Data sheet

BMP183
Digital pressure sensor

Bosch Sensortec

BOSCH
Invented for life

BMP183 Data sheet

Document revision	1.0
Document release date	June 13th, 2012
Document number	BST-BMP183-DS000-00
Technical reference code(s)	0 273 300 357
Notes	Data 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's appearance.

BMP183

DIGITAL PRESSURE SENSOR

Key features

Pressure range:	300 ... 1100hPa (+9000m ... -500m relating to sea level)
Supply voltage:	1.8 ... 3.6V (V_{DD})
	1.62V ... 3.6V (V_{DDIO})

Package:	LGA package with metal lid
	Small footprint: 3.6mm x 3.8mm
	Super-flat: 0.93mm height

Low power:	5µA at 1 sample / sec. in standard mode

Low noise:	0.06hPa (0.5m) in ultra low power mode
	0.02hPa (0.17m) ultra high resolution mode

- Temperature measurement included
- SPI interface
- Fully calibrated
- Pb-free, halogen-free and RoHS compliant,
- MSL 1

Typical applications

- Enhancement of GPS navigation (dead-reckoning, slope detection, etc.)
- In- and out-door navigation
- Leisure and sports
- Weather forecast
- Vertical velocity indication (rise/sink speed)

BMP183 general description

The BMP183 is the function compatible successor of the BMP085, a new generation of high precision digital pressure sensors for consumer applications.

The ultra-low power, low voltage electronics of the BMP183 is optimized for use in mobile phones, PDAs, GPS navigation devices and outdoor equipment. With a low altitude noise of merely 0.25m at fast conversion time, the BMP183 offers superior performance. The SPI interface allows for easy system integration with a microcontroller.

The BMP183 is based on piezo-resistive technology for EMC robustness, high accuracy and linearity as well as long term stability.

Robert Bosch is the world market leader for pressure sensors in automotive applications. Based on the experience of over 400 million pressure sensors in the field, the BMP183 continues a new generation of micro-machined pressure sensors.

Index of Contents

1. Electrical characteristics

If not stated otherwise, the given values are ±3-Sigma values over temperature/voltage range in the given operation mode. All values represent the new parts specification; additional solder drift is shown separately.

Table 1: Operating conditions, output signal and mechanical characteristics

Parameter	Symbol	Condition	Min	Typ	Max	Units
Operating temperature	T_A	operational	-40		+85	°C
		full accuracy	0		+65	
Supply voltage	V_{DD}	ripple max. 50mVpp	1.8	2.5	3.6	V
	V_{DDIO}		1.62	2.5	3.6	V
Supply current @ 1 sample / sec. 25°C	I_{DDLOW}	ultra low power mode		3		µA
	I_{DDSTD}	standard mode		5		µA
	I_{DDHR}	high resolution mode		7		µA
	I_{DDUHR}	Ultra high res. mode		12		µA
	I_{DDAR}	Advanced res. mode		32		µA
Peak current	I_{peak}	during conversion		650	1000	µA
Standby current	I_{DDSBM}	@ 25°C		0.1		µA
Relative accuracy pressure V_{DD} = 3.3V		950 . . . 1050 hPa @ 25 °C		±0.12		hPa
				±1.0		m
		700 ... 900hPa 25 . . . 40 °C		±0.12		hPa
				±1.0		m
Absolute accuracy pressure V_{DD} = 3.3V		300 . . . 1100 hPa 0 . . . +65 °C	-4.0	-1.0[1]	+2.0	hPa
		300 . . . 1100 hPa -20 . . . 0 °C	-6.0	-1.0[1]	+4.5	hPa
Resolution of output data		pressure		0.01		hPa
		temperature		0.1		°C
Noise in pressure		see table on page 12-13				

[1] The typical value is: -1±1

Absolute accuracy temperature V_{DD} = 3.3V		@ 25 °C	-1.5	±0.5	+1.5	°C
		0 . . . +65 °C	-2.0	±1.0	+2.0	°C
Conversion time pressure	$t_{c\_p\_low}$	ultra low power mode		3	4.5	ms
	$t_{c\_p\_std}$	standard mode		5	7.5	ms
	$t_{c\_p\_hr}$	high resolution mode		9	13.5	ms
	$t_{c\_p\_luhr}$	ultra high res. mode		17	25.5	ms
	$t_{c\_p\_ar}$	Advanced res. mode		51	76.5	ms
Conversion time temperature	t_{C_temp}	standard mode		3	4.5	ms
Serial data clock	f_{SCL}				3.4	MHz
Solder drifts[2]		Minimum solder height 50µm	-0.5		+2	hPa
Long term stability[3]		12 months		±1.0		hPa

[2] verified with BST customer shuttle boards
[3] Long term stability is specified in the full accuracy operating pressure range 0 ... 65°C

2. Absolute maximum ratings

Table 2: Absolute maximum ratings

Parameter	Condition	Min	Max	Units
Storage temperature		-40	+85	°C
Supply voltage	all pins	-0.3	+4.25	V
ESD rating	HBM, R = 1.5kΩ, C = 100pF		±2	kV
Overpressure			10,000	hPa

The BMP183 has to be handled as Electrostatic Sensitive Device (ESD).

Figure 1: ESD

3. Operation

3.1 Power supply and power on sequence

The BMP183 has two distinct power supply pins: VDD and VDDIO. VDD powers the internal digital and analogue circuitry and should not suffer from large voltage spikes. VDDIO is the supply for the digital interface and must match the voltages on the SPI interface. In case the voltage range allows it, VDD and VDDIO can be fed from a single supply line which must be >1.8V.

The preferred power on sequence is VDD first. Even though V_{DDIO} can be powered on before V_{DD}, there is a chance of excessive power consumption (a few mA) if this sequence is used, and the state of the output pins is undefined so that the bus can be locked. Therefore, V_{DD} *must* be powered before V_{DDIO} unless the limitations above are understood and not critical.

3.2 General description

The BMP183 is designed to be connected directly to a microcontroller of a mobile device via the SPI bus. The pressure and temperature data has to be compensated by the calibration data of the E^2PROM of the BMP183.

3.3 General function and application schematics

The BMP183 consists of a piezo-resistive sensor, an analog to digital converter and a control unit with E^2PROM and a SPI interface. The BMP183 delivers the uncompensated value of pressure and temperature. The E^2PROM has stored 176 bit of individual calibration data. This is used to compensate offset, temperature dependence and other parameters of the sensor.

- UP = pressure data (16 to 19 bit)
- UT = temperature data (16 bit)

Figure 2 depicts a typical circuit connecting BMP183 to the micro controller, power supply and GND.
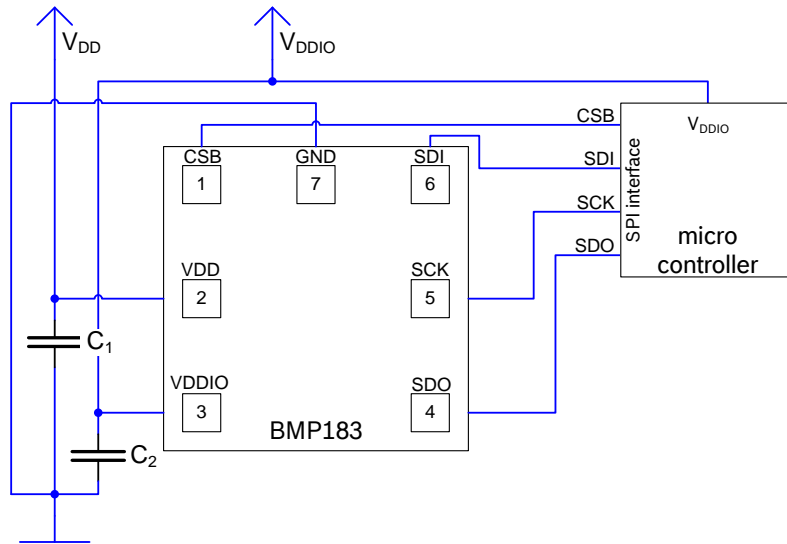

Figure 2: Typical application circuit

Note: Support capacitors for SPI bus required: $C_1 = C_2 = 100$nF.

3.4 Measurement of pressure and temperature

For all calculations presented here an ANSI C code is available from Bosch Sensortec ("BMP18x _API").

The microcontroller sends a start sequence to start a pressure or temperature measurement. After converting time, the result value (UP or UT, respectively) can be read via the interface. For calculating temperature in °C and pressure in hPa, the calibration data has to be used. These constants can be read out from the BMP183 E^2PROM via the interface at software initialization.

The sampling rate can be increased up to 128 samples per second (standard mode) for dynamic measurement. In this case, it is sufficient to measure the temperature only once per second and to use this value for all pressure measurements during the same period.

```
                    ( Start )
                        |
                        v
            +-----------------------+
            |   Start temperature   |
            |     measurement       |
            +-----------------------+
                        |
                   wait 4.5 ms
                        v
            +-----------------------+
            |       Read UT         |
            +-----------------------+
                        |
                        v
            +-----------------------+
            |   Start pressure      |
            |    measurement        |
            +-----------------------+
                        |
          wait (depends on mode, see below)
                        v
            +-----------------------+
            |       Read UP         |
            +-----------------------+
                        |
                        v
            +-----------------------+
            | calculate pressure and|
            | temperature in physical|
            |        units          |
            +-----------------------+
```
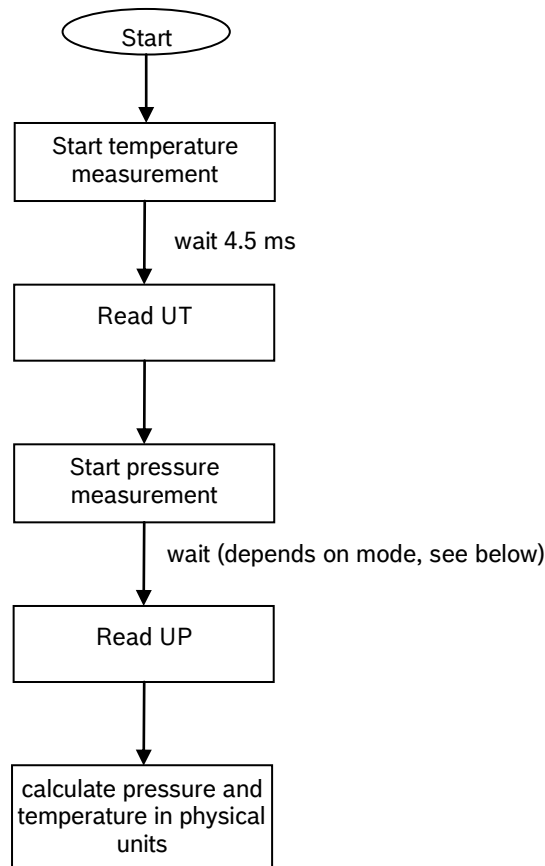
Figure 3: Measurement flow BMP183

3.4.1 Hardware pressure sampling accuracy modes

By using different modes the optimum compromise between power consumption, speed and resolution can be selected, see below table.

Table 3: Overview of BMP183 hardware accuracy modes, selected by driver software via the variable *oversampling_setting*

Mode	Parameter *oversampling_setting*	Internal number of samples	Conversion time pressure max. [ms]	Avg. current @ 1 sample/s typ. [µA]	RMS noise typ. [hPa]	RMS noise typ. [m]
ultra low power	0	1	4.5	3	0.06	0.5
standard	1	2	7.5	5	0.05	0.4
high resolution	2	4	13.5	7	0.04	0.3
ultra high resolution	3	8	25.5	12	0.03	0.25

For further information on noise characteristics see the relevant application note "Noise in pressure sensor applications".

All modes can be performed at higher speeds, e.g. up to 128 times per second for standard mode, with the current consumption increasing proportionally to the sample rate.

3.4.2 Software pressure sampling accuracy modes

For applications where a low noise level is critical, averaging is recommended if the lower bandwidth is acceptable. Oversampling can be enabled using the software API driver (with OSR = 3).

Table 4: Overview of BMP183 software accuracy mode,
selected by driver software via the variable *software_oversampling_setting*

Mode	Parameter *oversampling_setting*	software_ oversampl ing_settin g	Conversion time pressure max. [ms]	Avg. current @ 1 sample/s typ. [µA]	RMS noise typ. [hPa]	RMS noise typ. [m]
Advanced resolution	3	1	76.5	32	0.02	0.17

3.5 Calibration coefficients

The 176 bit E^2PROM is partitioned in 11 words of 16 bit each. These contain 11 calibration coefficients. Every sensor module has individual coefficients. Before the first calculation of temperature and pressure, the master reads out the E^2PROM data.
The data communication can be checked by checking that none of the words has the value 0 or 0xFFFF.

Table 5: Calibration coefficients

Parameter	BMP183 reg adr	
	MSB	LSB
AC1	0xAA	0xAB
AC2	0xAC	0xAD
AC3	0xAE	0xAF
AC4	0xB0	0xB1
AC5	0xB2	0xB3
AC6	0xB4	0xB5
B1	0xB6	0xB7
B2	0xB8	0xB9
MB	0xBA	0xBB
MC	0xBC	0xBD
MD	0xBE	0xBF

3.6 Calculating pressure and temperature

The mode (ultra low power, standard, high, ultra high resolution) can be selected by the variable *oversampling_setting* (0, 1, 2, 3) in the C code.

Calculation of true temperature and pressure in steps of 1Pa (= 0.01hPa = 0.01mbar) and temperature in steps of 0.1°C.

The following figure shows the detailed algorithm for pressure and temperature measurement.

This algorithm is available to customers as reference C source code ("BMP18x_API") from Bosch Sensortec and via its sales and distribution partners. **Please contact your Bosch Sensortec representative for details.**
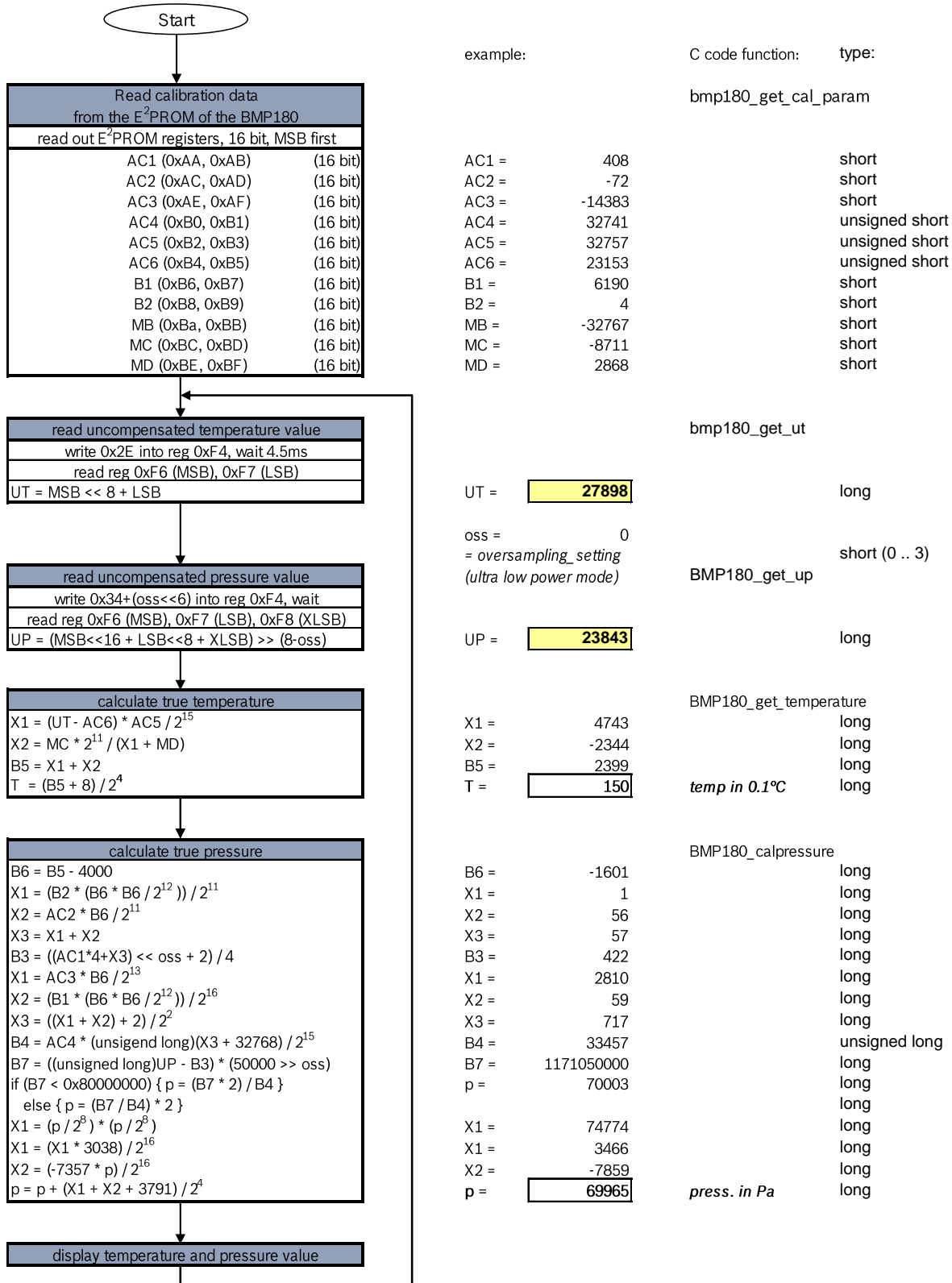
Calculation of pressure and temperature for BMP183

Start

	example:	C code function:	type:

Read calibration data
from the E^{2}PROM of the BMP180

read out E^{2}PROM registers, 16 bit, MSB first

bmp180_get_cal_param

	(16 bit)			
AC1 (0xAA, 0xAB)	(16 bit)	AC1 =	408	short
AC2 (0xAC, 0xAD)	(16 bit)	AC2 =	-72	short
AC3 (0xAE, 0xAF)	(16 bit)	AC3 =	-14383	short
AC4 (0xB0, 0xB1)	(16 bit)	AC4 =	32741	unsigned short
AC5 (0xB2, 0xB3)	(16 bit)	AC5 =	32757	unsigned short
AC6 (0xB4, 0xB5)	(16 bit)	AC6 =	23153	unsigned short
B1 (0xB6, 0xB7)	(16 bit)	B1 =	6190	short
B2 (0xB8, 0xB9)	(16 bit)	B2 =	4	short
MB (0xBa, 0xBB)	(16 bit)	MB =	-32767	short
MC (0xBC, 0xBD)	(16 bit)	MC =	-8711	short
MD (0xBE, 0xBF)	(16 bit)	MD =	2868	short

read uncompensated temperature value
write 0x2E into reg 0xF4, wait 4.5ms
read reg 0xF6 (MSB), 0xF7 (LSB)
UT = MSB << 8 + LSB

bmp180_get_ut

UT = **27898**   long

oss = 0
= *oversampling_setting*   short (0 .. 3)
(ultra low power mode)   BMP180_get_up

read uncompensated pressure value
write 0x34+(oss<<6) into reg 0xF4, wait
read reg 0xF6 (MSB), 0xF7 (LSB), 0xF8 (XLSB)
UP = (MSB<<16 + LSB<<8 + XLSB) >> (8-oss)

UP = **23843**   long

calculate true temperature

$X1 = (UT - AC6) * AC5 / 2^{15}$
$X2 = MC * 2^{11} / (X1 + MD)$
$B5 = X1 + X2$
$T = (B5 + 8) / 2^4$

BMP180_get_temperature

X1 =	4743	long
X2 =	-2344	long
B5 =	2399	long
T =	150	*temp in 0.1°C* long

calculate true pressure

$B6 = B5 - 4000$
$X1 = (B2 * (B6 * B6 / 2^{12})) / 2^{11}$
$X2 = AC2 * B6 / 2^{11}$
$X3 = X1 + X2$
$B3 = ((AC1*4+X3) << oss + 2) / 4$
$X1 = AC3 * B6 / 2^{13}$
$X2 = (B1 * (B6 * B6 / 2^{12})) / 2^{16}$
$X3 = ((X1 + X2) + 2) / 2^2$
$B4 = AC4 * (unsigend long)(X3 + 32768) / 2^{15}$
$B7 = ((unsigned long)UP - B3) * (50000 >> oss)$
if (B7 < 0x80000000) { p = (B7 * 2) / B4 }
  else { p = (B7 / B4) * 2 }
$X1 = (p / 2^8) * (p / 2^8)$
$X1 = (X1 * 3038) / 2^{16}$
$X2 = (-7357 * p) / 2^{16}$
$p = p + (X1 + X2 + 3791) / 2^4$

BMP180_calpressure

B6 =	-1601	long
X1 =	1	long
X2 =	56	long
X3 =	57	long
B3 =	422	long
X1 =	2810	long
X2 =	59	long
X3 =	717	long
B4 =	33457	unsigned long
B7 =	1171050000	long
p =	70003	long
		long
X1 =	74774	long
X1 =	3466	long
X2 =	-7859	long
p =	69965	*press. in Pa* long

display temperature and pressure value

Figure 4: Algorithm for pressure and temperature measurement

3.7 Calculating absolute altitude

With the measured pressure p and the pressure at sea level p_0 e.g. 1013.25hPa, the altitude in meters can be calculated with the international barometric formula:

$$\text{altitude} = 44330 * \left(1 - \left(\frac{p}{p_0} \right)^{\frac{1}{5.255}} \right)$$

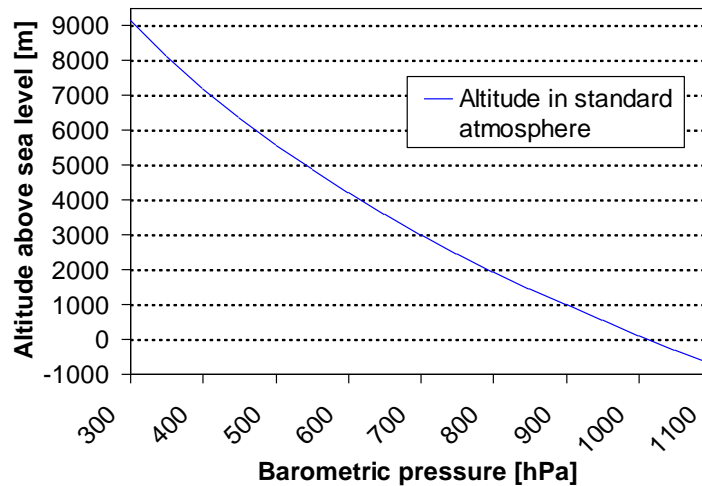Thus, a pressure change of Δp = 1hPa corresponds to 8.43m at sea level.

Figure 5: Transfer function: Altitude over sea level − Barometric pressure

3.8 Calculating pressure at sea level

With the measured pressure p and the absolute altitude the pressure at sea level can be calculated:

$$p_0 = \frac{p}{\left(1 - \dfrac{altitude}{44330}\right)^{5.255}}$$

Thus, a difference in altitude of Δaltitude = 10m corresponds to 1.2hPa pressure change at sea level.

4. Global Memory Map

The memory map below shows all externally accessible data registers which are needed to operate BMP183. The left columns show the memory addresses. The columns in the middle depict the content of each register bit. The colors of the bits indicate whether they are read-only, write-only or read- and writable. The memory is volatile so that the writable content has to be re-written after each power-on.

Not all register addresses are shown. These registers are reserved for further Bosch factory testing and trimming.

Register Name	Register Adress	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Reset state
out_xlsb	F8h	adc_out_xlsb<7:3>					0	0	0	00h
out_lsb	F7h	adc_out_lsb<7:0>								00h
out_msb	F6h	adc_out_msb<7:0>								80h
ctrl_meas	F4h	oss<1:0>		sco	measurement control					00h
soft reset	E0h	reset								00h
id	D0h	id<7:0>								55h
calib21 downto calib0	BFh *down* to AAh	calib21<7:0> *down* to calib0<7:0>								n/a

Registers:	Control registers	Calibration registers	Data registers	Fixed
Type:	read / write	read only	read only	read only

Figure 6: Memory map

Measurement control (register F4h <4:0>): Controls measurements. Refer to Figure 6 for usage details.

Sco (register F4h <5>): Start of conversion. The value of this bit stays "1" during conversion and is reset to "0" after conversion is complete (data registers are filled).

Oss (register F4h <7:6>): controls the oversampling ratio of the pressure measurement (00b: single, 01b: 2 times, 10b: 4 times, 11b: 8 times).

Soft reset (register E0h): Write only register. If set to 0xB6, will perform the same sequence as power on reset.

Chip-id (register D0h): This value is fixed to 0x55 and can be used to check whether communication is functioning.

After conversion, data registers can be read out in any sequence (i.e. MSB first or LSB first). Using a burst read is not mandatory.

5. SPI Interface

The BMP183 features a four wire SPI interface with clock speeds of up to 10 MHz. The interface is four wire SPI with CPOL = 1, CPHA = 1 (SPI mode 3).

The SPI bus is used to control the sensor, to read calibration data from the E^2PROM and to read the measurement data when A/D conversion is finished.

5.1 SPI specification

Table 6: Electrical parameters for the SPI interface

Parameter	Symbol	Min.	Typ	Max.	Units
Clock input frequency	f_{SCL}	0.0		10.0	MHz
Input-low level	V_{IL}	0		$0.2 * V_{DDIO}$	V
Input-high level	V_{IH}	$0.8 * V_{DDIO}$		V_{DDIO}	V
SCK low pulse	Tlow_sck4	20			ns
SCK high pulse	Thigh_sck_4	20			ns
SDI setup time	Tsetup_sdi_4	20			ns
SDI hold time	Thold_sdi_4	20			ns
SDO output delay	Tdelay_sdo_4			30	ns
CSB setup time	Tsetup_csb_4	20			ns
CSB hold time	Thold_csb_4	20			ns
Start-up time after power-up, before first communication	t_{Start}	10			ms

5.2 SPI protocol

CSB is active low with pull-up resistor integrated. Data on SDI is latched by BMP183 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 high.

In the SPI protocol, the MSB of the register address remains is not used. For example, register 0xF7 is addressed by 0x77 in SPI mode. Bit 7 is replaced by an R/W bit (read: '1', write: '0').
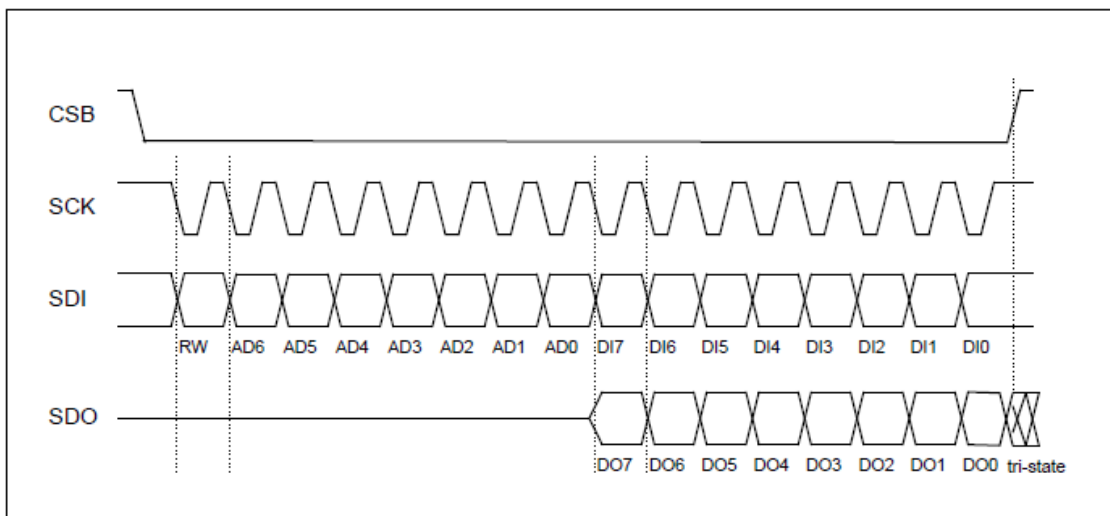
Figure 7: SPI protocol

When write is required, sequences of two bytes are required: one control byte to define the address to be written to and one data byte which is written:
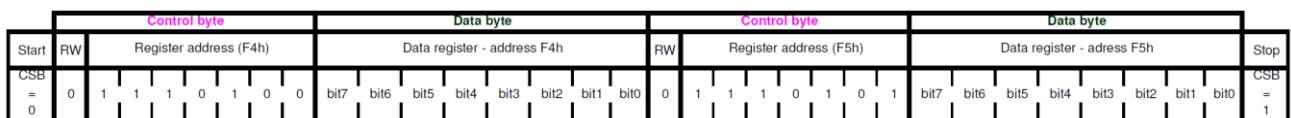
Figure 8: SPI write of two bytes

When read is required, the sequence consists in one control byte to define the first address to be read followed by data bytes. Addresses are automatically incremented.
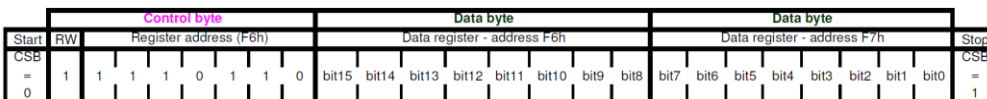
Figure 9: SPI read of two bytes

5.3 Start temperature and pressure measurement

Pressure and temperature measurement are always initiated by the bus master. A write command into register 0xF4 will start temperature or pressure measurement. The result can be read out after respecting the conversion time delay.

In Table 7, the write values for the different commands are listed.

Measurement	Control register value (register address 0xF4)	Max. conversion time [ms]
Temperature	0x2E	4.5
Pressure (oss = 0)	0x34	4.5
Pressure (oss = 1)	0x74	7.5
Pressure (oss = 2)	0xB4	13.5
Pressure (oss = 3)	0xF4	25.5

Table 7: Control registers values for different internal oversampling_setting (oss)

5.4 Read A/D conversion result or NVM data

To read out the temperature data word UT (16 bit), the pressure data word UP (16 to 19 bit) and the NVM data proceed as follows:

After lowering CSB, the master send the read command with the register start address.

NVM data registers: 0xAA (to read 0xAA − 0xBF)
ADC results UT or UP: 0xF6 (to read 0xF6 − 0xF7, optionally 0xF8)

After writing the read command + register address, the master sends further clock cycles in order to allow for the BMP183 to output the data to the SDO pin.

For ultra high resolution, the XLSB register with address 0xF8 can be read to extend the 16 bit word to up to 19 bits.

6. Package

6.1 Pin configuration

Picture shows the device in top view. Device pins are shown here transparently only for orientation purposes.
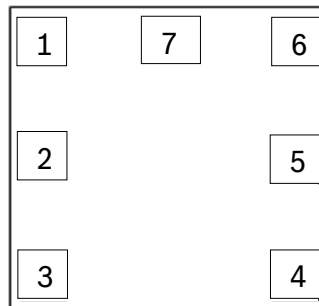
Figure 10: Layout pin configuration BMP183

Table 8: Pin configuration BMP183

in No	Name	Function
1	CSB	Chip select
2	VDD	Digital and analog power supply
3	VDDIO	Interface power supply
4	SDO	SPI data output
5	SCK	SPI clock input
6	SDI	SPI data input
7	GND	Ground; connected to lid

6.2 Outline dimensions

The sensor housing is a 7Pin LGA package with metal lid. Its dimensions are 3.60mm (±0.1 mm) x 3.80mm (±0.1 mm) x 0.93mm (±0.07 mm).

Note: All dimensions are in mm.

6.2.1 Bottom view
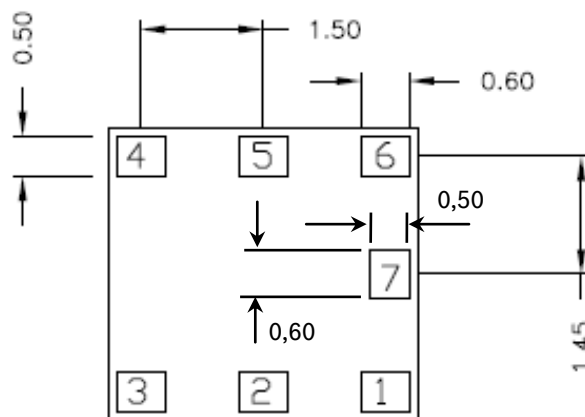
BOTTOM VIEW

Figure 11: Bottom view BMP183

6.2.2 Top view
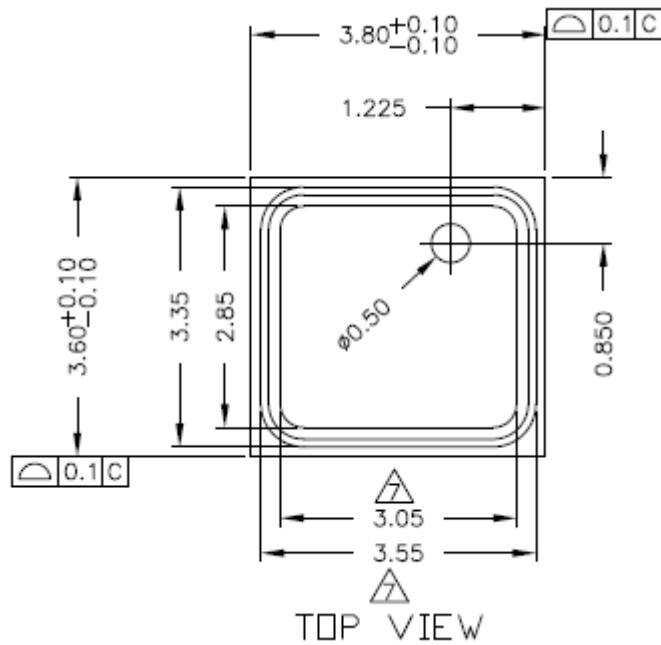
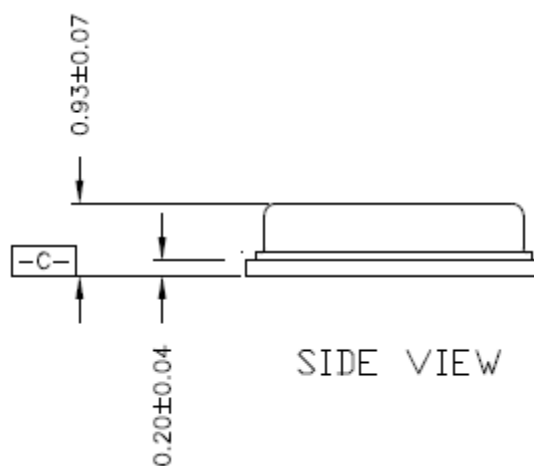Figure 12: Top view BMP183

6.2.3 Side view

Figure 13: Side view BMP183

6.3 Moisture sensitivity level and soldering

The BMP183 is classified MSL 1 (moisture sensitivity level) according to IPC/JEDEC standards J-STD-020D and J-STD-033A.

The device can be soldered Pb-free with a peak temperature of 260°C for 20 to 40 sec. 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).

To ensure good solder-ability, the devices shall be stored at room temperature (20°C).

The soldering process can lead to an offset shift.

6.4 RoHS compliancy

The BMP183 sensor meets the requirements of the EC directive "Restriction of hazardous substances (RoHS)", please refer also to:

"Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment".

The BMP183 sensor is also halogen-free.

6.5 Mounting and assembly recommendations

In order to achieve the specified performance for you design, the following recommendations and the "Handling, soldering & mounting instructions BMP183" 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 is sensitive to light, which can influence the accuracy of the measurement (photo-current of silicon).

- The BMP183 shall not the placed close the fast heating parts. In case of gradients > 3°C/sec. it is recommended to follow Bosch Sensortec application note ANP015, "Correction of errors induced by fast temperature changes". Please contact your Bosch Sensortec representative for details.

7. Legal disclaimer

7.1 Engineering samples

Engineering Samples are marked with an asterisk (*) 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.

7.2 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 security sensitive systems. Security sensitive systems are those for which a malfunction is expected to lead to bodily harm or significant property damage. In addition, they are not fit for use in products which interact with motor vehicle systems.

The resale and/or use of 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 must monitor the market for the purchased products, particularly with regard to product safety, and inform Bosch Sensortec without delay of all security relevant incidents.

7.3 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.

8. Document history and modification

Rev. No	Chapter	Description of modifications/changes	Date
1.0	All	Document creation	13-06-2012