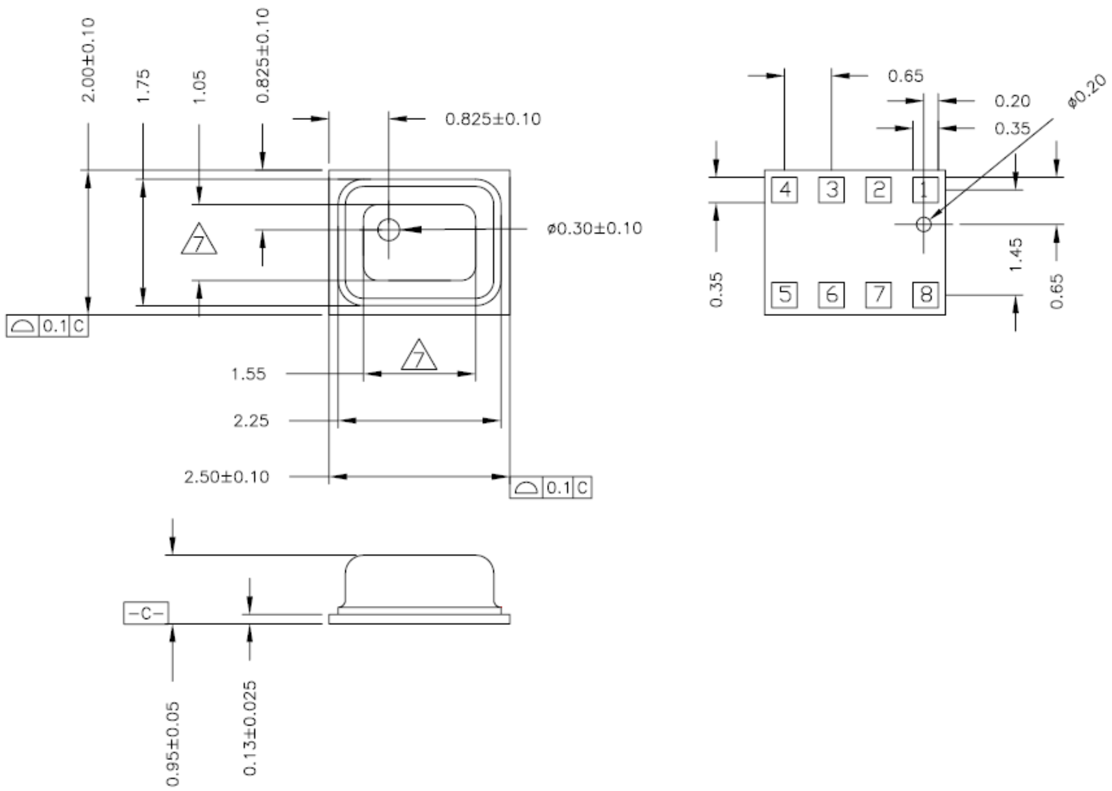

Figure 18: Package outline dimensions for top, bottom and side view

Note: General tolerances are ±50 µm (linear) and ±1° µm (angular)

7.2 Landing pattern recommendation

For the design of the landing pattern, the following dimensioning is recommended:

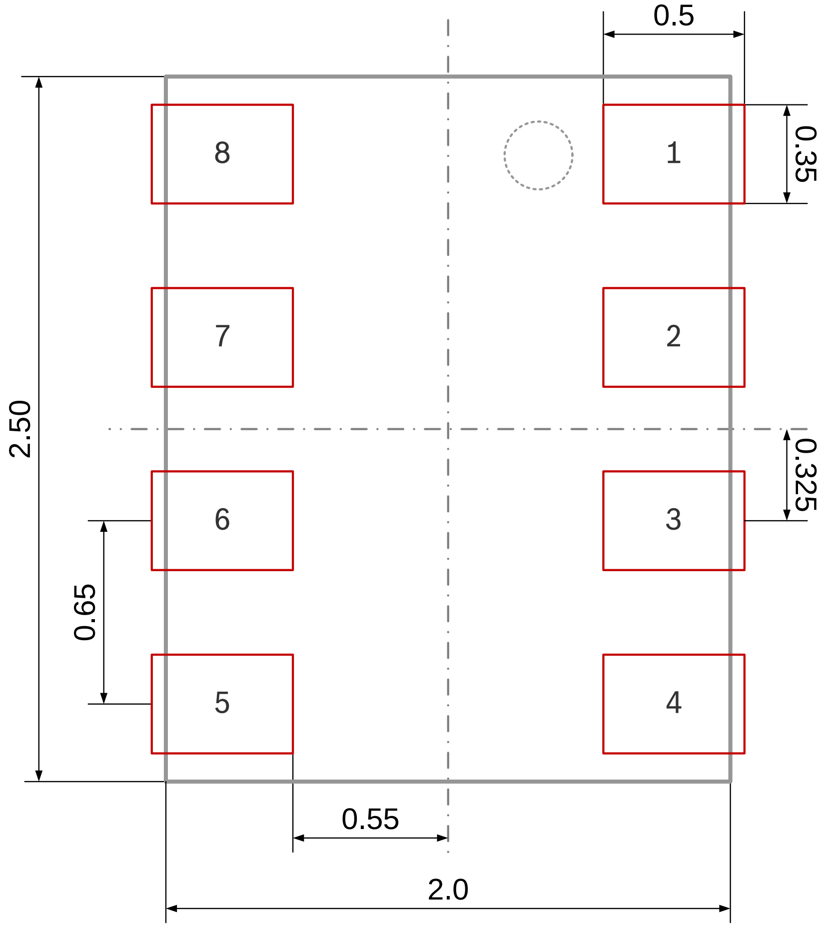

Figure 19: Recommended landing pattern (top view); dimensions are in mm

Note: red areas demark exposed PCB metal pads.

- In case of a solder mask defined (SMD) PCB process, the land dimensions should be defined by solder mask openings. The underlying metal pads are larger than these openings.
- In case of a non solder mask defined (NSMD) PCB process, the land dimensions should be defined in the metal layer. The mask openings are larger than the these metal pads.

7.3 Marking

7.3.1 Mass production devices

Table 30: Marking of mass production samples

Labeling	Name	Symbol	Remark
CCC TL ●	Lot counter	CCC	3 alphanumeric digits, variable to generate mass production trace-code
	Product number	T	1 alphanumeric digit, fixed to identify product type, T = "K" "K" is associated with the product BMP280
	Sub-con ID	L	1 alphanumeric digit, variable to identify subcon (L = "S" for underfill 0273300436)
	Orientation marker	●	Vent hole

7.3.2 Engineering samples

Table 31: Marking of engineering samples

Labeling	Name	Symbol	Remark
XXN CC ●	Eng. Sample ID	N	1 alphanumeric digit, fixed to identify engineering sample, N = " * " or "e" or "E"
	Sample ID	XX	2 alphanumeric digits, variable to generate trace-code
	Counter ID	CC	2 alphanumeric digits, variable to generate trace-code
	Orientation marker	●	Vent hole

7.4 Soldering guidelines

The moisture sensitivity level of the BMP280 sensors corresponds to JEDEC Level 1, see also:

- IPC/JEDEC J-STD-020C "Joint Industry Standard: Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices"
- IPC/JEDEC J-STD-033A "Joint Industry Standard: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices".

The sensor fulfils the lead-free soldering requirements of the above-mentioned IPC/JEDEC standard, i.e. reflow soldering with a peak temperature up to 260°C. The minimum height of the solder after reflow shall be at least 50µm. This is required for good mechanical decoupling between the sensor device and the printed circuit board (PCB).

Profile Feature		Pb-Free Assembly
Average Ramp-Up Rate (Ts_{max} to Tp)		3° C/second max.
Preheat – Temperature Min (Ts_{min}) – Temperature Max (Ts_{max}) – Time (ts_{min} to ts_{max})		 150 °C 200 °C 60-180 seconds
Time maintained above: – Temperature (T_L) – Time (t_L)		 217 °C 60-150 seconds
Peak/Classification Temperature (Tp)		260 °C
Time within 5 °C of actual Peak Temperature (tp)		20-40 seconds
Ramp-Down Rate		6 °C/second max.
Time 25 °C to Peak Temperature		8 minutes max.

Note 1: All temperatures refer to topside of the package, measured on the package body surface.

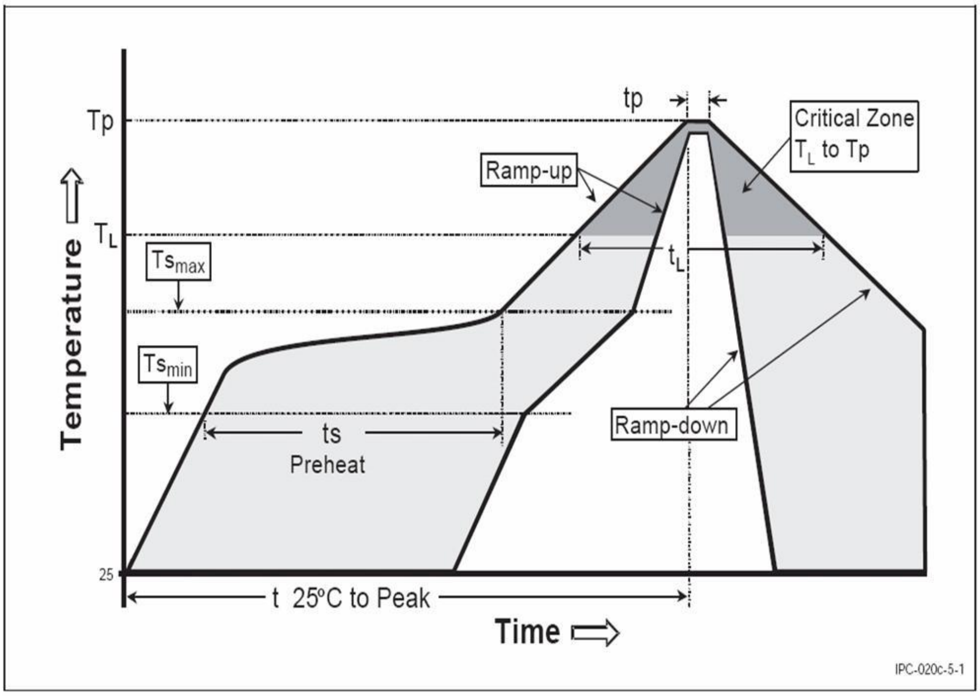

Figure 20: Soldering profile

7.5 Tape and reel specification

7.5.1 Dimensions

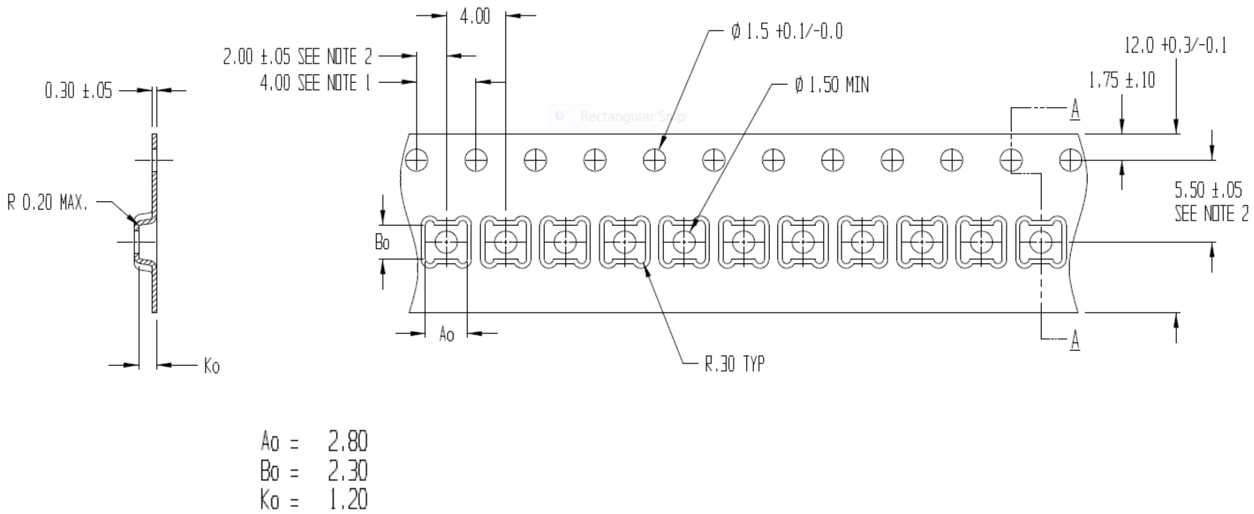

Figure 21: Tape and Reel dimensions

Quantity per reel: 10 kpcs.

7.5.2 Orientation within the reel

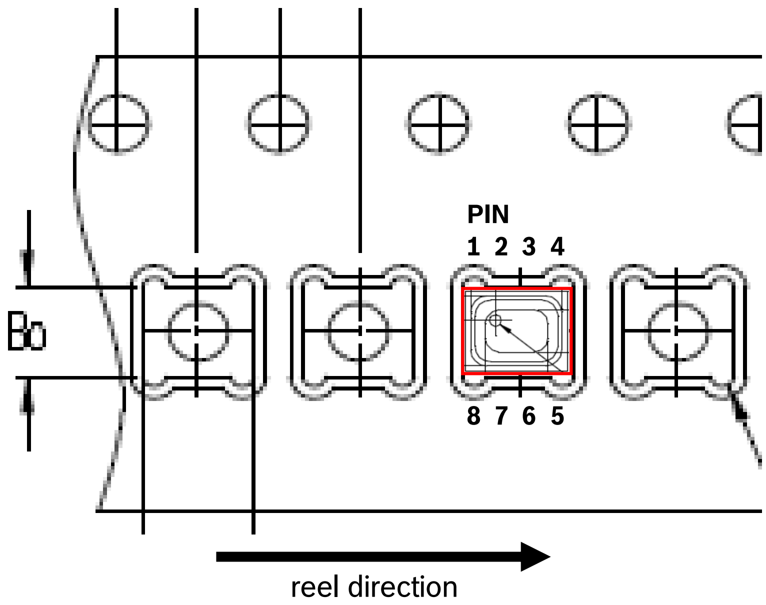

Figure 22: Orientation within tape

7.6安装和装配建议

在印刷电路板(PCB)上安装压力传感器时，除“处理、焊接和安装说明BMP280”外，还应考虑以下建议:

- 金属盖上方的间隙不小于0.1mm。
- 对于设备外壳，需要提供适当的通风，以防测量环境压力。
- 液体不得直接与设备接触。
- 在工作过程中，传感器芯片对光敏感，这可能会影响测量的精度(硅光电流)。通风口的位置尽量减少传感器芯片的光照。然而，BST建议避免将BMP280暴露在强光源下。
- 不能使用气相工艺进行焊接，因为传感器可能会损坏。

7.7环境安全

7.7.1 RoHS

BMP280传感器符合欧盟有害物质限制(RoHS)指令的要求，请参见:

欧洲议会和理事会2011年6月8日关于限制在电气和电子设备中使用某些有害物质的指令2011/65/EU。

7.7.2卤素含量

BMP280是无卤素的。有关分析结果的更多详细信息，请联系您的博世Sensortec代表。

7.7.3包装内部结构

在博世Sensortec改善其产品和确保大规模产品供应的雄心范围内，博世Sensortec为BMP280的LGA包提供了额外的来源(例如第二个来源)。

虽然Bosch Sensortec注意到上述所有技术包装参数对于所有来源都是100%相同的，但不同包装来源之间的化学含量和内部结构可能存在差异。然而，由于博世Sensortec广泛的产品认证过程的保证，这对BMP280产品的使用或质量没有影响。

8. 附录1:32位系统的计算公式

8.1浮点补偿公式

请注意，强烈建议使用Bosch　Sensortec提供的API来执行读取和补偿。如果不希望这样做，可以应用下面的代码，但风险由用户承担。压力和温度值都应以20位整数格式接收，存储在32位有符号整数中。

变量t_fine(带符号的32位)将精细分辨率温度值传递给压力补偿公式，可以作为一个全局变量来实现。

数据类型"BMP280_S32_t" 应该定义一个32位有符号整型变量类型，并且可以通常定义为"长符号int"。本规范的修订版本为1.1版。

```
// Returns temperature in DegC, double precision. Output value of "51.23" equals 51.23 DegC.
// t_fine carries fine temperature as global value
BMP280_S32_t t_fine;
double bmp280_compensate_T_double(BMP280_S32_t adc_T)
{
    double var1, var2, T;
    var1  = (((double)adc_T)/16384.0 - ((double)dig_T1)/1024.0) * ((double)dig_T2);
    var2  = ((((double)adc_T)/131072.0 - ((double)dig_T1)/8192.0) *
        (((double)adc_T)/131072.0 - ((double) dig_T1)/8192.0)) * ((double)dig_T3);
    t_fine = (BMP280_S32_t)(var1 + var2);
    T  = (var1 + var2) / 5120.0;
    return T;
}

// Returns pressure in Pa as double. Output value of "96386.2" equals 96386.2 Pa = 963.862 hPa
double bmp280_compensate_P_double(BMP280_S32_t adc_P)
{
    double var1, var2, p;
    var1 = ((double)t_fine/2.0) - 64000.0;
    var2 = var1 * var1 * ((double)dig_P6) / 32768.0;
    var2 = var2 + var1 * ((double)dig_P5) * 2.0;
    var2 = (var2/4.0)+(((double)dig_P4) * 65536.0);
    var1 = (((double)dig_P3) * var1 * var1 / 524288.0 + ((double)dig_P2) * var1) / 524288.0;
    var1 = (1.0 + var1 / 32768.0)*((double)dig_P1);
    if (var1 == 0.0)
    {
        return 0; // avoid exception caused by division by zero
    }
    p = 1048576.0 - (double)adc_P;
    p = (p - (var2 / 4096.0)) * 6250.0 / var1;
    var1 = ((double)dig_P9) * p * p / 2147483648.0;
    var2 = p * ((double)dig_P8) / 32768.0;
    p = p + (var1 + var2 + ((double)dig_P7)) / 16.0;
    return p;
}
```

8.2 32位定点补偿公式

请注意，强烈建议使用Bosch Sensortec提供的API来执行读取和补偿。如果不希望这样做，可以应用下面的代码，但风险由用户承担。压力和温度值都应以20位正格式接收，存储在32位有符号整数中。变量t_fine(带符号的32位)将精细分辨率温度值传递给压力补偿公式，可以作为一个全局变量来实现。数据类型"BMP280_S32_t" 应该定义一个32位有符号整型变量类型，通常可以定义为"长符号整型"。数据类型"BMP280_U32_t" 应该定义一个32位无符号整型变量类型，并且可以通常定义为"long unsigned int" 。用32位整数补偿压力值的精度通常为1 Pa (1-sigma)。在非常高的滤波器级别，这增加了一个明显的噪音量的输出值，并降低了他们的分辨率。

```
// Returns temperature in DegC, resolution is 0.01 DegC. Output value of "5123" equals 51.23 DegC.
// t_fine carries fine temperature as global value
BMP280_S32_t t_fine;
BMP280_S32_t bmp280_compensate_T_int32(BMP280_S32_t adc_T)
{
```

```
    BMP280_S32_t var1, var2, T;
    var1  = ((((adc_T>>3) - ((BMP280_S32_t)dig_T1<<1))) * ((BMP280_S32_t)dig_T2)) >> 11;
    var2  = (((((adc_T>>4) - ((BMP280_S32_t)dig_T1)) * ((adc_T>>4) - ((BMP280_S32_t)dig_T1))) >> 12) *
        ((BMP280_S32_t)dig_T3)) >> 14;
    t_fine = var1 + var2;
    T  = (t_fine * 5 + 128) >> 8;
    return T;
}

// Returns pressure in Pa as unsigned 32 bit integer. Output value of "96386" equals 96386 Pa = 963.86 hPa
BMP280_U32_t bmp280_compensate_P_int32(BMP280_S32_t adc_P)
{
    BMP280_S32_t var1, var2;
    BMP280_U32_t p;
    var1 = (((BMP280_S32_t)t_fine)>>1) - (BMP280_S32_t)64000;
    var2 = (((var1>>2) * (var1>>2)) >> 11 ) * ((BMP280_S32_t)dig_P6);
    var2 = var2 + ((var1*((BMP280_S32_t)dig_P5))<<1);
    var2 = (var2>>2)+(((BMP280_S32_t)dig_P4)<<16);
    var1 = (((dig_P3 * (((var1>>2) * (var1>>2)) >> 13 )) >> 3) + ((((BMP280_S32_t)dig_P2) * var1)>>1))>>18;
    var1 =((((32768+var1))*((BMP280_S32_t)dig_P1))>>15);
    if (var1 == 0)
    {
        return 0; // avoid exception caused by division by zero
    }
    p = (((BMP280_U32_t)(((BMP280_S32_t)1048576)-adc_P)-(var2>>12)))*3125;
    if (p < 0x80000000)
    {
        p = (p << 1) / ((BMP280_U32_t)var1);
    }
    else
    {
        p = (p / (BMP280_U32_t)var1) * 2;
    }
    var1 = (((BMP280_S32_t)dig_P9) * ((BMP280_S32_t)(((p>>3) * (p>>3))>>13)))>>12;
    var2 = (((BMP280_S32_t)(p>>2)) * ((BMP280_S32_t)dig_P8))>>13;
    p = (BMP280_U32_t)((BMP280_S32_t)p + ((var1 + var2 + dig_P7) >> 4));
    return p;
}
```

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10. Document history and modification

Rev. No	Chapter	Description of modification/changes	Date
0.1		Document creation	2012-08-06
1.0	9.2	Change of product use	2013-11-26
	Table 2	Update of min/max data (only for restricted version)	
		Added comment on the sampling rate	
1.1	1, 3.3.1	Changed value for resolution, values for *osrs_p* settings changed	2014-02-10
	5.2	Changed sentence and added drawing	2014-02-18
	3.7	Added max values for current consumption	2014-05-08
1.11	4.5.3	Modified write in normal mode	2014-06-25
	5.2	Modified SDI/SCK ESD drawing	
1.12	1	Changed min/max values for standby current, only valid for 25 °C	2014-07-12
	Table 1	Pressure resolution 0.16Pa	2014-07-12
1.13	Page 2	New technical reference codes added	2014-11-12
	7.3	New details about laser marking added	
1.14	Table 6	Changed contents of table	2015-05-04
	Page 1	Removed TRC 0 273 300 354 & 0273 300 391	
	Page 44	Updated RoHS directive to 2011/65/EU effective 8 June 2011	2015-05-07
1.15	Page 2, 3	Modified target devices, applications	2015-10-15
1.16		Special customer-only	2016-01-28
1.17	7.3	Added all available TRC	2016-06-07
1.18	7.3	New marking	2016-11-02
1.19	Page 1	Update of technical reference code	2018-01-08

Bosch Sensortec GmbH
Gerhard-Kindler-Strasse 9
72770 Reutlingen / Germany

contact@bosch-sensortec.com
www.bosch-sensortec.com

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