BMP390L

Digital pressure sensor

BMP390L –Datasheet

Document revision	1.2
Document release date	February 2020
Document number	BST-BMP390L-DS001-02
Technical reference code(s)	0273 017 023
Notes	Data and descriptions in this document are subject to change without notice. Product photos and pictures are for illustration purposes only and may differ from the real product appearance.

BMP390

Digital pressure sensor

The BMP390 is a digital sensor with pressure and temperature measurement based on proven sensing principles. The sensor module is housed in an extremely compact 10-pin metal-lid LGA package with a footprint of only 2.0 × 2.0 mm² and max 0.8 mm package height. Its small dimensions and its low power consumption of 3.2 µA @1Hz allow the implementation in battery driven devices such as mobile phones, GPS modules or watches.

Typical applications

- Vertical velocity indication (e.g. rise/sink speed)
- Internet of things
- Enhancement of GPS navigation
  (e.g. time-to-first-fix improvement, dead-reckoning, slope detection)
- Indoor navigation & localization (floor detection, elevator detection)
- Outdoor navigation, leisure and sports applications
- Weather forecast
- Health care applications (e.g. spirometry)
- Fitness applications like enhancement of calorie detection
- AR & VR applications
- Context awareness

Target Devices

- Flying toys
- Drones
- Handsets such as mobile phones, tablet PCs, GPS devices
- Navigation systems
- Portable health care devices
- Home weather stations
- Watches
- White goods

Key features

Table 1: Key Features of BMP390

Package	2.0 mm x 2.0 mm x 0.75 mm metal lid LGA
Digital interface	I²C (up to 3.4 MHz) and SPI (3 and 4 wire, up to 10 MHz)
Supply voltage	V_{DD} main supply voltage range: 1.65 V to 3.6 V V_{DDIO} interface voltage range: 1.2 V to 3.6 V
Relative accuracy	typ. ± 3 Pa, equiv. to ± 0.25 m (700 ... 1100 hPa, 25 . . . 40 °C)
Absolute accuracy	typ. ± 50 Pa (300 ...1100 hPa, -0 ...+65 °C)
Temperature coefficient offset	mean value ± 0.6 Pa/K (25 – 40°C @900 hPa)
Current consumption	3.2 µA at 1 Hz pressure and temperature 1.4 µA in sleep mode
Operating range	-40 – +85 °C, 300–1250 hPa
The product is RoHS compliant, halogen-free, MSL1	

BMP390 enables accurate altitude tracking and is specifically suited for mobile applications. The best-in-class TCO between -20-65°C for accurate altitude measurement over a wide temperature range of the BMP390 greatly enhance use cases like indoor navigation and localization. It is compatible for use with other Bosch sensors, including the IMUs like BMI260 for better performance, robustness and stability. The new BMP390 sensor offers outstanding design flexibility, providing a single package solution that can also be easily integrated into other existing and upcoming devices such as smartphones, wearables smart homes and industrial products.

The sensor is more accurate than its predecessor BMP380, covering a wide measurement range from 300 hPa to 1250 hPa.

This new barometric pressure sensor exhibits an attractive price-performance ratio coupled with low power consumption.

It is available in a compact 10-in 2.0 x 2.0 x 0.75 mm³ LGA package with metal lid

Due to the built-in hardware synchronization of the pressure sensor data and its ability to synchronize data from external devices such as acceleration sensors, the BMP390 is ideally suited for fitness and navigation applications which require highly accurate, low power and low latency sensor data fusion.

The new interrupt functionality provides simple access to data and storage. Examples of interrupts than can be used in a power efficient manner without using software algorithms include: Data ready interrupt, watermark interrupt (on byte level) or FIFO full interrupt.

BMP390 also includes a new FIFO functionality. This greatly improves ease of use while helping to reduce power consumption of the overall device system during full operation. The integrated 512 byte FIFO buffer supports low power applications and prevents data loss in non-real-time systems.

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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
- Typical values of currents and state machine timings are determined at 25°C, minimum/maximum values of currents are determined at -40°C/85°C.
- Minimum/maximum values of state machine timings are determined using corner lots over 0…+65 °C temperature range.

Table 2: General electrical parameter specifications

Operating Conditions BMP390						
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Operating temperature range	T_A	operational	-40	25	+85	°C
		full accuracy	0		+65	
Operating pressure range	P	full accuracy	300		1250	hPa
Sensor supply voltage	V_{DD}	ripple max. 50mVpp	1.65	1.8	3.6	V
Interface supply voltage	V_{DDIO}		1.2	1.8	3.6	V
Sleep current	I_{DDSL}	VDD = VDDIO = 1.8 V		1.4		µA
	I_{DDSL}	VDD = VDDIO = 3.6 V		1.5		µA
Peak current	I_{peak}	during pressure measurement		660	730	µA
Peak current	I_{DDT}	during temperature measurement		240	320	µA
Relative accuracy pressure[1]	A_{rel}	700 . . . 1100 hPa 25 . . . 40 °C, 10 kPa steps		±0.03		hPa
				+/-25 cm		cm
Offset temperature coefficient[4]	TCO	900 hPa 25 . . . 40 °C		±0.6[2]		Pa/K
Absolute accuracy	A^{P}_{full}	900 hPa 25 °C		±0.33		hPa

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[1] Per 10kPa steps

[2] Mean value

pressure	A^{P}_{full}	300. . . 1100 hPa 0 . . . 65 °C		±0.50		hPa
	A^{P}_{ext}	900. . . 1100 hPa 25 . . . 40 °C		±0.40		hPa
	A^{P}	1100. . . 1250 hPa 0. . . 65 °C		±0.50		hPa
	A^{P}	300. . . 1100 hPa -20 °C		±0.50		hPa
	A^{P}	900. . . 1100 hPa, 25-65°C post soldering + 168 HTOL				hPa
Resolution of output data in highest resolution mode at lowest bandwidth	R^{P}	Pressure		0.016		Pa
RMS Noise in pressure	$V_{p,full}$	25 Hz ODR, 16xOSR_P & 2xOSR_T		0.9		Pa
	$V_{p,filtered}$	Lowest bandwidth, highest resolution See chapter 3.4.4		0.02		Pa
Absolute accuracy temperature[5]	A^{T}	@ 25 °C		±0.5		°C
		0 . . . +65 °C		±1.50		°C
Long term stability[6]	ΔP_{stab}	12 months		±0.16		hPa
Solder drifts		Minimum solder height 50 µm		< ±0.8		hPa
Start-up time	$t_{startup}$	Time to first communication after both VDD > 1.8 V and VDDIO > 1.8 V			2	ms
Possible sampling rate	f_{sample}	*osrs_t* = *osrs_p* = 1; See chapter 3.9			200	Hz
ODR accuracy				+/-2	+/- 12[7]	%
Power-on time from stand-by mode					3	ms

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[5] 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.

[6] Long term stability is specified in the full accuracy operating pressure range 0 ... 65°C

[7] From 0 to 85°C (typical – 25°C)

2. Absolute maximum ratings

The absolute maximum ratings are provided in Table 3 .

Table 3: Absolute maximum ratings

Parameter	Symbol	Condition	Min	Max	Unit
Voltage at any supply pin		V_{DD} and V_{DDIO} Pin	-0.3	3.6	V
Voltage at any interface pin			Vss -0.3	V_{DDIO} + 0.3	V
Storage temperature		≤ 65% rel. H.	-45	+85	°C
Overpressure survivability	P_{OVER}			2 000 000	Pa
Mechanical shock	M_S	MIL-STD-883H 2002.5		20.000	g
Maximum allowable dust particle inside package	$Dust_{MAX}$	ISO 12103-1 A2		300[8]	µm
ESD		Charge device model (CDM)	Class C2a: 500V to <750V		
		Human body model (HBM)	Class 2: 2 kV		

Note: Stresses above these listed maximum ratings may cause permanent damage to the device. Exposure beyond specified electrical characteristics (Table 2) may affect device reliability or cause malfunction.

3. Functional description

The BMP390 consists of a Piezo-resistive pressure sensing element and a mixed-signal ASIC. The ASIC performs A/D conversions and provides the conversion results and sensor specific compensation data through a digital interface.

BMP390 provides highest flexibility to the designer and can be adapted to the requirements regarding accuracy, measurement time and power consumption by selecting from a high number of possible combinations of the sensor settings.

BMP390 can be operated in three power modes (see section 3.3):

sleep mode | normal mode | forced mode

In sleep mode, no measurements are performed. Normal mode comprises an automated perpetual cycling between an active measurement period and an inactive standby period. In forced mode, a single measurement is performed. When the measurement is finished, the sensor returns to sleep mode.

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[8] Defined by hole size

A set of oversampling settings is available ranging from ultra-low power to highest resolution setting in order to adapt the sensor to the target application. The settings are predefined combinations of pressure measurement oversampling and temperature measurement oversampling. Pressure and temperature measurement oversampling can be selected independently from 0 to 32 times oversampling (see sections 3.4.1 and 3.4.2):

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

BMP390 is equipped with a built-in IIR filter in order to minimize short-term disturbances in the output data caused by the slamming of a door or window. The filter coefficient ranges from 0 (off) to 127.

3.1. Block diagram

Figure 1 shows a simplified block diagram of the BMP390:

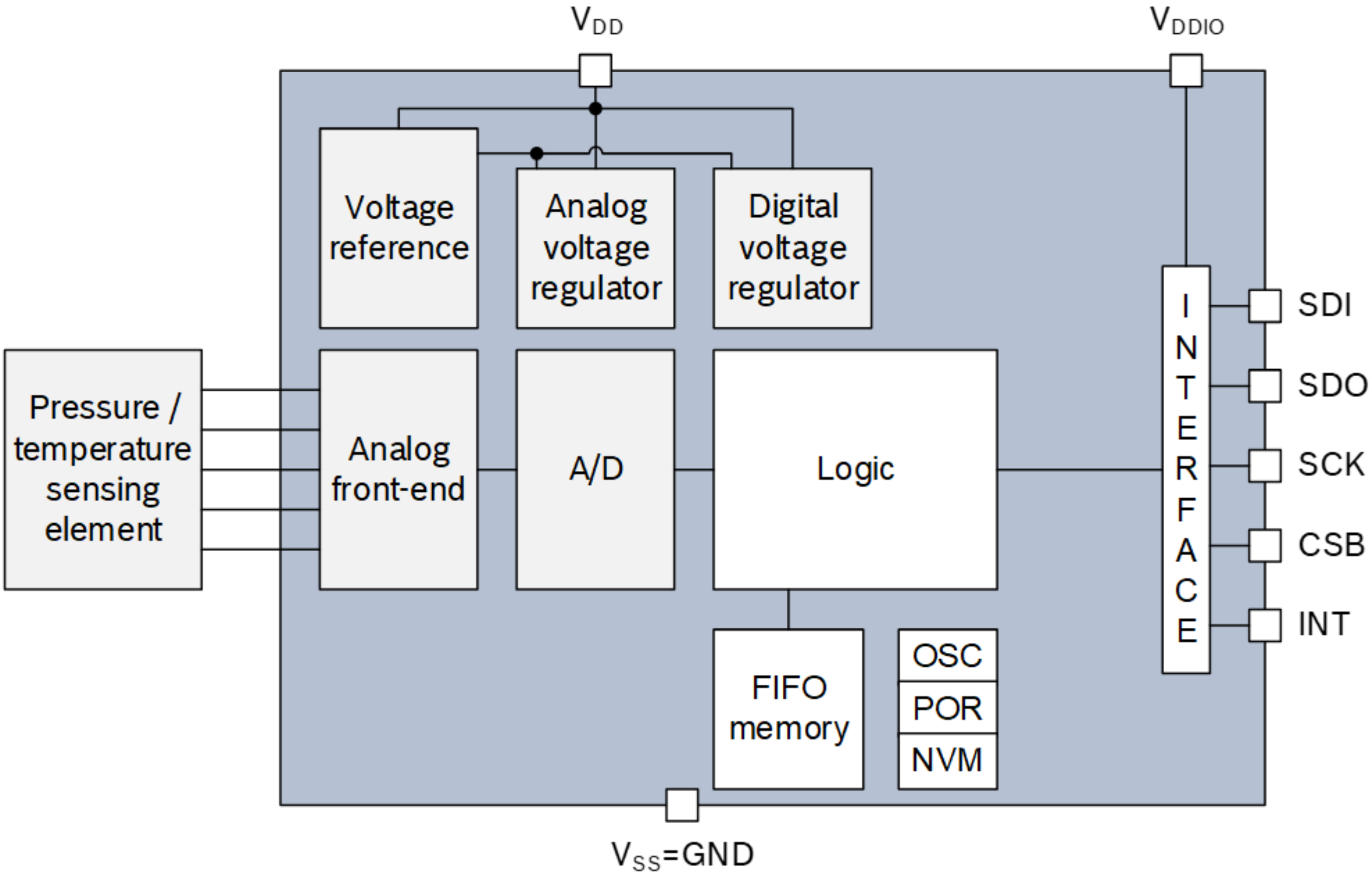

Figure 1: Block Diagram BMP390

3.2. Power management

The BMP390 has two separate power supply pins

- V_{DD} is the main power supply for all internal analog and digital regulator blocks.
- V_{DDIO} is a separate power supply pin, used for the supply of the digital interface.

V_{DD} and V_{DDIO} pins can be energized in any order.

A power-on reset generator is built in which resets the logic circuitry and the register values after the power-on sequence. The slope for ramp up time must not be less than 10 ms. After powering up, the sensor settles in sleep mode (see section 3.3).

Completion of the power-on-reset or soft reset is indicated by the bit *por_detected[0].* The bit is cleared after reading.

Holding any interface pin (SDI, SDO, SCK or CSB) at a logical high level when V_{DDIO} is switched off can permanently damage the device due caused by excessive current flow through the ESD protection diodes.

3.3. Power modes

The BMP390 offers three power modes: sleep mode, forced mode and normal mode. These can be selected using the mode[1:0] bits in control register *"pwr_ctrl"*.

Table 4: mode settings

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

3.3.1. Sleep mode

Sleep mode is set by default after power on reset. In sleep mode, no measurements are performed and power consumption (I_{DDSL}) is at a minimum. All registers are accessible; Chip-ID and compensation coefficients can be read.

3.3.2. Forced mode

In forced mode, a single measurement is performed according to selected measurement and filter options. When the measurement is finished, the sensor returns to sleep mode and the measurement results can be obtained from the data registers. For a next measurement, forced mode needs to be selected again. Forced mode is recommended for applications which require low sampling rate or host-based synchronization.

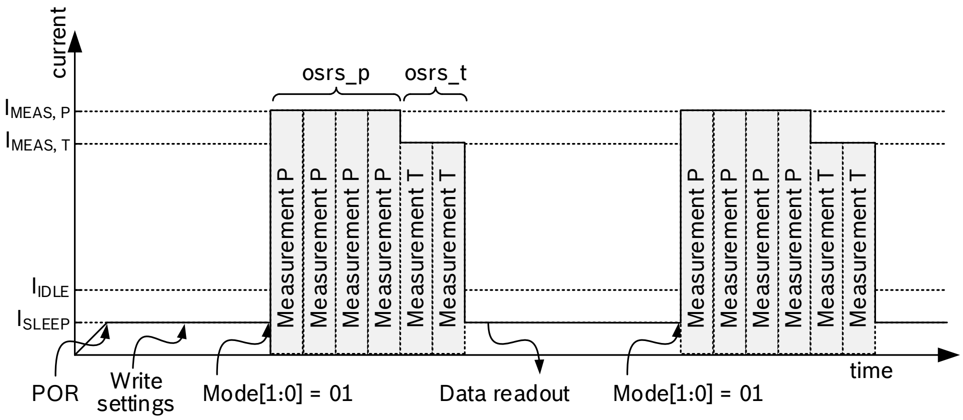

Figure 2: Force mode timing diagram

3.3.3. Normal mode

Normal mode continuously cycles between an (active) measurement period and an (inactive) standby period. The measurement rate is set in the *odr_sel* register (see 4.3.19), where various prescaler for sample frequencies $f_{sampling}$=200Hz can be selected. The sampling period τ calculated by

$$\tau_{sampling} = prescaler/f_{sampling}.$$

After setting the mode, measurement and filter options, the last measurement results can be obtained from the data registers without the need of further write accesses. Normal mode is recommended when using the IIR filter, and useful for applications in which short-term disturbances (e.g. blowing into the sensor) should be filtered.

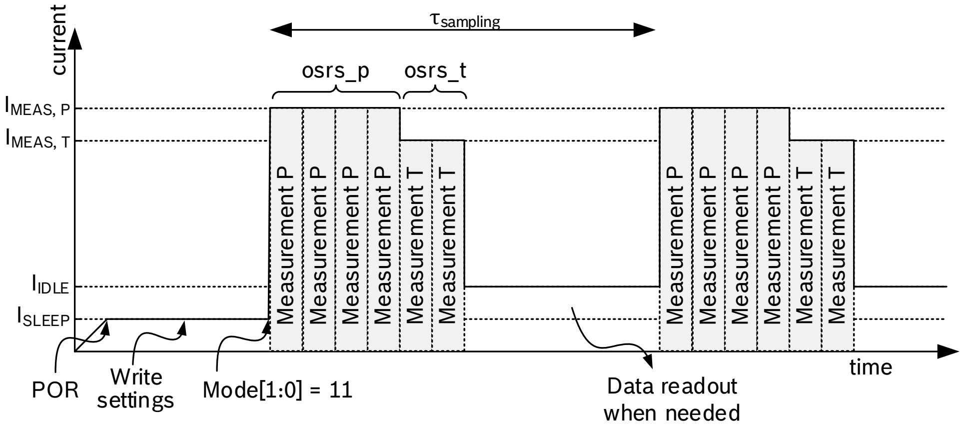

Figure 3: Normal mode timing diagram

3.3.4. Mode transition diagram

The supported mode transitions are displayed below. If the device is currently performing a measurement, execution of mode switching commands is delayed until the end of the currently running measurement period. Further mode change commands are ignored until the last mode change command is executed. Also, mode change commands that are not legal are ignored.

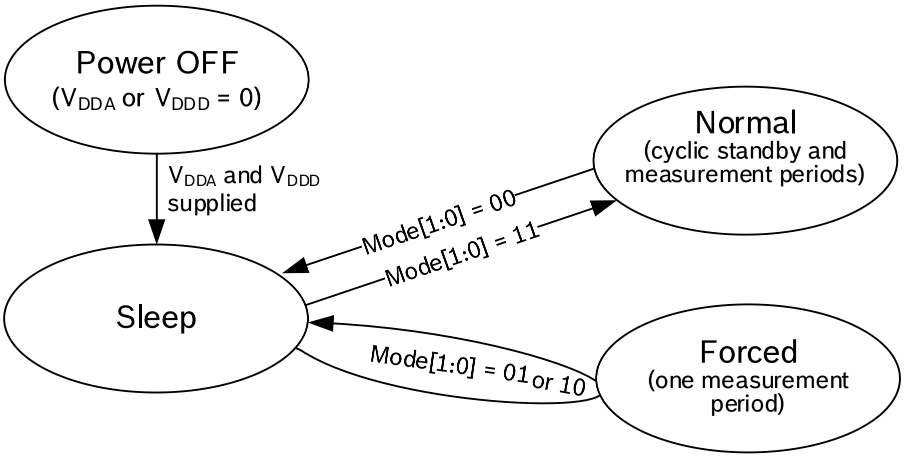

Figure 4: Mode transition diagram

3.4. Measurement flow

The BMP390 measurement period consists of a temperature and pressure measurement with selectable oversampling. After the measurement period, the data are passed through an optional IIR filter, which removes short-term fluctuations in pressure (e.g. caused by slamming a door). The flow is depicted in the diagram below.

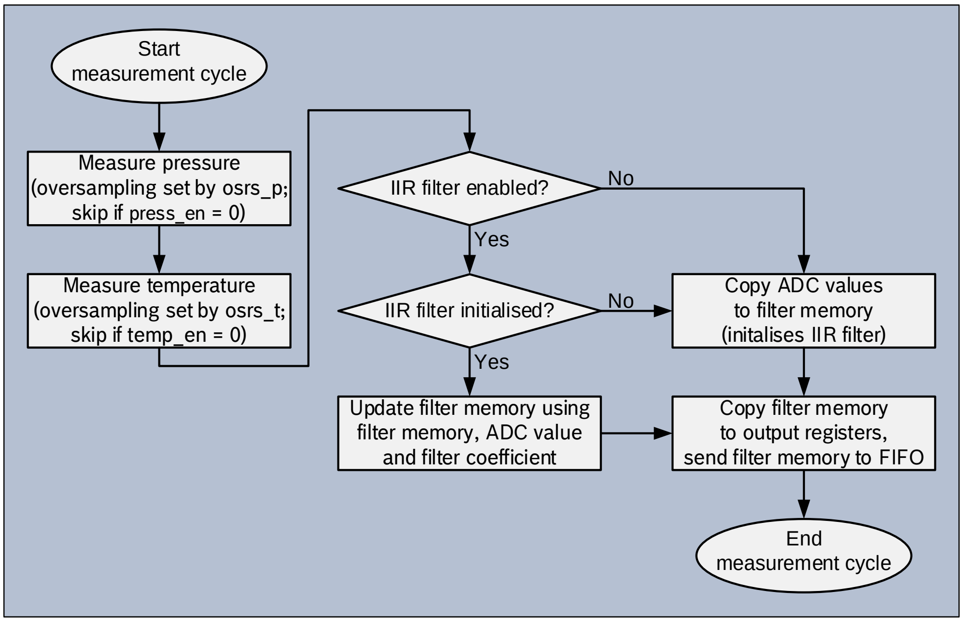

Figure 5: BMP390 measurement cycle

The individual blocks of the diagram above will be detailed in the following subsections.

3.4.1. Pressure measurement

Pressure measurement can be enabled or skipped. Skipping the measurement could be useful if BMP390 is used as temperature sensor. When enabled, several oversampling options exist. Each oversampling step reduces noise and increases the output resolution by one bit, which is stored in the XLSB data register.

Enabling the measurement is selected by press_en bit in *"PW_CTRL[0]"* register (see 4.3.17). The oversampling setting *osr_p* can be configured in *"OSR[2:0]"* register (see 4.3.18).

Table 5: *osr_p* settings

Oversampling setting	*osr_p*	Pressure oversampling	Typical pressure resolution	Recommended temperature oversampling
Ultra low power	000	×1	16 bit / 2.64 Pa	×1
Low power	001	×2	17 bit / 1.32 Pa	×1
Standard resolution	010	×4	18 bit / 0.66 Pa	×1
High resolution	011	×8	19 bit / 0.33 Pa	×1
Ultra high resolution	100	×16	20 bit / 0.17 Pa	×2
Highest resolution	101	×32	21 bit / 0.085 Pa	×2

3.4.2. Temperature measurement

Temperature measurement can be enabled or skipped. Skipping the measurement could be useful to measure pressure extremely rapidly. When enabled, several oversampling options exist. Each oversampling step reduces noise and increases the output resolution by one bit, which is stored in the XLSB data register. Noise and increases the output resolution by one bit, which is stored in the XLSB data register.

Enabling the measurement is selected by temp_en bit in *"PW_CTRL[1]"* register (see 4.3.17). The oversampling setting *osr_t* can be configured in *"OSR[5:3]"* register (see 4.3.18).

Table 6: *osrs_t* settings

osr_t	Temperature oversampling	Typical temperature resolution
000	×1	16 bit / 0.0050 °C
001	×2	17 bit / 0.0025 °C
010	×4	18 bit / 0.0012 °C
011	×8	19 bit / 0.0006 °C
100	×16	20 bit / 0.0003 °C
101	×32	21 bit / 0.00015 °C

It is recommended to base the value of *osr_t* on the selected value of *osrs_p* as per Table 5. Temperature oversampling above ×2 is possible, but will not significantly improve the accuracy of the pressure output any further. The reason for this is that the noise of the compensated pressure value depends more on the raw pressure than on the raw temperature noise. Following the recommended setting will result in an optimal noise-to-power ratio.

3.4.3. IIR filter

The environmental pressure is subject to many short-term changes, caused e.g. by slamming of a door or window, or wind blowing into the sensor. To suppress these disturbances in the output data without causing additional interface traffic and processor work load, the BMP390 features an internal IIR filter. It effectively reduces the bandwidth of the output signals[9]. The output of a next measurement step is filter using the following formula:

$$data_{filtered} = \frac{data_{filtered\_old} * filter\_coefficient + data_{ADC}}{filter\_coefficient + 1}$$

where data_filtered_old is the data coming from the previous acquisition, and data_ADC is the data coming from the ADC before IIR filtering.

The IIR filter can be configured using setting *iir_filter* in *"CONFIG"* register (see 4.3.21).

When writing to the register *filter*, the filter is reset. The next value will pass through the filter and be the initial memory value for the filter. IIR filter is reset if the temperature or pressure measurement is disabled (*temp_en* or *press_en* registers changed from '1' to '0') or when a transition from sleep mode to normal mode occurs. After enabling of pressure or temperature measurement, the filtering will start, thus the next incoming value will pass unfiltered and be the initial value of the IIR filter.

The step response (e.g. response to in sudden change in height) of different filter settings is displayed in Figure 6.

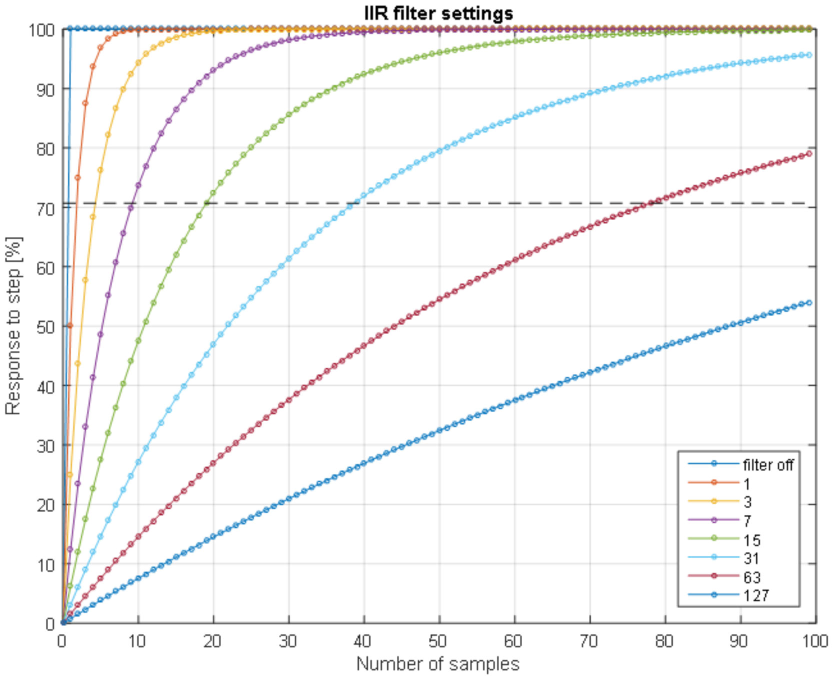

Figure 6: Step response at different IIR filter settings

3.4.4. Oversampling

Noise depends on the oversampling and filter settings selected. The stated values were determined in a controlled pressure environment and are based on the average standard deviation of 32 consecutive measurement points taken at highest sampling rate (for details please refer to Table 22). This is required to exclude long term drifts from the noise measurement.

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[9] 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 7: Noise in pressure

Typical RMS noise in pressure [Pa]								
Oversampling setting	**IIR filter coefficient**							
	off	**2**	**4**	**8**	**16**	**32**	**64**	**128**
Ultra low power	3.7	2.0	1.2	0.8	0.4	0.2	0.1	0.1
Low power	2.7	1.5	0.9	0.5	0.3	0.2	0.1	0.1
Standard resolution	2.0	1.1	0.7	0.4	0.3	0.2	0.1	0.04
High resolution	1.6	0.9	0.6	0.3	0.2	0.1	0.1	0.03
Ultra high resolution	1.2	0.6	0.4	0.2	0.1	0.1	0.04	0.03
Highest resolution	0.9	0.5	0.3	0.2	0.1	0.1	<0.1	<0.1

Table 8: Noise in temperature

Typical RMS noise in temperature [°C]	
Temperature oversampling	**IIR filter off**
Ultra low power	0.005
Low power	0.005
Standard resolution	0.005
High resolution	0.005
Ultra high resolution	0.004
Highest resolution	0.003

3.5. Filter selection

In order to select optimal settings, the following use cases are suggested:

Table 9: Recommended filter settings based on use cases

Use case	Mode	Over-sampling setting	osrs_p	osrs_t	IIR filter coeff. (see 4.3.21)	I_{DD} [µA] (see 3.8)	ODR [Hz] (see 3.4.1)	RMS Noise [cm] (see 3.4.4)
handheld device low-power (e.g. Android)	Normal	High resolution	x8	×1	2	145	12.5	11
handheld device dynamic (e.g. Android)	Normal	Standard resolution	×4	×1	4	310	50	10
Weather monitoring (lowest power),	Forced	Ultra low power	×1	×1	Off	4	1/60	55
Drop detection	Normal	Low power	×2	×1	Off	358	100	36
Indoor navigation	Normal	Ultra high resolution	×16	×2	4	560	25	5
Drone	Normal	Standard Resolution	x8	x1	2	570	50	11

3.6. FIFO Description

The BMP390 contains a 512 Bytes FIFO (first-in-first-out) data buffer. To enable data collecting in the FIFO, *fifo_mode* is set at ‘1’ and data to be collected are defined through *fifo_press_en* and *fifo_temp_en*. The FIFO mode is disabled, when no writing is defined which according to the following two cases:

- *fifo_mode*=’0’
- *fifo_mode*=’1’ and *fifo_press_en*=’0’ and *fifo_temp_en*=’0’

If the FIFO is disabled when FIFO byte count is greater than 0, no new frame is written to the FIFO, but FIFO is operational:

- Frames already written in the FIFO remain stored and can be read out
- FIFO interrupts and their corresponding statuses are still evaluated
- after all bytes are read out, Sensortime (if enabled) and Empty frames are generated
- FIFO can be flushed

3.6.1. FIFO input data

Storing of pressure and/or temperature measurement results is enabled by setting fifo_press_en=’1’ and fifo_temp_en=’1’ respectively. Storing of data can be enabled or disabled on a per-channel basis in any combination. Filtered or unfiltered data are stored to the FIFO; if data_select=”01”, filtered data are stored, otherwise unfiltered data are stored to the FIFO. The Number of bytes available in FIFO is readable through fifo_length_1<0> (MSBs) and fifo_length_0<7:0> (LSBs) registers.

The FIFO byte count registers fifo_length_0 and fifo_length_1 are updated only when a full frame has been written to FIFO and is available for read-out. FIFO byte count registers are also updated after each full-frame read from the FIFO.

FIFO byte count registers increment or decrement is equal to frame length; intermediate increments (corresponding to a partial frame) are not readable.

3.6.2. FIFO data sampling selection

The FIFO input data rate is reduced by selecting a down-sampling factor in register fifo_subsampling. Down-sampling factor ranges from 1 to 128 and is equal to $2^{\text{fifo\_subsampling}}$. Down-sampling is applied in the normal mode only and is aligned to the measurement timing grid. Down-sampling counter is reset and data saved to the FIFO at the end of the first measurement when a transition from sleep mode to normal mode occurs.

3.6.3. FIFO read out

FIFO is read out via fifo_data register. FIFO reads are never blocked, however an ongoing read from the FIFO does not block writing to the FIFO.

During burst read, the address counter stops incrementing when fifo_data address is reached; this allows a complete reading of the FIFO content within one burst read transaction.

3.6.4. FIFO overflow behavior

A FIFO overflow occurs if the FIFO is full and a new data is written to the FIFO. FIFO full means free space is less than maximum frame length (9 bytes). In case of overflow the FIFO can either stop recording data or overwrite the oldest data. The behavior is controlled by register fifo_stop_on_full.

- Streaming mode, fifo_stop_on_full=’0’:
  if the new frame does not fit inside the remaining free space in the FIFO RAM, FIFO will repeatedly delete the oldest frame until it creates enough space for the new one.
- FIFO stop-on-full mode, fifo_stop_on_full=’1’:
  The newest frame is discarded. Normal operation resumes if the FIFO full condition no longer persists.

3.6.5. FIFO Frames

One data frame is composed of a header and a set of data organize as described in table below.

Table 10: Data frame composition

Bit	7	6	5	4	3	2	1	0
Header	fh_mode[1:0]		fh_param[3:0]				0	0
Data	Data bytes							

The number of data bytes is defined by the header.

3.6.5.1. Header Format

Table 11: Header format

fh_mode[1:0]	Definition	fh_param[3:0]
10	Sensor frame	Sensor enable bits
01	Control frame: configuration error	0001
01	Control frame: FIFO input configuration change	0010

3.6.5.2. Sensor Frame Format

A sensor frame consists of a header and data bytes

Table 12: Sensor frame format

Bit	7	6	5	4	3	2	1	0
Header	1	0	s	t	0	p	0	0
Data	data bytes							

Sensor data in frame is defined by s (time), t (temperature) and p (pressure) sensor enable bits:

- If s=’1’, the frame corresponds to the sensor-time frame, in that case, t=p=’0’
- If t=’1’ or/and p=’1’, the frame corresponds to a normal pressure or/and a temperature frame
- If s=t=p=’0’, the frame corresponds to an empty frame

Table 13: Sensor-time frame

Bit	7	6	5	4	3	2	1	0
Header	1	0	1	0	0	0	0	0
Sensor-time	time_xlsb[7:0]							
	time_lsb[7:0]							
	time_msb[7:0]							

The data for the sensor-time frame consists of register sensor_time content at the time the sensortime frame transmission has started. A sensor-time frame is not stored in the FIFO, but append to every FIFO burst read operation after all data has been transmitted if fifo_time_en='1'.

Table 14: Normal pressure and temperature frame

Bit	7	6	5	4	3	2	1	0
Header	1	0	0	1	0	1	0	0
Temp	temp_xlsb[7:0]							
	temp_lsb[7:0]							
	temp_msb[7:0]							
Press	press_xlsb[7:0]							
	press_lsb[7:0]							
	press_msb[7:0]							

If one of t and p is '0', the corresponding data is not part of the frame; the frame is therefore reduced to 4 bytes.

A FIFO empty frame is a sensor frame with no sensor enabled. This frame is returned if the last frames was read-out or if FIFO is empty.

Table 15: FIFO empty frame format

Bit	7	6	5	4	3	2	1	0
Header	1	0	0	0	0	0	0	0
Data	0	0	0	0	0	0	0	0

When a configuration error is detected, a configuration error frame is stored into the FIFO

Table 16: Control frame: FIFO input configuration

Bit	7	6	5	4	3	2	1	0
Header	0	1	0	0	1	0	0	0
Opcode	0	0	0	0	0	0	0	1

Table 17: Control frame: configuration error

Bit	7	6	5	4	3	2	1	0
Header	0	1	0	0	0	1	0	0
Opcode	0	0	0	0	0	0	0	1

If FIFO is enabled and a change in registers “FIFO_CONF_2” or “OSR” or “ODR” or “CONFIG” or press_en or temp_en occurs, a control frame is inserted just before the first sensor frame with new configuration is stored to the FIFO. If multiple configuration change becomes active at the same time, only one control frame is inserted. Configuration changes are tracked when the device is in normal mode.

3.6.6. **Corner cases**

3.6.6.1. Under-read

In case the FIFO is under-read (not all frames were taken from the FIFO, but the last frame read was read entirely), the next readout will continue at the frame that was just about to be sent.

3.6.6.2. Partial frame read

In case the FIFO is under-read and a partial data frame read occurred (not all frames were taken from the FIFO, and the last frame read was not read entirely), the entire last data frame is repeated upon the next read access.

When fifo_stop_on_full=’0’, the oldest frames are overwritten when new frames are available and the FIFO is full. When this happens, the partially read data frame is not repeated but the oldest frame available in the RAM is sent instead.

Sensortime frame is not repeated when read only partially, its payload always contains current sensortime counter value.

If the read of the frame is interrupted after two or more bits of the frame’s last byte were already read, then frame is discarded even though not all bits were read and the frame was read only partially.

3.6.6.3. Over-read

If the burst read continues after all frames have been read out, a sensortime frame is sent after the FIFO becomes empty during a burst read operation if fifo_time_en=’1’. After that or when FIFO was completely read, the empty frame is returned as long as the burst read is

active.

3.6.7. FIFO flush conditions

The FIFO can be flushed by issuing either *fifo_flush* or a *softreset* in the command register “CMD” (see 4.3.23):

Table 18: fifo_fluch and softreset commands

	Value
fifo_flush	0xB0
softreset	0xB6

3.7. Interrupts

The BMP390 provides an interrupt pin (INT), which allows to signal certain events to the host processor. Different events can be mapped to the interrupt pin, which all are processed with a logical OR.

The available interrupts are listed below and can be read in the “INT_STATUS” register (see 4.3.9):

- FIFO watermark interrupt
- FIFO full interrupt
- Data ready interrupt

3.7.1. Interrupt default mode

After a power-on or soft reset has completed, the interrupt pin is in push-pull and active high mode.

3.7.2. Interrupt pin latching

The chip can be operated in non-latched or latched mode:

- Non-latched mode: Interrupts’ conditions are selected as a contributors to the INT pad. INT pad is de-asserted as soon as the conditions of all the interrupts propagated to the INT pad are not valid.
  For data ready, interrupt contribution is de-asserted by reading *int_status* or after 2.5ms after assertion of the interrupt.
  For FIFO interrupts, INT pad contributions are not affected by fifo_data readings, only by the interrupt conditions
- Latched mode: Interrupt statuses are selected as contributors of the INT pad.

The minimum interrupt pulse width is $T_{int} = 1\mu s$

3.7.3. Monitoring

The status of interrupt bits is always visible in the “INT_STATUS” register. (see 4.3.9) for details.

3.7.4. Interrupt Pin Configuration

The interrupt pin / pad is configured by the Bits in the “INT_CTRL” register (see 4.3.15). However, the status bits are not influenced thereby.

The output mode of the INT pad is controlled by *int_od* bit:

Table 19: int_od

int_od=’0’	**Push-pull**
int_od=’1’	Open-drain

The level of the interrupt pad can be configured and switched by *int_level* between active low and active high:

Table 20: int_level

int_level=’0’	**active_low**
int_level=’1’	active_high

The latching of interrupts for INT pad and INT_STATUS register can be enabled by *int_latch=’1’* or disabled by *int_latch=’0’*.

FIFO interrupts are mapped to the INT pad by enabling the respective functions. For mapping FIFO watermark reached interrupt to the pad, the *fwtm_en* bit shall be written to ’1’ (disabling by ‘0’). The FIFO full interrupt can be mapped by writing *ffull_en* with ‘1’).

3.7.5. Interrupt functions

3.7.5.1. FIFO watermark interrupt

The FIFO watermark interrupt is used to signal, that fill level of the FIFO has reached a pre-set limit.

Fifo_length_1 & fifo_length_0 ≥ *fifo_wtm_1 & fifo_wtm_0*

The watermark level can be set and adjusted by the user by writing the registers and 0x15 “FIFO_WTM_0” and 0x16 “FIFO_WTM_1” (see 4.3.12) in a single burst transaction. If the FIFO watermark level is set to zero, the interrupt condition will never be satisfied.

The status of the watermark interrupt can be read back through the *fwm_int* bit. The interrupt condition is also updated after the end of a serial interface transaction which wrote into the registers fifo_wtm_0 or fifo_wtm_1.

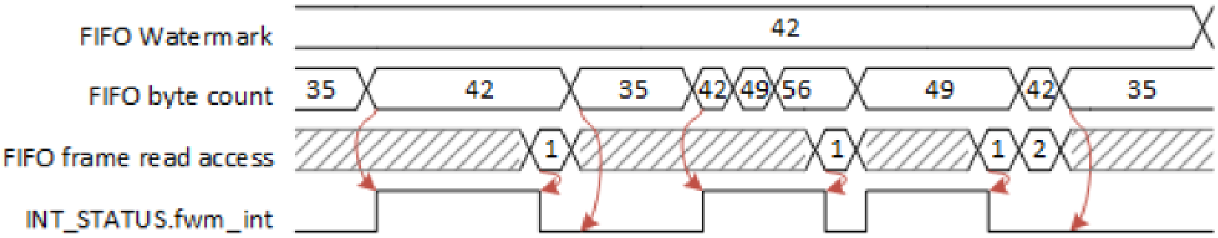


Figure 7: FIFO watermark interrupt, non-latched with reads from FIFO

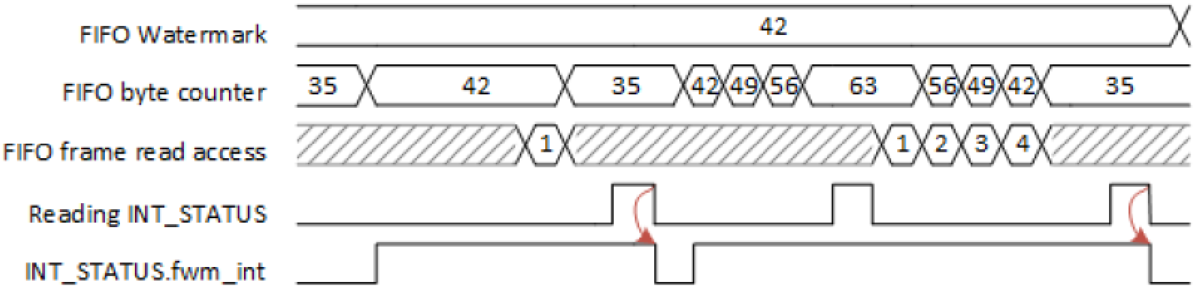


Figure 8: FIFO watermark interrupt, latched, with reads from FIFO

3.7.5.2. FIFO full interrupt

FIFO Full interrupt status is asserted when the full interrupt condition is satisfied, when the filling level of the FIFO number of unread bytes in the FIFO = *fifo_length_1 & fifo_length_0* is equal or higher than 504.

The status of the FIFO full interrupt can be read back through the ffull_int bit. Interrupt status is cleared by reading the ffull_int bit high '1' when the FIFO filling level is lower than 504.

The FIFO full interrupt is propagated to INT pad only when it is enabled by setting bit ffull_en='1'. Latching mode configuration bit int_latch selects whether the interrupt status or condition is propagated to the INT pad.

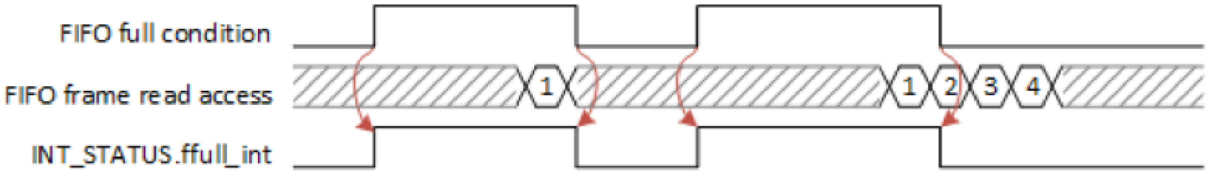


Figure 9:FIFO full interrupt, non-latched, with reads from FIFO

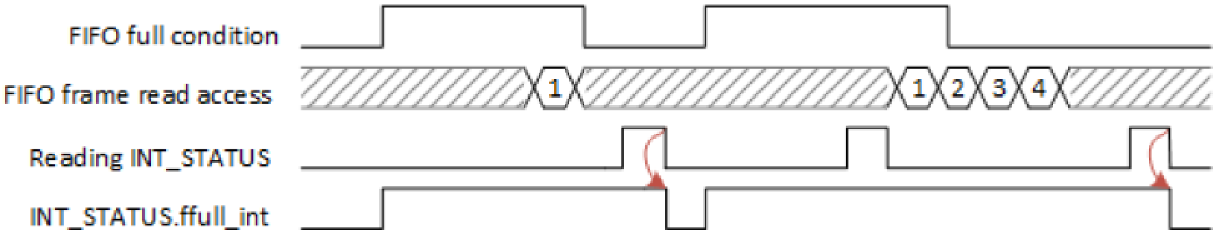


Figure 10: FIFO full interrupt, latched, with reads from FIFO

3.7.5.3. Data ready

Data ready interrupt status *int_status.drdy* is asserted after a pressure and temperature measurement ends and conversion results are stored to the data registers and to the FIFO. The status of the interrupt can be read back through the *drdy* bit. The data ready interrupt is propagated to INT pad when it is enabled by setting *drdy_en*='1'. Interrupt status is cleared by reading *drdy* bit high '1'. Data ready INT pad contribution is cleared automatically 2.5 ms after the interrupt assertion in the non-latched mode (int_latch='0').

Corner cases:

- If data ready interrupt is changed from latched to non-latched mode (int_latched changed from '1' to '0') after the interrupt was already asserted;
  timer is not running and it is not starting during the ongoing measurement, self-clearing does not happen. Timer is starting when next data ready comes.
- If data ready is changed to be propagated to INT pad (*drdy_int* changed from '0' to '1') after the interrupt was already asserted;
  data ready INT pad contribution remains '0' until next data ready interrupt assertion.

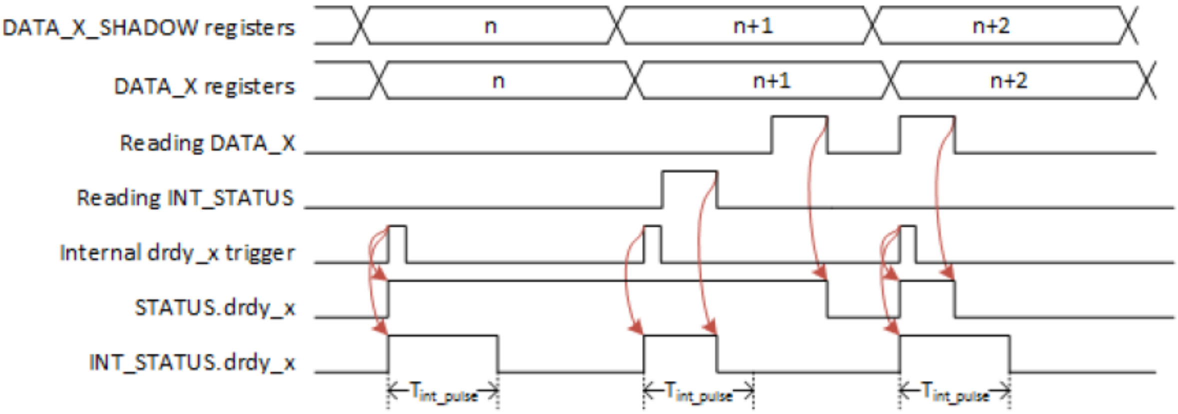


Figure 11: Data ready interrupt, non-latched mode, with read of data registers

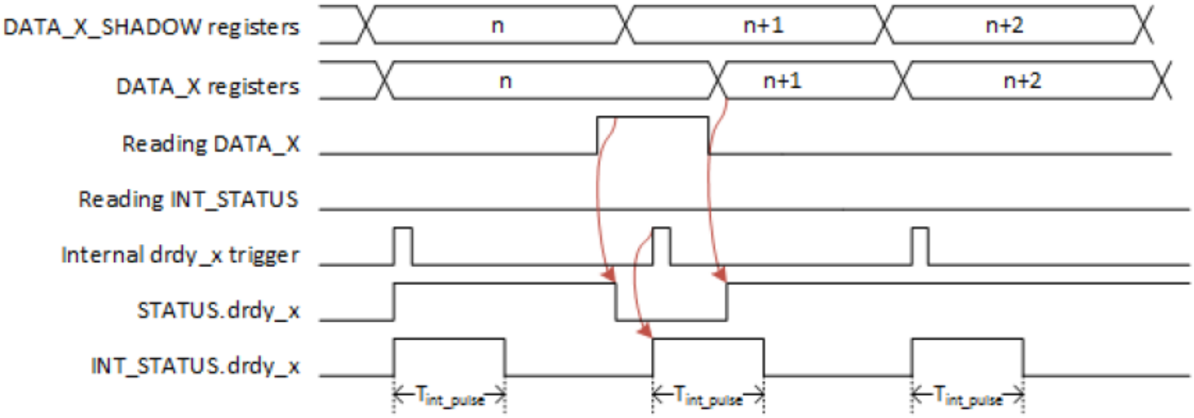


Figure 12: Data ready interrupt, non-latched mode, with read of data registers during register update

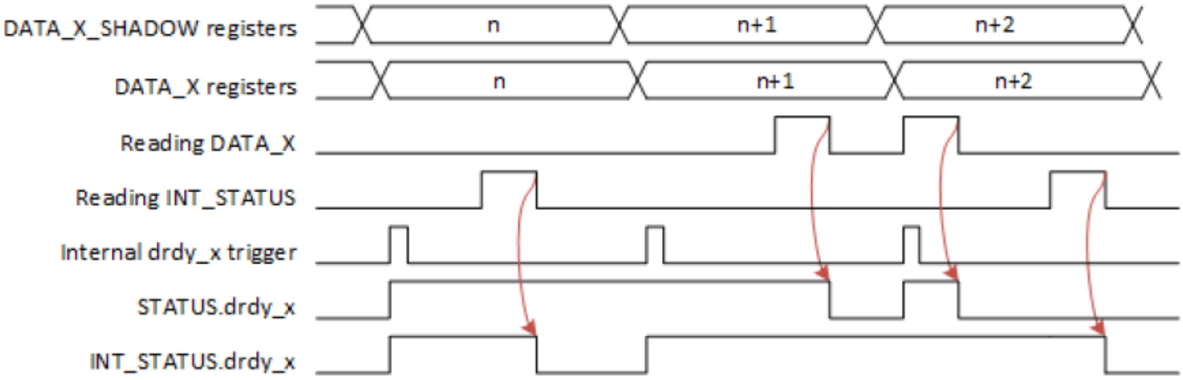


Figure 13: Data ready interrupt, latched mode, with read of data registers

3.8. Current consumption

The current consumption depends on ODR and oversampling setting. The values given below are normalized to an ODR of 1 Hz. The actual consumption at a given ODR can be calculated by multiplying the consumption in Table 21 with the ODR used. The actual ODR is defined either by the frequency at which the user sets forced measurements or by oversampling and sampling period settings in normal mode in Table 24.

Table 21: Current consumption

Oversampling setting	Pressure oversampling	Temperature oversampling		I_{DD} [µA] @ 1 Hz forced mode	
			Typ	Calculated Forced Mode	Max
Ultra low power	×1	×1	3.4	4.3	7.4
Low power	×2	×1	4.8	5.6	9.3
Standard resolution	×4	×1	7.8	8.2	12.8
High resolution	×8	×1	13.8	13.3	19.5
Ultra high resolution	×16	×2	26.2	24.3	33.5
highest resolution	×32	×2	46.4	45.0	59.2

3.9. Measurement timings

The rate at which measurements can be performed in forced mode depends on the oversampling settings *osr_t* and *osr_p*. Thus in normal mode, the measurement rate is determined by the sampling frequency fsample.

3.9.1. Measurement time

The following table explains the typical and maximum measurement time based on selected oversampling setting. The minimum achievable frequency is determined by the maximum measurement time.

Table 22: measurement time

Oversampling setting	Pressure oversampling	Temperature oversampling	Measurement time[ms]		Measurement rate [Hz]	
			Typ	Max	Typ	Min
Ultra low power	×1	×1	4.82	5.70	207.08	175.39
Low power	×2	×1	6.84	7.96	146.00	125.56
Standard resolution	×4	×1	10.88	12.48	91.83	80.07
High resolution	×8	×1	18.69	21.53	52.71	46.42
Ultra high resolution	×16	×2	37.14	41.89	26.91	23.86
highest resolution	×32	×2	69.46	78.09	14.39	12.80

3.9.2. Measurement rate in forced mode and normal mode

In both forced mode and normal mode the pressure and temperature measurement duration follow the equation:

$$T_{conv} = 234\mu s + press\_en \cdot (392\mu s + 2^{osr\_p} \cdot 2020\mu s) + temp\_en \cdot (163\mu s + 2^{osr\_t} \cdot 2020\mu s)$$

With:

T_{conv} = total conversion time in µs

$press\_en$ = “0” or “1”, depending of the status of the press_en bit

$temp\_en$ = “0” or “1”, depending of the status of the temp_en bit

2^{osr_p} = amount of pressure oversampling repetitions

2^{osr_t} = amount of temperature oversampling repetitions

Maximum possible readout frequency in forced mode (typical):

$$f_{max} = \frac{1}{T_{conv}[\mu s] \cdot 10^6}$$

Maximum possible readout frequency in normal mode:

$$odr\_sel = \left\lceil log_2\left(\frac{200Hz}{f_{max}[Hz]}\right)\right\rceil$$

$$f_{max\_normal\_mode} = \frac{200Hz}{2^{odr\_sel}}$$

3.10. Data readout from data registers

To read out data after a conversion, it is strongly recommended to use a burst read and not address every register individually. This will prevent a possible mix-up of bytes belonging to different measurements and reduce interface traffic. Data readout is done by starting a burst read from register *press_xlsb* to *temp_msb*. The data are read out in an unsigned 24-bit format both for pressure and for temperature.

The timing for data readout in forced mode should be done so that the maximum measurement times (see Sec. 3.9.1) are respected. In normal mode, readout can be done at a speed similar to the expected data output rate (see Sec. 3.9.2). After the uncompensated values of temperature and pressure have been read, the actual pressure and temperature need to be calculated using the compensation parameters stored in the device. The procedure is elaborated in Sec. 3.11.

3.10.1. Data register shadowing

In normal mode, measurement timing is not necessarily synchronized to readout. This means that new measurement results may become available while the user is reading the results from the previous measurement. In this case, shadowing is performed in order to guarantee data consistency. Shadowing will only work if all data registers are read in a single burst read. Therefore, the user must use burst reads if he does not synchronize data readout with the measurement cycle. Using several independent read commands may result in inconsistent data.

If a new measurement is finished and the data registers are still being read, the new measurement results are transferred into shadow data registers. The content of shadow registers is transferred into data registers as soon as the user ends the burst read, even if not all data registers were read. Reading across several data registers can therefore only be guaranteed to be consistent within one measurement cycle if a single burst read command is used. The end of the burst read is marked by the rising edge of CSB pin. After the end of the burst read, all user data registers are updated at once.

3.11. Output compensation

The BMP390 output consists of the ADC output values (including oversampling). However, each sensing element behaves differently, and thus in order to receive the most accurate physical values for temperature and pressure, compensation formulae have to be applied to the raw output values received from the sensor. The coefficients used for the compensation are stored into the devices' non-volatile memory (NVM) during production (see Table 23). For the compensation formula please see Appendix 0.

3.11.1. Memory Map Trimming Coefficients

Table 23: Trimming Coefficient listing in register map with size and sign attributes

Memory-ADR_Read [dec]	Memory-ADR_Read [hex]	Register content	Trimming Coefficient	Size	Sign
69	0x45	NVM_PAR_P11<7:0>	NVM_PAR_P11	8 Bit	signed
68	0x44	NVM_PAR_P10<7:0>	NVM_PAR_P10	8 Bit	signed
67	0x43	NVM_PAR_P9<15:8>	NVM_PAR_P9	16 Bit	signed
66	0x42	NVM_PAR_P9<7:0>			
65	0x41	NVM_PAR_P8<7:0>	NVM_PAR_P8	8 Bit	signed
64	0x40	NVM_PAR_P7<7:0>	NVM_PAR_P7	8 Bit	signed
63	0x3F	NVM_PAR _P6<15:8>	NVM_PAR _P6	16 Bit	unsigned
62	0x3E	NVM_PAR _P6<7:0>			
61	0x3D	NVM_PAR _P5<15:8>	NVM_PAR _P5	16 Bit	unsigned
60	0x3C	NVM_PAR _P5<7:0>			
59	0x3B	NVM_PAR _P4<7:0>	NVM_PAR _P4	8 Bit	signed
58	0x3A	NVM_PAR _P3<7:0>	NVM_PAR _P3	8 Bit	signed
57	0x39	NVM_PAR _P2<15:8>	NVM_PAR _P2	16 Bit	signed
56	0x38	NVM_PAR _P2<7:0>			
55	0x37	NVM_PAR _P1<15:8>	NVM_PAR _P1	16 Bit	signed
54	0x36	NVM_PAR _P1<7:0>			
53	0x35	NVM_PAR _T3<7:0>	NVM_PAR _T3	8 Bit	signed
52	0x34	NVM_PAR _T2<15:8>	NVM_PAR _T2	16 Bit	unsigned
51	0x33	NVM_PAR _T2<7:0>			
50	0x32	NVM_PAR _T1<15:8>	NVM_PAR _T1	16 Bit	unsigned
49	0x31	NVM_PAR _T1<7:0>			

4. Global memory map and register description

4.1. General remarks

All communication with the device is performed by reading and writing registers. All Registers have a width of 8 bits. There are several registers which are reserved; they should not be written to and no specific value is guaranteed when they are read. For details on the interface, consult chapter 5.

4.2. Datasheet Memory Map

The memory map is given in Table 24.

Table 24: BMP390 memory map

read/write	read only	write only	reserved

Register Address	Register Name	Default Value	7	6	5	4	3	2	1	0
0x7E	CMD	0x00	cmd							
0x7D	-	-	reserved							
...	-	-	reserved							
0x20	-	-	reserved							
0x1F	CONFIG	0x00	reserved				iir_filter			short_in
0x1E	-	-	reserved							
0x1D	ODR	0x00	reserved			odr_sel				
0x1C	OSR	0x02	reserved		osr_t			osr_p		
0x1B	PWR_CTRL	0x00	reserved		mode		reserved		temp_en	press_en
0x1A	IF_CONF	0x00	reserved					i2c_wdt_sel	i2c_wdt_en	spi3
0x19	INT_CTRL	0x02	reserved	drdy_en	int_ds	ffull_en	fwtm_en	int_latch	int_level	int_od
0x18	FIFO_CONFIG_2	0x02	reserved			data_select		fifo_subsampling		
0x17	FIFO_CONFIG_1	0x02	reserved			fifo_temp_en	fifo_press_en	fifo_time_en	fifo_stop_on_full	fifo_mode
0x16	FIFO_WTM_1	0x00	reserved							fifo_water_mark_8
0x15	FIFO_WTM_0	0x01	fifo_water_mark_7_0							
0x14	FIFO_DATA	0x00	fifo_data							
0x13	FIFO_LENGTH_1	0x00	fifo_byte_counter_11_8							
0x12	FIFO_LENGTH_0	0x00	fifo_byte_counter_7_0							
0x11	INT_STATUS	0x00	reserved				drdy	reserved	ffull_int	fwm_int
0x10	EVENT	0x01	reserved						itf_act_pt	por_detected
0x0F	-	-	reserved							
0x0E	SENSORTIME_2	0x00	sensor_time_23_16							
0x0D	SENSORTIME_1	0x00	sensor_time_15_8							
0x0C	SENSORTIME_0	0x00	sensor_time_7_0							
0x0B	-	-	reserved							
0x0A	-	-	reserved							
0x09	DATA_5	0x80	temp_23_16							
0x08	DATA_4	0x00	temp_15_8							
0x07	DATA_3	0x00	temp_7_0							
0x06	DATA_2	0x80	press_23_16							
0x05	DATA_1	0x00	press_15_8							
0x04	DATA_0	0x00	press_7_0							
0x03	STATUS	0x00	reserved	drdy_temp	drdy_press	cmd_rdy	reserved			
0x02	ERR_REG	0x00	reserved					conf_err	cmd_err	fatal_err
0x01	REV_ID	0x01	rev_id_major				rev_id_minor			
0x00	CHIP_ID	0x60	chip_id_fixed				chip_id_nvm			

4.3. Register description

4.3.1. Register 0x00 “CHIP_ID”

The “CHIP_ID” register contains the chip identification code.

Table 25: Register 0x00 “CHIP_ID”

	Name	Description
Bit 7..0		Chip id.

4.3.2. Register 0x01 “REV_ID”

The “Rev_ID” register contains the mask revision of the ASIC

Table 26: Register 0x01 “REV_ID”

	Name	Description
Bit 7..0		Rev id.

4.3.3. Register 0x02 “ERR_REG”

Sensor Error conditions are reported in the “ERR_REG” register.

Table 27: Register 0x02 “ERR_REG”

	Name	Description
Bit 0	*fatal_err*	Fatal error
Bit 1	*cmd_err*	Command execution failed. Cleared on read.
Bit 2	*conf_err*	sensor configuration error detected (only working in normal mode). Cleared on read.

4.3.4. Register 0x03 “STATUS”

The Sensor Status Flags are stored in the “STATUS” register.

Table 28: Register 0x03 “STATUS”

	Name	Description
Bit 4	*cmd_rdy*	CMD decoder status. 0: Command in progress 1: Command decoder is ready to accept a new command
Bit 5	*drdy_press*	Data ready for pressure. It gets reset, when one pressure DATA register is read out
Bit 6	*drdy_temp*	Data ready for temperature sensor. It gets reset, when one temperature DATA register is read out

4.3.5. Register 0x04 .. 0x06 Pressure Data

The 24Bit pressure data is split and stored in three consecutive registers

0x04	“DATA_0”
0x05	“DATA_1”
0x06	“DATA_2”

Table 29: Pressure Data Registers

Register	0x06 DATA_2	0x05 DATA_1	0x04 DATA_0
Bit	7..0	7..0	7..0
name	PRESS_MSB_23_16	PRESS_LSB_15_8	PRESS_XLSB_7_0
Data	**pressure data**		

4.3.6. Register 0x07 .. 0x09 Temperature Data

The 24Bit temperature data is split and stored in three consecutive registers

0x07	“DATA_3”
0x08	“DATA_4”
0x09	“DATA_5”

Table 30: Temperature Data Registers

Register	0x09 DATA_5	0x08 DATA_4	0x07 DATA_3
Bit	7..0	7..0	7..0
name	TEMP_MSB_23_16	TEMP_LSB_15_8	TEMP_XLSB_7_0
Data	**temperature data**		

4.3.7. Register 0x0C .. 0x0E Sensor Time

The 24Bit sensor time is split and stored in three consecutive registers

- 0x0C “SENSORTIME_0”
- 0x0D “SENSORTIME_1”
- 0x0E “SENSORTIME_2”

Table 31: Sensor Time Registers

Register	**0x0E SENSORTIME_2**	**0x0D SENSORTIME_1**	**0x0C SENSORTIME_0**
Bit	7..0	7..0	7..0
name	sensor_time_23_16	sensor_time_15_8	sensor_time_7_0
Data	**Sensor time**		

4.3.8. Register 0x10 “EVENT”

The “EVENT” register contains the sensor status flags.

Table 32: Register 0x10 “EVENT”

	Name	**Description**
Bit 0	*por_detected*	‘1’ after device power up or softreset. Clear-on-read
Bit 1	itf_act_pt	‘1’ when a serial interface transaction occurs during a pressure or temperature conversion. Clear-on-read

4.3.9. Register 0x11 “INT_STATUS”

The “INT_STATUS” register shows interrupt status and is cleared after reading.

Table 33: Register 0x11 “INT_STATUS”

	Name	**Description**
Bit 0	*fwm_int*	FIFO Watermark Interrupt
Bit 1	*ffull_int*	FIFO Full Interrupt
Bit 3	*drdy*	data ready interrupt

4.3.10. Register 0x12 .. 0x13 “FIFO_LENGTH”

The FIFO byte counter indicates the current fill level of the FIFO buffer. Its size is 9 bit for 512 bytes and therefore split in two registers “FIFO_LENGTH_0” and “FIFO_LENGTH_1”.

Table 34: FIFO Length Split

Register	**0x13 FIFO_LENGTH_1**								**0x12 FIFO_LENGTH_0**							
Bit	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
name	fifo_byte_counter_11_8								fifo_byte_counter_7_0							

4.3.11. Register 0x14 “FIFO_DATA”

The “FIFO_DATA” is the data output register.

Table 35: Register 0x14 “FIFO_DATA”

	Name	**Description**
Bit 7..0	*fifo_data*	FIFO read data.

4.3.12. Register 0x15 .. 0x16 FIFO Watermark

The FIFO Watermark size is 9 Bit and therefore written to the FIFO_WTM_0 and FIFO_WTM_1 registers.

Table 36: FIFO Watermark Register Overview

Register	**0x16 FIFO_WTM_1**								**0x15 FIFO_WTM_0**							
Bit	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
name	fifo_water_mark_8								fifo_water_mark_7_0							

4.3.13. Register 0x17 “FIFO_CONFIG_1”

The “FIFO_CONFIG_1” register contains the FIFO frame content configuration.

Table 37: Register 0x17 “FIFO_CONFIG_1”

	Name	**Description**
Bit 0	*fifo_mode*	Enables or disables the FIFO 0 disable 1 enable FIFO mode
Bit 1	*fifo_stop_on_full*	Stop writing samples into FIFO when FIFO is full. 0 disable do not stop writing to FIFO when full 1 enable Stop writing into FIFO when full.
Bit 2	*fifo_time_en*	Return sensortime frame after the last valid data frame. 0 disable do not return sensortime frame 1 enable return sensortime frame
Bit 3	*fifo_press_en*	Store pressure data in FIFO 0 disable no pressure data is stored 1 enable pressure data is stored
Bit 4	*fifo_temp_en*	Store temperature data in FIFO 0 disable no temperature data is stored 1 enable temperature data is stored

4.3.14. Register 0x18 "FIFO_CONFIG_2"

The "FIFO_CONFIG_2" register extends the FIFO_CONFIG_1 register.

Table 38: Register 0x18 "FIFO_CONFIG_2"

	Name	Description
Bit 2..0	*fifo_subsampling*	FIFO downsampling selection for pressure and temperature data, factor is 2^fifo_subsampling
Bit 4..3	*data_select*	for pressure and temperature, select data source 0 unfiltered data (compensated or uncompensated) 1 filtered data (compensated or uncompensated) 11/10 reserved, same as for "unfilt"

4.3.15. Register 0x19 "INT_CTRL"

Interrupt configuration can be set in the "INT_CTRL" register. It affects INT_STATUS registers and the INT pin.

Table 39: Register 0x19 "INT_CTRL"

	Name	Description
Bit 0	*int_od*	Configure output: open-drain or push-pull 0 push-pull 1 open-drain
Bit 1	*int_level*	level of INT pin 0 active_low 1 active_high
Bit 2	*int_latch*	Latching of interrupts for INT pin and INT_STATUS register 0 disabled 1 enabled
Bit 3	*fwtm_en*	enable FIFO watermark reached interrupt for INT pin and INT_STATUS. 0 disabled 1 enabled
Bit 4	*ffull_en*	enable Fifo full interrupt for INT pin and INT_STATUS 0 disabled 1 enabled
Bit 5	*int_ds*	0 low 1 high
Bit 6	*drdy_en*	enable temperature / pressure data ready interrupt for INT pin and INT_STATUS 0 disabled 1 enabled

4.3.16. Register 0x1A "IF_CONF"

The "IF_CONF" register controls the serial interface settings.

Table 40: Register 0x1A "IF_CONF"

	Name	Description
Bit 0	*spi3*	Configure SPI Interface Mode for primary interface 0 spi4 SPI 4-wire mode 1 spi3 SPI 3-wire mode
Bit 1	*i2c_wdt_en*	Enable for the I2C Watchdog timer, backed by NVM 0 disabled Watchdog disabled 1 enabled Watchdog enabled
Bit 2	*i2c_wdt_sel*	Select timer period for I2C Watchdog , backed by NVM 0 wdt_short I2C watchdog timeout after 1.25 ms 1 wdt_long I2C watchdog timeout after 40 ms

4.3.17. Register 0x1B "PWR_CTRL"

The "PWR_CTRL" register enables or disables pressure and temperature measurement. Although, the measurement mode can be set here.

Table 41: Register 0x1B "PWR_CTRL"

	Name	Description
Bit 0	*press_en*	0 press_off Disables the pressure sensor. 1 press_on Enables the pressure sensor.
Bit 1	*temp_en*	0 temp_off Disables the temperature sensor. 1 temp_on Enables the temperature sensor.
Bit 5..4	*mode*	00 sleep mode 01/10 forced mode 11 normal mode

4.3.18. Register 0x1C “OSR”

The “OSR” register controls the oversampling settings for pressure and temperature measurements.

Table 42: Register 0x1C “OSR”

	Name	Description
Bit 2..0	*osr_p*	Oversampling setting pressure measurement 000 x1 no oversampling. 001 x2 x2 oversampling. 010 x4 x4 oversampling. 011 x8 x8 oversampling. 100 x16 x16 oversampling. 101 x32 x32 oversampling.
Bit 5..3	*osr4_t*	Oversampling setting temperature measurement 000 x1 no oversampling 001 x2 x2 oversampling 010 x4 x4 oversampling 011 x8 x8 oversampling 100 x16 x16 oversampling 101 x32 x32 oversampling

4.3.19. Register 0x1D “ODR”

The “ODR” register set the configuration of the output data rates by means of setting the subdivision/subsampling.

Table 43: Register 0x1D “ODR”

	Name	Description
Bit 4..0	*odr_sel*	subdivision factor for pressure and temperature measurements is 2^value. Allowed values are 0..17. Other values are saturated at 17.

4.3.20. Control settings for odr_sel

Table 44: Control settings for *odr_sel*

odr_sel	prescaler	Name	Description	Sampling Period
0x00	1	ODR_200	ODR 200Hz	5 ms
0x01	2	ODR_100	ODR 100Hz	10 ms
0x02	4	ODR_50	ODR 50Hz	20 ms
0x03	8	ODR_25	ODR 25Hz	40 ms
0x04	16	ODR_12p5	ODR 25/2Hz	80 ms
0x05	32	ODR_6p25	ODR 25/4Hz	160 ms
0x06	64	ODR_3p1	ODR 25/8Hz	320 ms
0x07	127	ODR_1p5	ODR 25/16Hz	640 ms
0x08	256	ODR_0p78	ODR 25/32Hz	1.280 s
0x09	512	ODR_0p39	ODR 25/64Hz	2.560 s
0x0A	1024	ODR_0p2	ODR 25/128Hz	5.120 s
0x0B	2048	ODR_0p1	ODR 25/256Hz	10.24 s
0x0C	4096	ODR_0p05	ODR 25/512Hz	20.48 s
0x0D	8192	ODR_0p02	ODR 25/1024Hz	40.96 s
0x0E	16384	ODR_0p01	ODR 25/2048Hz	81.92 s
0x0F	32768	ODR_0p006	ODR 25/4096Hz	163.84 s
0x10	65536	ODR_0p003	ODR 25/8192Hz	327.68 s
0x11	131072	ODR_0p0015	ODR 25/16384Hz	655.36 s

4.3.21. Register 0x1F "CONFIG"

The "CONFIG" register controls the IIR filter coefficients.

Table 45: Register 0x1F "CONFIG"

	Name	Description
Bit 3..1	*iir_filter*	filter coefficient for IIR filter 000 coef_0 filter coefficient is 0 -> bypass-mode 001 coef_1 filter coefficient is 1 010 coef_3 filter coefficient is 3 011 coef_7 filter coefficient is 7 100 coef_15 filter coefficient is 15 101 coef_31 filter coefficient is 31 110 coef_63 filter coefficient is 63 111 coef_127 filter coefficient is 127

4.3.22. Register 0x30 .. 0x57 "calibration data"

The overview over the calibration data can be found in Chapter 3.11.1.

4.3.23. Register 0x7E "CMD"

The available commands of the "CMD" register are listed below.

Table 46: Register 0x7E "CMD"

	Name	Description
Bit 7..0	*cmd*	All Available commands (Note: Register will always read as 0x00)

Table 47: available cmd commands listed below

Value	Name	Description
0x00	nop	reserved. No command.
0xB0	fifo_flush	Clears all data in the FIFO, does not change FIFO_CONFIG registers
0xB6	softreset	Triggers a reset, all user configuration settings are overwritten with their default state

5. Digital interfaces

The BMP390 supports the I²C and SPI digital interfaces; it acts as a slave for both protocols. The I²C interface supports the standard, fast and high speed modes. The SPI interface supports both SPI mode ‘00’ (CPOL = CPHA = ‘0’) and mode ‘11’ (CPOL = CPHA = ‘1’) in 4-wire and 3-wire configuration.

The following transactions are supported:

- Single byte write
- Multiple byte write (using pairs of register addresses and register data)
- Single byte read
- Multiple byte read (using a single register address which is auto-incremented)

5.1. Interface selection

Interface selection is done automatically based on CSB (chip select) status. If CSB is connected to V_{DDIO}, the I²C interface is active. If CSB is pulled down, the SPI interface is activated. After CSB has been pulled down once (regardless of whether any clock cycle occurred), the I²C interface is disabled until the next power-on-reset. This is done in order to avoid inadvertently decoding SPI traffic to another slave as I²C data. Since power-on-reset is only executed when both V_{DD} and V_{DDIO} are established, there is no risk of incorrect protocol detection due to power-up sequence used. However, if I²C is to be used and CSB is not directly connected to V_{DDIO} but rather through a programmable pin, it must be ensured that this pin already outputs the V_{DDIO} level during power-on-reset of the device. If this is not the case, the device will be locked in SPI mode and not respond to I²C commands.

5.2. I²C Interface

The I²C slave interface is compatible with Philips I²C Specification Revision 6 (April 2014). For detailed timings refer to Table 49. All modes (standard, fast, high speed) are supported. SDA and SCL are not pure open-drain. Both pads contain ESD protection diodes to V_{DDIO} and GND.

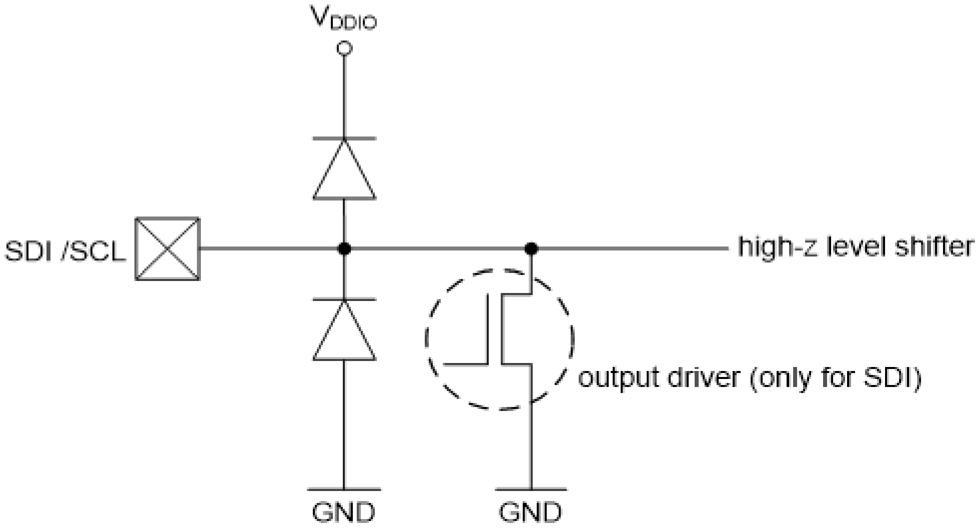


Figure 14: SDI/SCK ESD drawing

The 7-bit device address is 111011x. The 6 MSB bits are fixed. The last bit is changeable by SDO value and can be changed during operation. Connecting SDO to GND results in slave address 1110110 (0x76); connection it to V_{DDIO} results in slave address 1110111 (0x77), which is the same as BMP180’s I²C address. The SDO pin cannot be left floating; if left floating, the I²C address will be undefined.

The I²C interface uses the following pins:

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

The CSB is not used and is left open. SDI is bi-directional with open drain to VSS: it must be externally connected to V_{DDIO} via a pull up resistor. Refer to chapter 6 for connection instructions.

The following abbreviations will be used in the I²C protocol figures:

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

5.2.1. I²C write

Writing is done by sending the slave address in write mode (RW = ‘0’), resulting in slave address 111011X0 (‘X’ is determined by state of SDO pin. Then the master sends pairs of register addresses and register data. The transaction is ended by a stop condition. This is depicted in Figure 15.

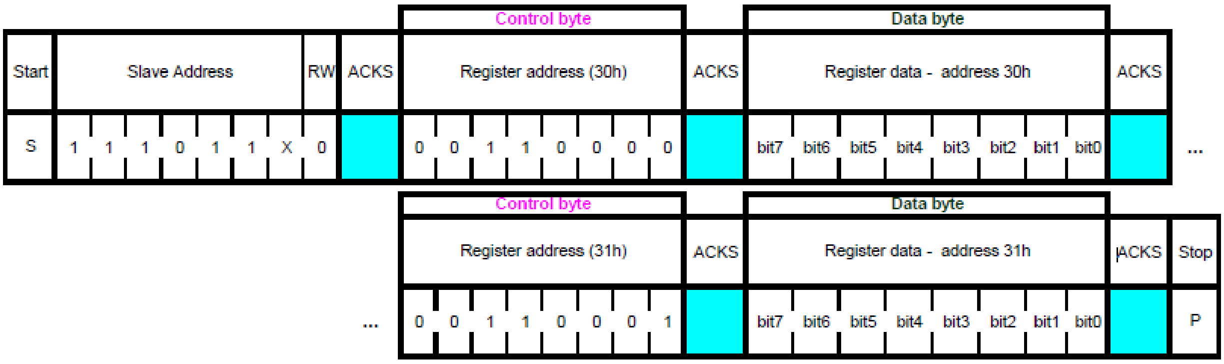


Figure 15: I²C write

5.2.2. I²C read

To be able to read registers, first the register address must be sent in write mode (slave address 111011X0). Then either a stop or a repeated start condition must be generated. After this the slave is addressed in read mode (RW = ‘1’) at address 111011X1, after which the slave sends out data from auto-incremented register addresses until a NOACKM and stop condition occurs. This is depicted in Figure 16, where two bytes are read from register 0xF6 and 0xF7.

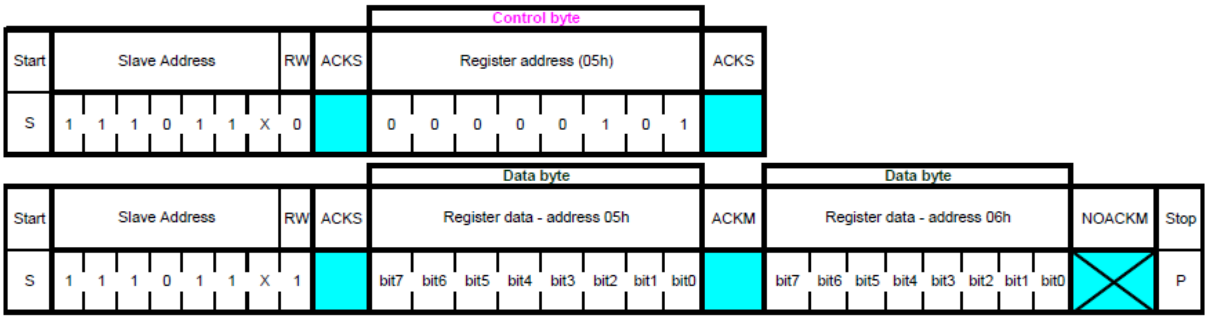


Figure 16: I²C multiple byte read

5.3. SPI interface

The SPI interface is compatible with SPI mode ‘00’ (CPOL = CPHA = ‘0’) and mode ‘11’ (CPOL = CPHA = ‘1’). The automatic selection between mode ‘00’ and ‘11’ is determined by the value of SCK after the CSB falling edge.

The SPI interface has two modes: 4-wire and 3-wire. The protocol is the same for both. The 3-wire mode is selected by setting *spi3=‘1’* in register *“IF_CONF[0]” (see 4.3.14)*. The pad SDI is used as a data input/output pad in 3-wire mode.

The SPI interface uses the following pins:

- 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

Refer to chapter 6 for connection instructions.

CSB is active low and has an integrated pull-up resistor. Data on SDI is latched by the device at SCK rising edge and SDO is changed at SCK falling edge. Communication starts when CSB goes to low and stops when CSB goes to high; during these transitions on CSB, SCK must be stable. The SPI protocol is shown in Figure 17.

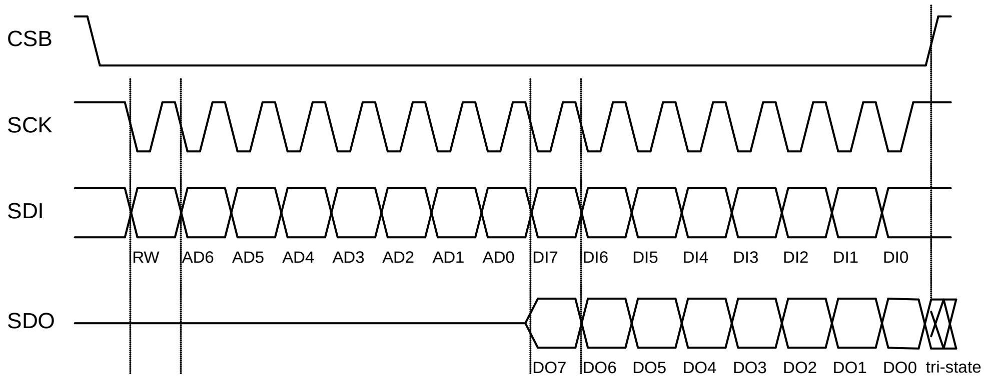


Figure 17: SPI protocol (shown for mode ‘11’ in 4-wire configuration)

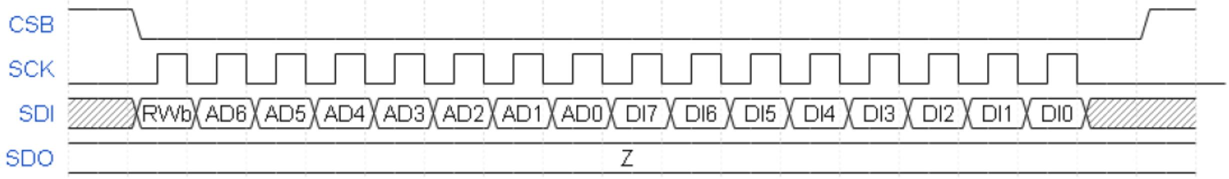
In SPI mode, only 7 bits of the register addresses are used; the MSB of register address is not used and replaced by a read/write bit (RW = ‘0’ for write and RW = ‘1’ for read).

Example: address 0xF7 is accessed by using SPI register address 0x77. For write access, the byte 0x77 is transferred, for read access, the byte 0xF7 is transferred.

5.3.1. SPI write

Writing is done by lowering CSB and sending pairs control bytes and register data. The control bytes consist of the SPI register address (= full register address without bit 7) and the write command (bit7 = RW = ‘0’). Several pairs can be written without raising CSB. The transaction is ended by a raising CSB. The SPI write protocol is depicted in Figure 18.

Figure 18: 4 wire SPI sequence



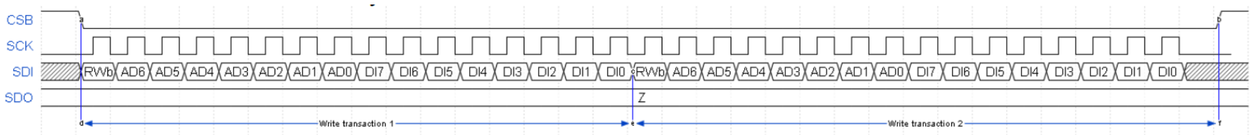


Figure 19: SPI multiple write

5.3.2. SPI read

Reading is done by lowering CSB and first sending one control byte. The control bytes consist of the SPI register address (= full register address without bit 7) and the read command (bit 7 = RW = ‘1’). After writing the control byte, one dummy byte is sent and there after data bytes. The register address is automatically incremented. The SPI read protocol is shown in Figure 20.

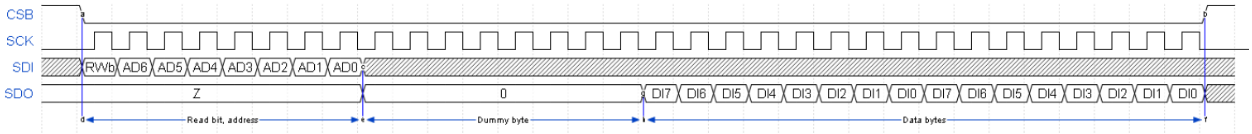


Figure 20: SPI multiple byte read

5.4. Interface parameter specification

5.4.1. General interface parameters

The general interface parameters are given in the table below:

Table 48: interface parameters

Parameter	Symbol	Condition	Min	Typ	Max	Units
Input – low level	Vil	SCK, SDI and CSB			0.25 V_{DDIO}	V
Input – high level	Vih	SCK, SDI and CSB	0.7 V_{DDIO}			V
Output – low level	Vol	SDI, SDO and INT, iol=3 mA			0.2 V_{DDIO}	V
Output – high level	Voh	SDI, SDO and INT ioh=1 mA	0.8 V_{DDIO}			V
CSB Pull-up resistor	Rcsb	Internal pull-up resistance to V_{DDIO}	75	100	125	kΩ
I²C bus load capacitor	Cb	On SDI and SCK			400	pF

5.4.2. I²C timings

For I²C timings, the following abbreviations are used:

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

All other naming refers to I²C specification 2.1 (January 2000).

The I²C timing diagram is shown in

Figure 21. The corresponding values are given in Table 49.

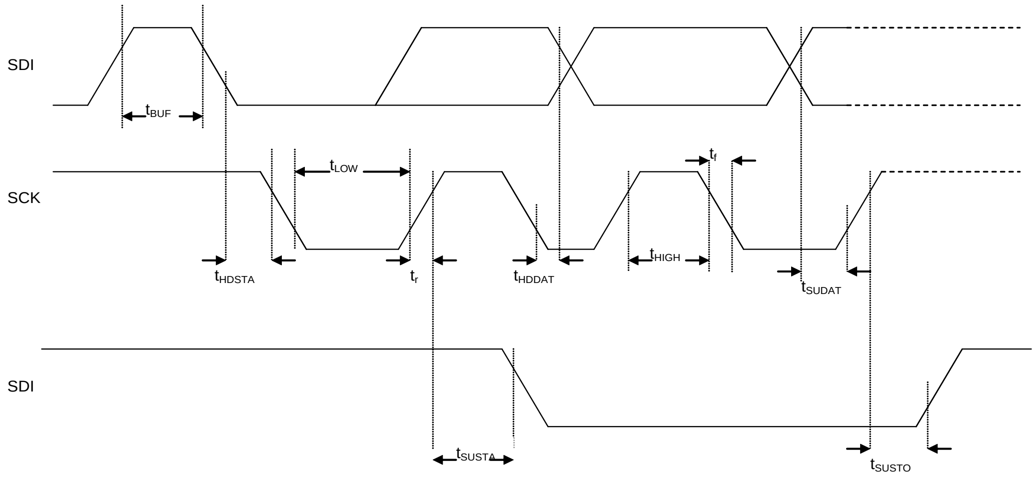


Figure 21: I²C timing diagram

Table 49: I²C timings

Parameter	Symbol	Condition	Min	Typ	Max	Units
SCK frequency	Fi2c			400	3400	kHz
SDI input setup time	$t_{SU;DAT}$	S&F Mode HS mode	160 30			ns ns
SDI output 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			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

The above-mentioned I2C specific timings correspond to the following internal added delays:

- Input delay between SDI and SCK inputs: SDI is more delayed than SCK by typically 120 ns in Standard and Fast Modes and by typically 20 ns in High Speed Mode.
- Output delay from SCK falling edge to SDI output propagation is typically 140 ns in Standard and Fast Modes and typically 70 ns in High Speed Mode.

5.4.3. SPI timings

The SPI timing diagram is in Figure 22, while the corresponding values are given inTable 50. All timings apply both to 4- and 3-wire SPI.

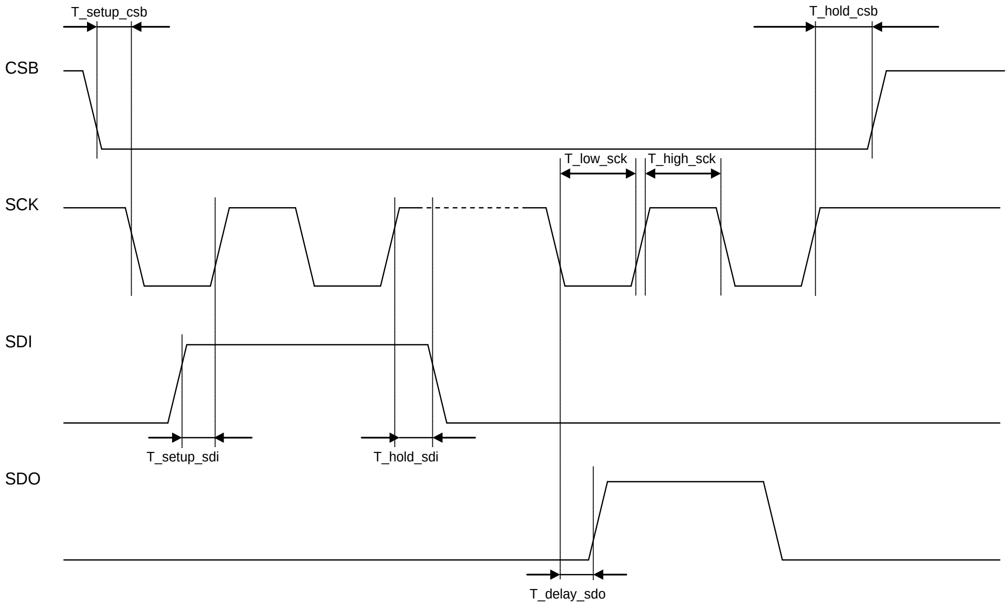


Figure 22: SPI timing diagram

Table 50: 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

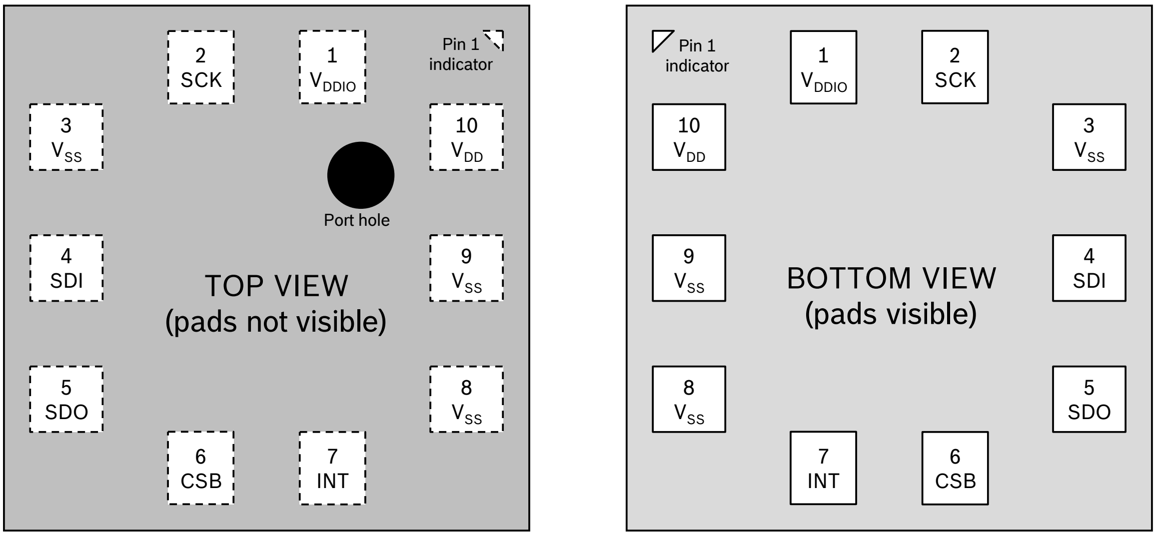


Figure 23: Pin-out top and bottom view

Table 51: Pin description

Pin	Name	I/O Type	Description	Connect to		
				SPI 4W	SPI 3W	I²C
1	VDDIO	Supply	Digital interface supply	V_{DDIO}		
2	SCK	In	Serial clock input	SCK	SCK	SCL
3	VSS	Supply	Ground	GND		
4	SDI	In/Out	Serial data input	SDI	SDI/SDO	SDA
5	SDO	In/Out	Serial data output	SDO	DNC	SA0
6	CSB	In	Chip select	CSB	CSB	CSB
7	INT	Out	INT output	host INT input or DNC		
8	VSS	Supply	Ground	GND		
9	VSS	Supply	Ground	GND		
10	VDD	Supply	Analog supply	V_{DD}		

6.2. Connection diagram ¾-wire SPI

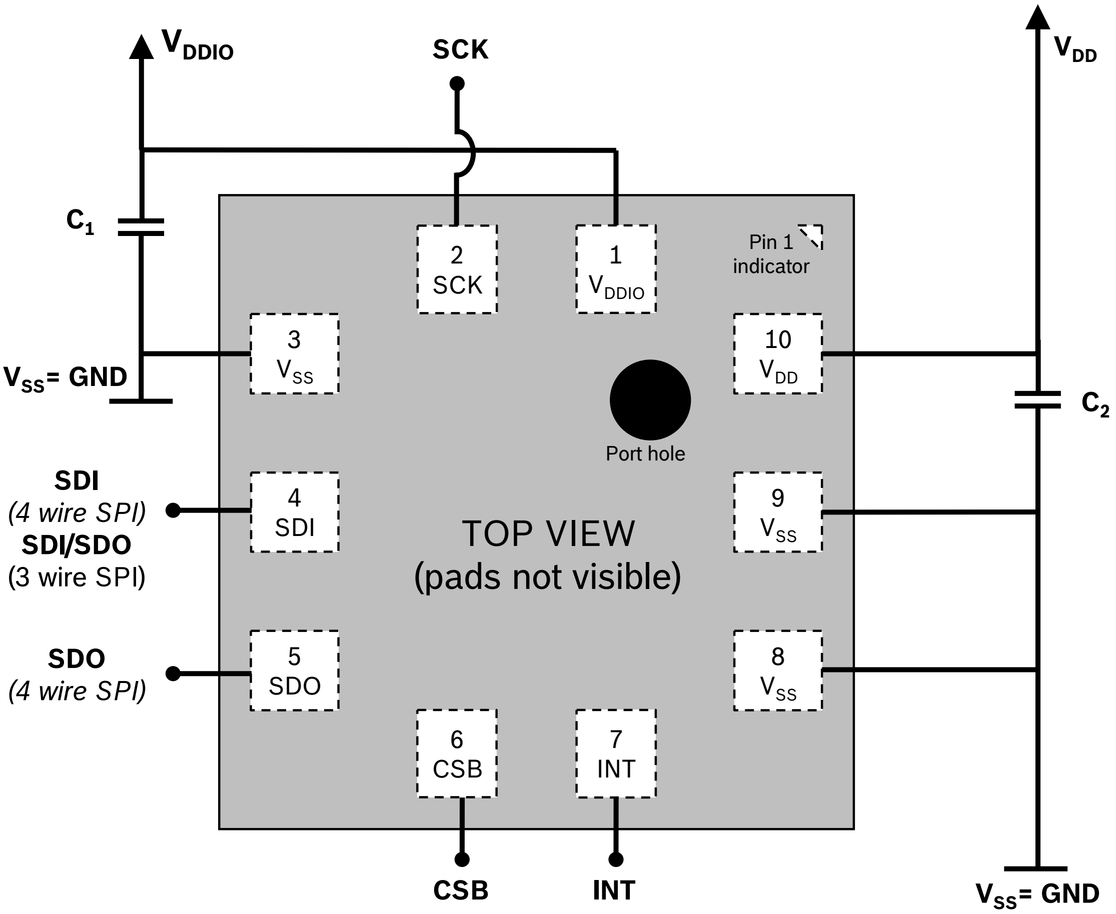


Figure 24: 3 and 4-wire SPI connection diagram (Pin1 marking indicated).

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

6.3. Connection diagram I²C

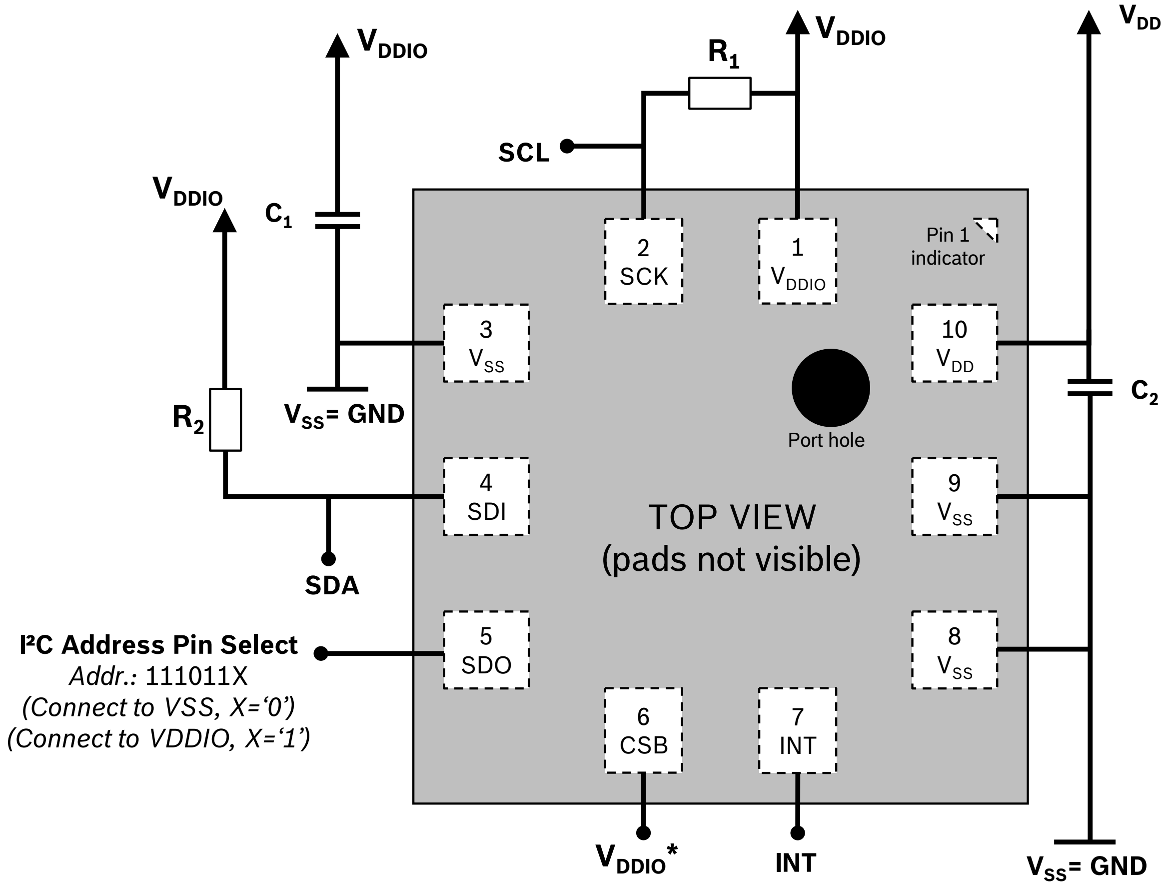


Figure 25: I²C connection diagram (Pin1 marking indicated)

Notes:

- the recommended value for C_1, C_2 is 100 nF and for R_1, R_2 is 4.7 kΩ.
- *: It is recommended to connect the BMP390 CSB pin to programmable pin which drives V_{DDIO} at POR of device (see Chapter 5.1)

7. Package, reel and environment

7.1. Outline dimensions

The sensor housing is a 10-pin metal-lid LGA 2.0×2.0×0.75 mm³ package (typ.). Its dimensions are depicted in Figure 26.

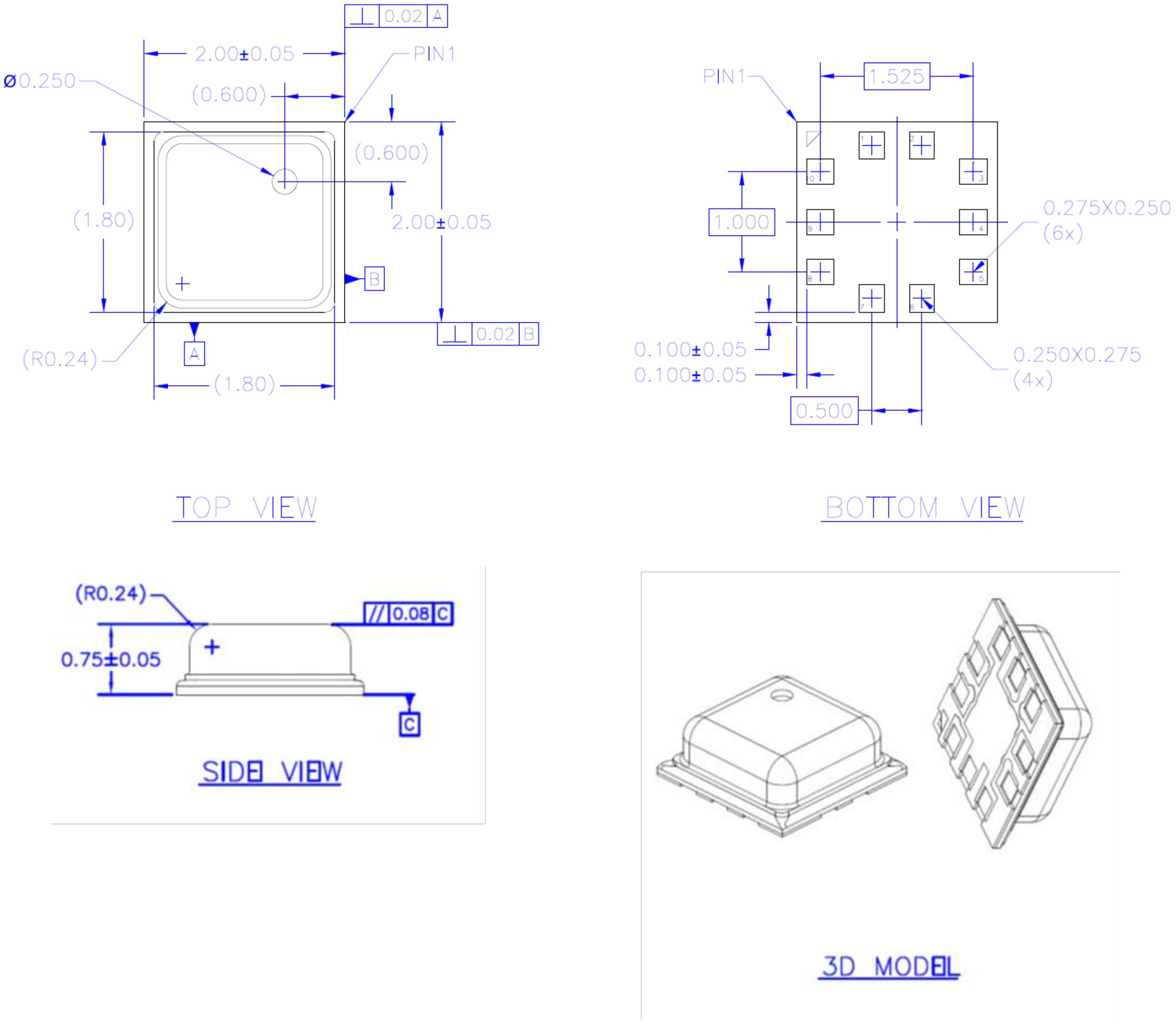


Figure 26: Package outline dimensions BMP390 for top, bottom, side and 3D view

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

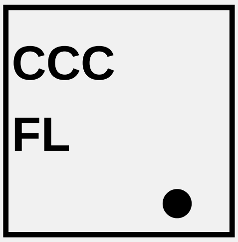
7.2. Landing pattern

Bosch Sensortec suggests the BMP390 outline Dimensions (see 7.1- bottom view) as landing pattern.

7.3. Marking

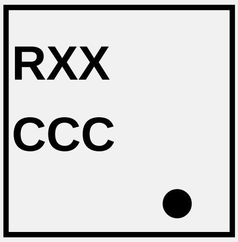
7.3.1. Mass production samples

Table 52: Marking of mass production samples

Labeling	Name	Symbol	Remark
	Lot Counter ID	CCC	3 alphanumeric digits, variable to generate mass production trace code
	Product number	F	alphanumeric digit to identify product type, “4” is associated with the product BMP390L (part number 0273.017.023)
	Sub-con ID	L	1 alphanumeric digit, variable to identify sub-con (L = “P”)
	Orientation marker	●	Vent hole

7.3.2. Engineering samples

Table 53: Marking of engineering samples

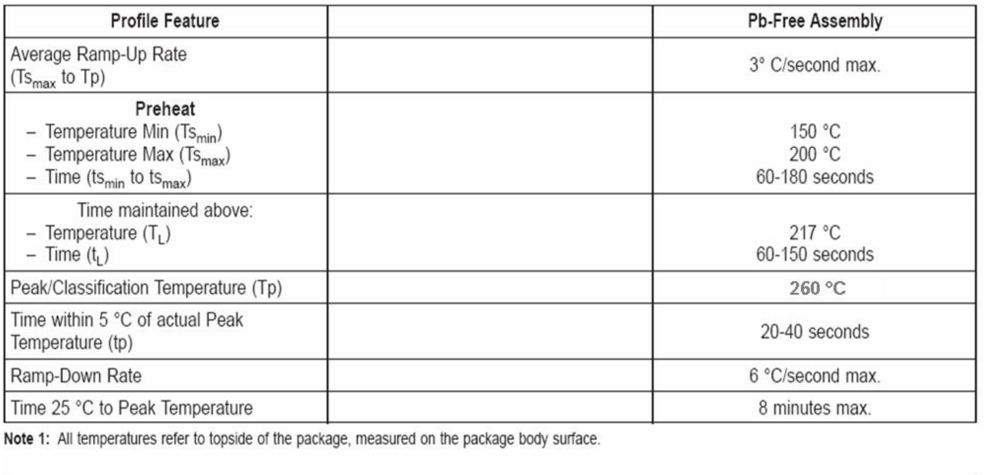
Labeling	Name	Symbol	Remark
	Eng. Sample ID	R	1 alphanumeric digit, fixed identification of sample status R=”A” or “C” or “F”
	Sample ID	XX	2 alphanumeric digit, variable identification of sample lot number
	Counter ID	CCC	2 or 3 alphanumeric digits, variable to generate trace-code
	Orientation marker	●	Vent hole

7.4. Soldering guidelines

The moisture sensitivity level of the BMP390 sensors corresponds to JEDEC Level 1, see also:

- IPC/JEDEC J-STD-020E “Joint Industry Standard: Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices”
- IPC/JEDEC J-STD-033D “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 20 µm. 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.

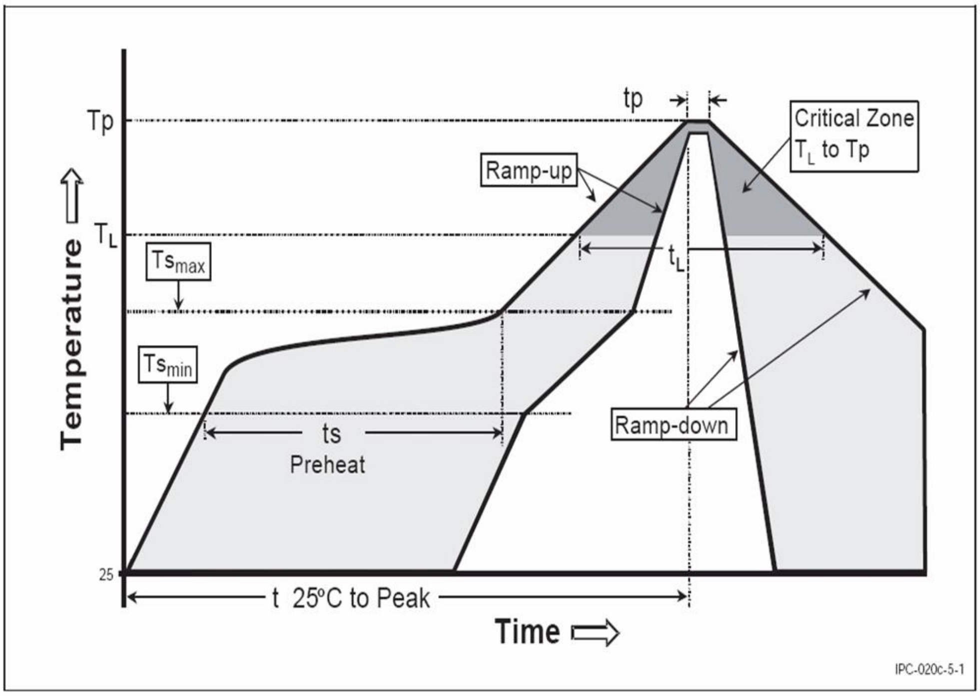
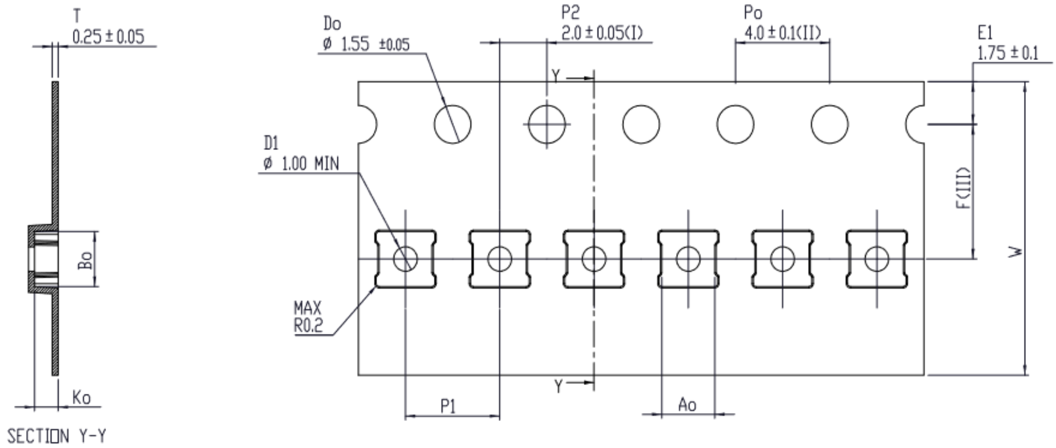


Figure 27: Soldering profile

7.5. Tape and reel specification

7.5.1. Dimensions



Ao	2.20 +/- 0.05
Bo	2.20 +/- 0.05
Ko	0.95 +/- 0.05
F	5.50 +/- 0.05
P_1	4.00 +/- 0.1
W	12.00 +/- 0.3

Figure 28: Tape and Reel dimensions

Quantity per reel: 2.5 kpcs.

7.5.2. Orientation within the reel

The orientation of the sensor placement inside the tape on reel can be found below.

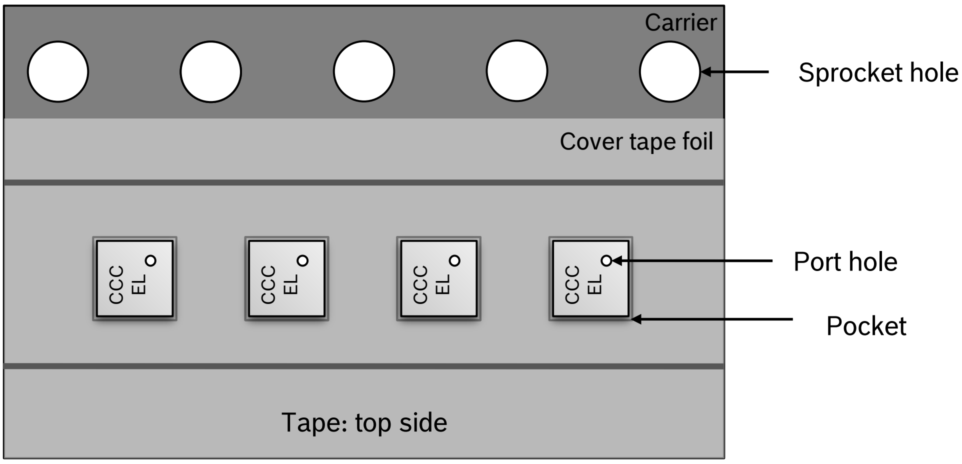


Figure 29: Orientation within tape

7.6. Mounting and assembly recommendations

In addition to “Handling, soldering & mounting instructions BMP38x”, the following recommendations should be taken into consideration when mounting a pressure sensor on a printed-circuit board (PCB):

- The clearance above the metal lid shall be 0.1mm at minimum.
- For the device housing appropriate venting needs to be provided in case the ambient pressure shall be measured.
- Liquids shall not come into direct contact with the device.

- During operation the sensor chip is sensitive to light, which can influence the accuracy of the measurement (photo-current of silicon). The position of the vent hole minimizes the light exposure of the sensor chip. Nevertheless, BST recommends to avoid the exposure of BMP390 to strong light sources.
- Soldering must not be done using vapor phase processes since the sensor might be damaged.

7.7. Environmental safety

7.7.1. RoHS

The BMP390 sensor meets the requirements of the EC restriction of hazardous substances (RoHS) directive, see also: Directive 2015/863 (amending Annex II to Directive 2011/65/EU) of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

7.7.2. Halogen content

The BMP390 is halogen-free. For more details on the analysis results please contact your Bosch Sensortec representative.

7.7.3. Internal package structure

Within the scope of Bosch Sensortec's ambition to improve its products and secure the mass product supply, Bosch Sensortec qualifies additional sources (e.g. 2nd source) for the LGA package of the BMP390.

While Bosch Sensortec took care that all of the technical packages parameters are described above are 100% identical for all sources, there can be differences in the chemical content and the internal structural between the different package sources.

However, as secured by the extensive product qualification process of Bosch Sensortec, this has no impact to the usage or to the quality of the BMP390 product.

8. Legal disclaimer

8.1. Engineering samples

Engineering Samples are marked with an asterisk (*), (e) or (E). Samples may vary from the valid technical specifications of the product series contained in this data sheet. They are therefore not intended or fit for resale to third parties or for use in end products. Their sole purpose is internal client testing. The testing of an engineering sample may in no way replace the testing of a product series. Bosch Sensortec assumes no liability for the use of engineering samples. The Purchaser shall indemnify Bosch Sensortec from all claims arising from the use of engineering samples.

8.2. Product use

Bosch Sensortec products are developed for the consumer goods industry. They may only be used within the parameters of this product data sheet. They are not fit for use in life-sustaining or safety-critical systems. Safety-critical systems are those for which a malfunction is expected to lead to bodily harm, death or severe property damage. In addition, they shall not be used directly or indirectly for military purposes (including but not limited to nuclear, chemical or biological proliferation of weapons or development of missile technology), nuclear power, deep sea or space applications (including but not limited to satellite technology).

The resale and/or use of Bosch Sensortec products are at the purchaser's own risk and his own responsibility. The examination of fitness for the intended use is the sole responsibility of the purchaser.

The purchaser shall indemnify Bosch Sensortec from all third party claims arising from any product use not covered by the parameters of this product data sheet or not approved by Bosch Sensortec and reimburse Bosch Sensortec for all costs in connection with such claims.

The purchaser accepts the responsibility to monitor the market for the purchased products, particularly with regard to product safety, and to inform Bosch Sensortec without delay of all safety-critical incidents.

8.3. Application examples and hints

With respect to any examples or hints given herein, any typical values stated herein and/or any information regarding the application of the device, Bosch Sensortec hereby disclaims any and all warranties and liabilities of any kind, including without limitation warranties of non-infringement of intellectual property rights or copyrights of any third party. The information given in this document shall in no event be regarded as a guarantee of conditions or characteristics. They are provided for illustrative purposes only and no evaluation regarding infringement of intellectual property rights or copyrights or regarding functionality, performance or error has been made.

Appendix: Computation formulae reference implementation

The code below gives a provides a C implementation of the compensation algorithms discussed in Sec. 3.10.

The struct BMP390_calib_data is a structure, that contains the calibration coefficients. And the t_lin variable that carries a temperature value over to the pressure compensation.

8.4. Calibration coefficient

The calibration coefficents are stored as described in Table 23. The compensation formula is implemented in floating point. Therefore the coefficient have to be converted into floating point numbers by the following formulas.

$$PAR\_T1 = \frac{NVM\_PAR\_T1}{2^{-8}} \qquad PAR\_T2 = \frac{NVM\_PAR\_T2}{2^{30}} \qquad PAR\_T3 = \frac{NVM\_PAR\_T3}{2^{48}}$$

$$PAR\_P1 = \frac{NVM\_PAR\_P1 - 2^{14}}{2^{20}} \qquad PAR\_P2 = \frac{NVM\_PAR\_P2 - 2^{14}}{2^{29}} \qquad PAR\_P3 = \frac{NVM\_PAR\_P3}{2^{32}}$$

$$PAR\_P4 = \frac{NVM\_PAR\_P4}{2^{37}} \qquad PAR\_P5 = \frac{NVM\_PAR\_P5}{2^{-3}} \qquad PAR\_P6 = \frac{NVM\_PAR\_P6}{2^{6}}$$

$$PAR\_P7 = \frac{NVM\_PAR\_P7}{2^{8}} \qquad PAR\_P8 = \frac{NVM\_PAR\_P8}{2^{15}} \qquad PAR\_P9 = \frac{NVM\_PAR\_P9}{2^{48}}$$

$$PAR\_P10 = \frac{NVM\_PAR\_P10}{2^{48}} \qquad PAR\_P11 = \frac{NVM\_PAR\_P11}{2^{65}}$$

8.5. Temperature compensation

```c
static float BMP390_compensate_temperature(uint32_t uncomp_temp, struct BMP390_calib_data *calib_data)
{
    float partial_data1;
    float partial_data2;

    partial_data1 = (float)(uncomp_temp – calib_data->par_t1);
    partial_data2 = (float)(partial_data1 * calib_data->par_t2);
    /* Update the compensated temperature in calib structure since this is
    * needed for pressure calculation */
    calib_data->t_lin = partial_data2 + (partial_data1 * partial_data1) * calib_data->par_t3;

    /* Returns compensated temperature */
    return calib_data->t_lin;
}
```

8.6. Pressure compensation

```
static float BMP390_compensate_pressure(uint32_t uncomp_press, struct BMP390_calib_data *calib_data)
{
        /* Variable to store the compensated pressure */
        float comp_press;
        /* Temporary variables used for compensation */
        float partial_data1;
        float partial_data2;
        float partial_data3;
        float partial_data4;
        float partial_out1;
        float partial_out2;
        /* Calibration data */

        partial_data1 = calib_data->par_p6 * calib_data->t_lin;
        partial_data2 = calib_data->par_p7 * (calib_data->t_lin * calib_data->t_lin);
        partial_data3 = calib_data->par_p8 * (calib_data->t_lin * calib_data->t_lin * calib_data->t_lin);
        partial_out1 = calib_data->par_p5 + partial_data1 + partial_data2 + partial_data3;

        partial_data1 = calib_data->par_p2 * calib_data->t_lin;
        partial_data2 = calib_data->par_p3 * (calib_data->t_lin * calib_data->t_lin);
        partial_data3 = calib_data->par_p4 * (calib_data->t_lin * calib_data->t_lin * calib_data->t_lin);
        partial_out2 = (float)uncomp_press *
                (calib_data->par_p1 + partial_data1 + partial_data2 + partial_data3);

        partial_data1 = (float)uncomp_press * (float)uncomp_press;
        partial_data2 = calib_data->par_p9 + calib_data->par_p10 * calib_data->t_lin;
        partial_data3 = partial_data1 *         partial_data2;
        partial_data4 = partial_data3 + ((float)uncomp_press * (float)uncomp_press * (float)uncomp_press) * calib_data->par_p11;
        comp_press = partial_out1 + partial_out2 + partial_data4;

        return comp_press;
}
```

9. Document history and modification

Rev. No	Section	Description of modification/changes	Date
1.2		Document Creation	01.02.20120

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Document number: BST-BMP390L-DS001-02
Revision_1.2_022020