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Data sheet

# BMP180

## Digital pressure sensor

Bosch Sensortec



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### **BMP180 Data sheet**

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# BMP180

## 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: 5 $\mu$ A 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
- I<sup>2</sup>C 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)

### **BMP180 general description**

The BMP180 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 BMP180 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 BMP180 offers superior performance. The I<sup>2</sup>C interface allows for easy system integration with a microcontroller.

The BMP180 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 BMP180 continues a new generation of micro-machined pressure sensors.

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## 1. Electrical characteristics

If not stated otherwise, the given values are  $\pm 3$ -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*	+2.0	hPa
		300 ... 1100 hPa -20 ... 0 °C	-6.0	-1.0*	+4.5	hPa
Resolution of output data		pressure		0.01		hPa
		temperature		0.1		°C
Noise in pressure		see table on page 12-13				
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	$t_{c\_p\_low}$	ultra low power mode		3	4.5	ms

pressure	$t_{c\_p\_std}$	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		Minimum solder height 50 $\mu$ m	-0.5		+2	hPa
Long term stability**		12 months		$\pm 1.0$		hPa

\* The typical value is:  $-1\pm 1$

\*\* 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 = 1.5k $\Omega$ , C = 100pF		$\pm 2$	kV
Overpressure			10,000	hPa

The BMP180 has to be handled as Electrostatic Sensitive Device (ESD).



Figure 1: ESD

## 3. Operation

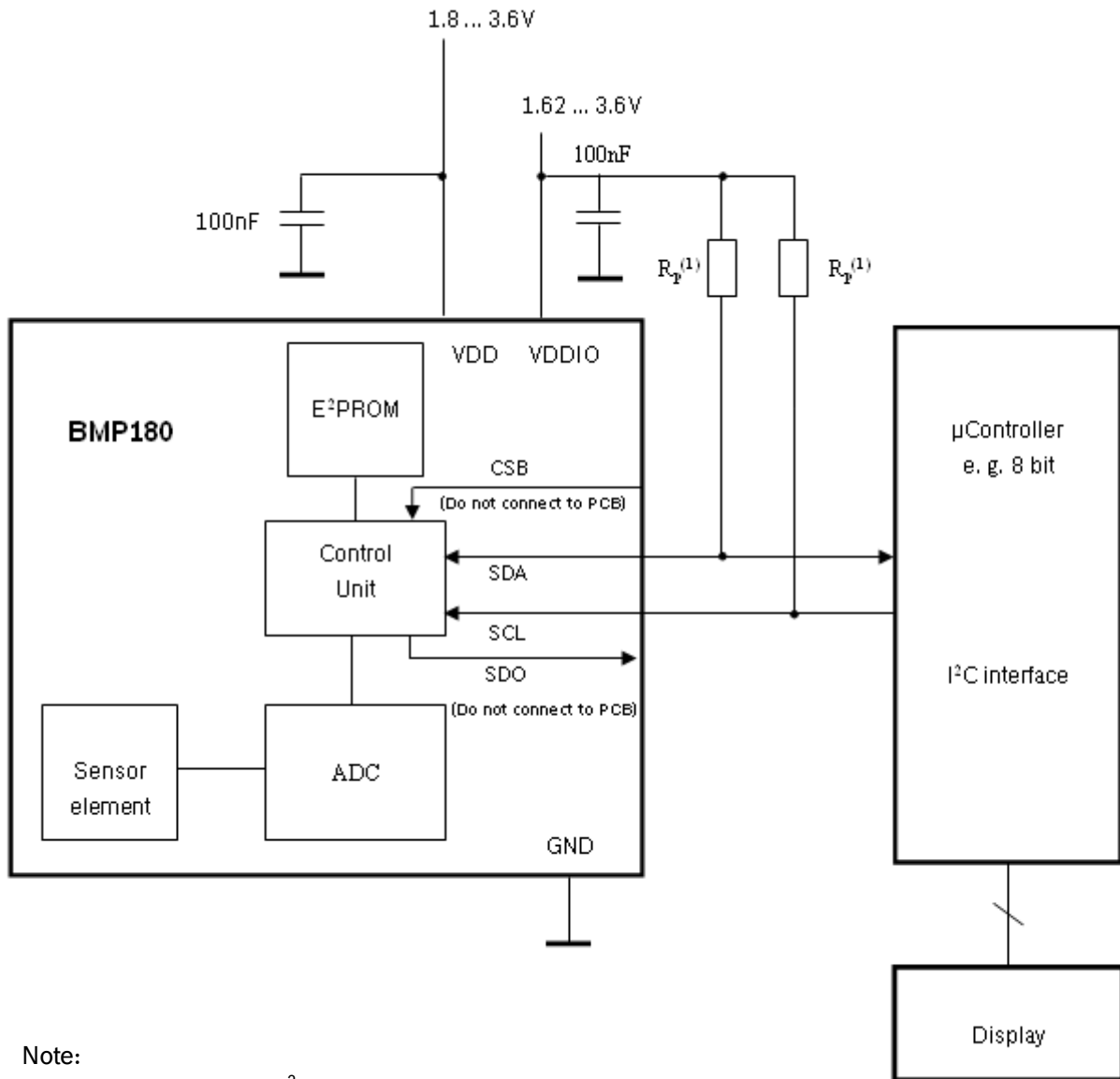
### 3.1 General description

The BMP180 is designed to be connected directly to a microcontroller of a mobile device via the I<sup>2</sup>C bus. The pressure and temperature data has to be compensated by the calibration data of the E<sup>2</sup>PROM of the BMP180.

### 3.2 General function and application schematics

The BMP180 consists of a piezo-resistive sensor, an analog to digital converter and a control unit with E<sup>2</sup>PROM and a serial I<sup>2</sup>C interface. The BMP180 delivers the uncompensated value of pressure and temperature. The E<sup>2</sup>PROM 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)



Note:

(1) Pull-up resistors for I<sup>2</sup>C bus,  $R_p = 2.2k\Omega \dots 10k\Omega$ , typ. 4.7k $\Omega$

Figure 2: Typical application circuit

### 3.3 Measurement of pressure and temperature

For all calculations presented here an ANSI C code is available from Bosch Sensortec (“BMP180\_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 I<sup>2</sup>C 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 BMP180 E<sup>2</sup>PROM via the I<sup>2</sup>C 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.

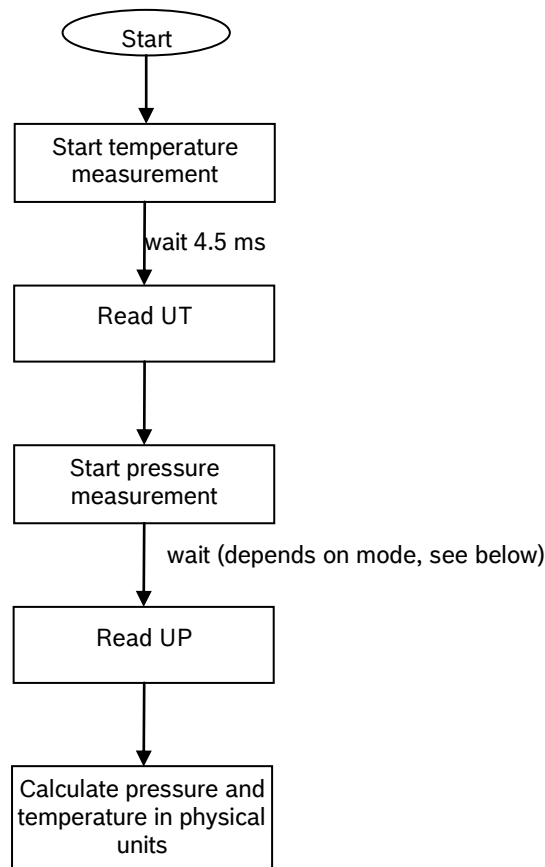


Figure 3: Measurement flow BMP180

### 3.3.1 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 BMP180 hardware accuracy modes, selected by driver software via the variable *oversampling\_setting*

Mode	Parameter <i>oversampling_setting</i>	Internal number of samples	Conversion time pressure max. [ms]	Avg. current @ 1 sample/s typ. [ $\mu$ A]	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.

### 3.3.2 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 BMP180 software accuracy mode, selected by driver software via the variable *software\_oversampling\_setting*

Mode	Parameter <i>oversampling_setting</i>	software_oversampling_setting	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

### 3.4 Calibration coefficients

The 176 bit E<sup>2</sup>PROM 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<sup>2</sup>PROM 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	BMP180 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



### 3.5 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 (“BMP180\_ 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 BMP180

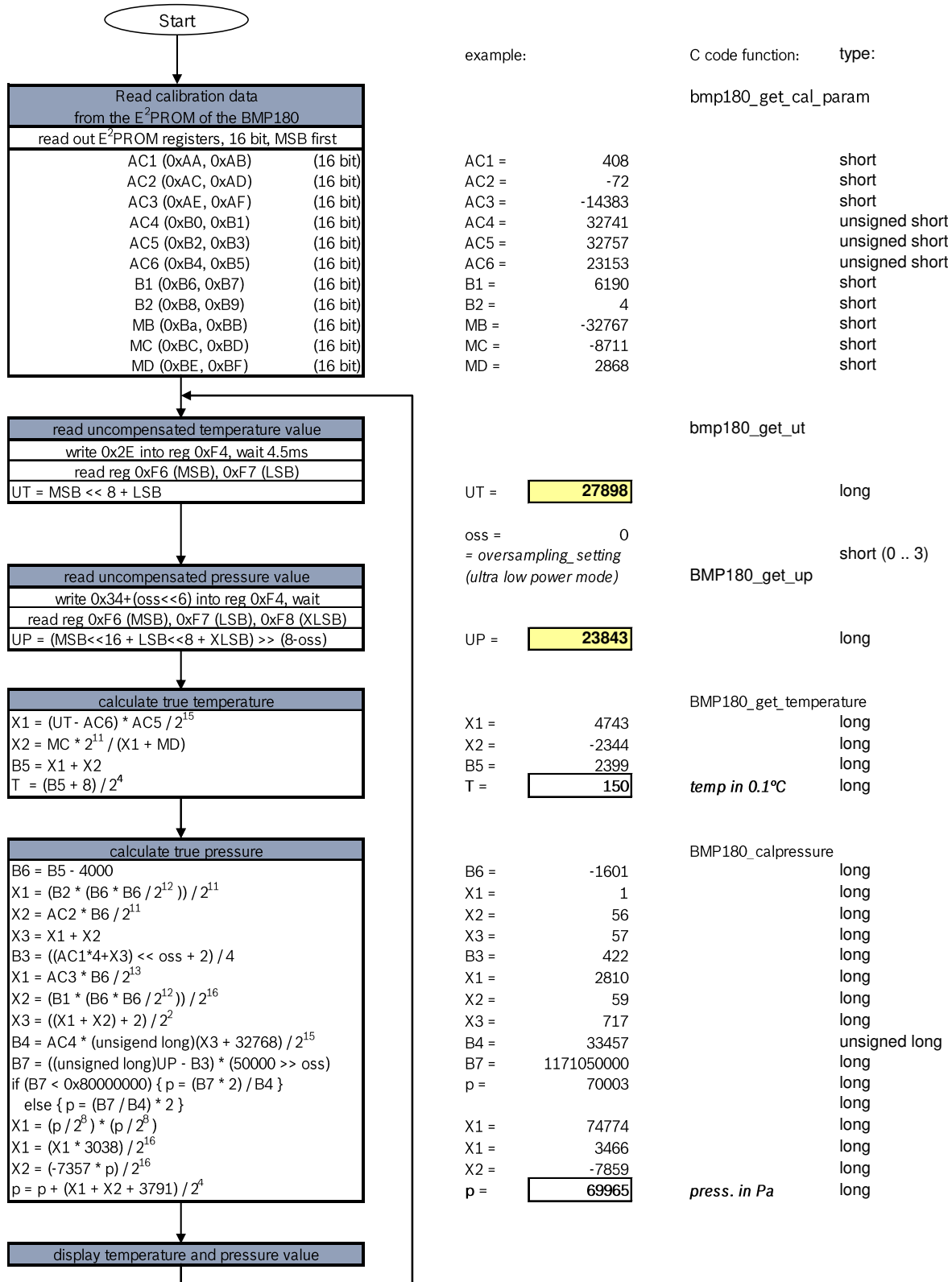


Figure 4: Algorithm for pressure and temperature measurement

3.6 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  $\Delta p = 1\text{hPa}$  corresponds to 8.43m at sea level.

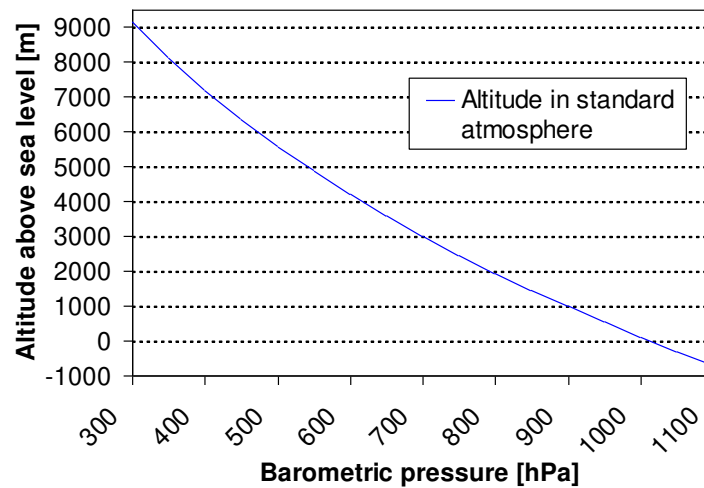


Figure 5: Transfer function: Altitude over sea level – Barometric pressure

### 3.7 Calculating pressure at sea level

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

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

Thus, a difference in altitude of  $\Delta\text{altitude} = 10\text{m}$  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 BMP180. 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 Address	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 downto AAh	calib21<7:0> downto 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. I<sup>2</sup>C Interface

- I<sup>2</sup>C is a digital two wire interface
- Clock frequencies up to 3.4Mbit/sec. (I<sup>2</sup>C standard, fast and high-speed mode supported)
- SCL and SDA needs a pull-up resistor, typ. 4.7kOhm to V<sub>DDIO</sub>  
 (one resistor each for all the I<sup>2</sup>C bus)

The I<sup>2</sup>C bus is used to control the sensor, to read calibration data from the E<sup>2</sup>PROM and to read the measurement data when A/D conversion is finished. SDA (serial data) and SCL (serial clock) have open-drain outputs.

For detailed I<sup>2</sup>C-bus specification please refer to:

[http://www.nxp.com/acrobat\\_download/literature/9398/39340011.pdf](http://www.nxp.com/acrobat_download/literature/9398/39340011.pdf)

### 5.1 I<sup>2</sup>C specification

Table 6: Electrical parameters for the I<sup>2</sup>C interface

Parameter	Symbol	Min.	Typ	Max.	Units
Clock input frequency	f <sub>SCL</sub>			3.4	MHz
Input-low level	V <sub>IL</sub>	0		0.2 * V <sub>DDIO</sub>	V
Input-high level	V <sub>IH</sub>	0.8 * V <sub>DDIO</sub>		V <sub>DDIO</sub>	V
Voltage output low level @ V <sub>DDIO</sub> = 1.62V, I <sub>OL</sub> = 3mA	V <sub>OL</sub>			0.3	V
SDA and SCL pull-up resistor	R <sub>pull-up</sub>	2.2		10	kOhm
SDA sink current @ V <sub>DDIO</sub> = 1.62V, V <sub>OL</sub> = 0.3V	I <sub>SDA_sink</sub>		9		mA
Start-up time after power-up, before first communication	t <sub>Start</sub>	10			Ms



## 5.2 Device and register address

The BMP180 module address is shown below. The LSB of the device address distinguishes between read (1) and write (0) operation, corresponding to address 0xEF (read) and 0xEE (write).

Table 7: BMP180 addresses

A7	A6	A5	A4	A3	A2	A1	W/R
1	1	1	0	1	1	1	0/1

## 5.3 I<sup>2</sup>C protocol

The I<sup>2</sup>C interface protocol has special bus signal conditions. Start (S), stop (P) and binary data conditions are shown below. At start condition, SCL is high and SDA has a falling edge. Then the slave address is sent. After the 7 address bits, the direction control bit R/W selects the read or write operation. When a slave device recognizes that it is being addressed, it should acknowledge by pulling SDA low in the ninth SCL (ACK) cycle.

At stop condition, SCL is also high, but SDA has a rising edge. Data must be held stable at SDA when SCL is high. Data can change value at SDA only when SCL is low.

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.

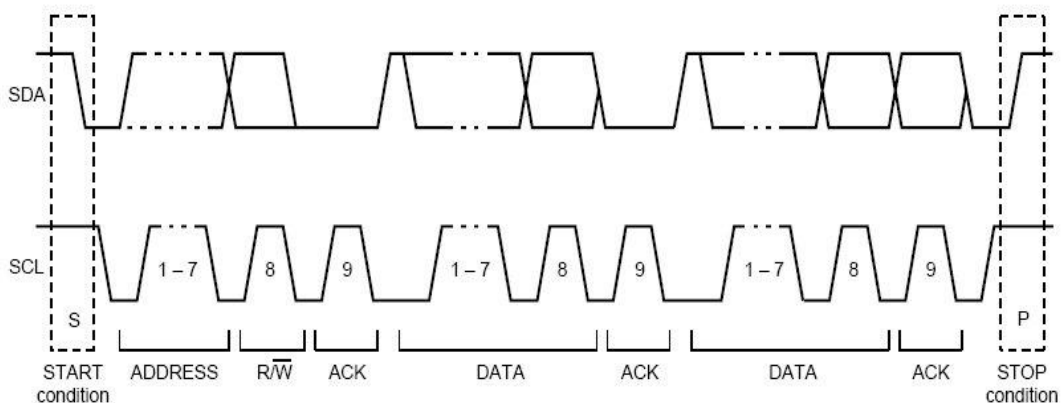


Figure 7: I<sup>2</sup>C protocol

### 5.4 Start temperature and pressure measurement

The timing diagrams to start the measurement of the temperature value UT and pressure value UP are shown below. After start condition the master sends the device address write, the register address and the control register data. The BMP180 sends an acknowledgement (ACKS) every 8 data bits when data is received. The master sends a stop condition after the last ACKS.

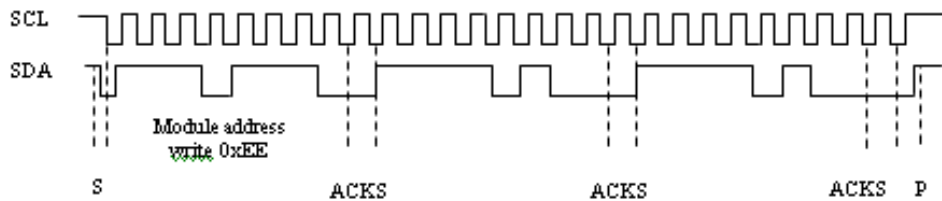


Figure 8: Timing diagram for starting pressure measurement

#### Abbreviations:

S	Start
P	Stop
ACKS	Acknowledge by Slave
ACKM	Acknowledge by Master
NACKM	Not Acknowledge by Master

Table 8: Control registers values for different internal oversampling\_setting (oss)

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

### 5.5 Read A/D conversion result or E<sup>2</sup>PROM data

To read out the temperature data word UT (16 bit), the pressure data word UP (16 to 19 bit) and the E<sup>2</sup>PROM data proceed as follows:

After the start condition the master sends the module address write command and register address. The register address selects the read register:

E<sup>2</sup>PROM data registers 0xAA to 0xBF

Temperature or pressure value UT or UP 0xF6 (MSB), 0xF7 (LSB), optionally 0xF8 (XLSB)

Then the master sends a restart condition followed by the module address read that will be acknowledged by the BMP180 (ACKS). The BMP180 sends first the 8 MSB, acknowledged by the master (ACKM), then the 8 LSB. The master sends a "not acknowledge" (NACKM) and finally a stop condition.

Optionally for ultra high resolution, the XLSB register with address 0xF8 can be read to extend the 16 bit word to up to 19 bits; refer to the application programming interface (API) software rev. 1.1 ("BMP180\_API", available from Bosch Sensortec).

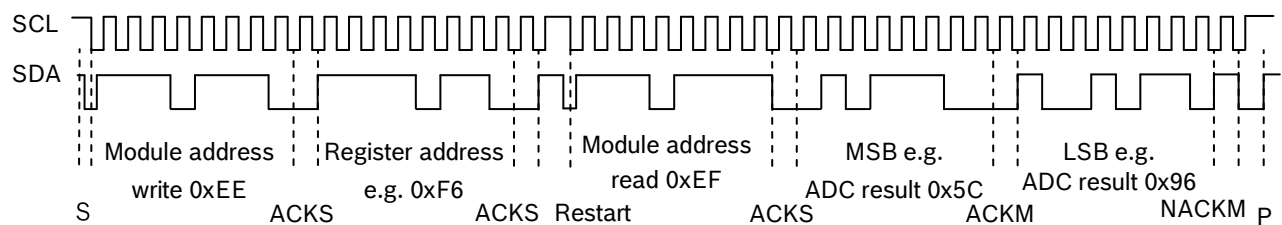


Figure 9: Timing diagram read 16 bit A/D conversion result

## 6. Package

### 6.1 Pin configuration

Picture shows the device in top view. Device pins are shown here transparently only for orientation purposes.

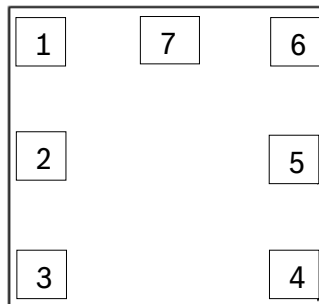


Figure 10: Layout pin configuration BMP180

Table 9: Pin configuration BMP180

in No	Name	Function
1	CSB*	Chip select
2	VDD	Power supply
3	VDDIO	Digital power supply
4	SDO*	SPI output
5	SCL	I2C serial bus clock input
6	SDA	I2C serial bus data (or SPI input)
7	GND	Ground

\* A pin compatible product variant with SPI interface is possible upon customer's request. For I<sup>2</sup>C (standard case) CSB and SDO are not used, they have to be left open.

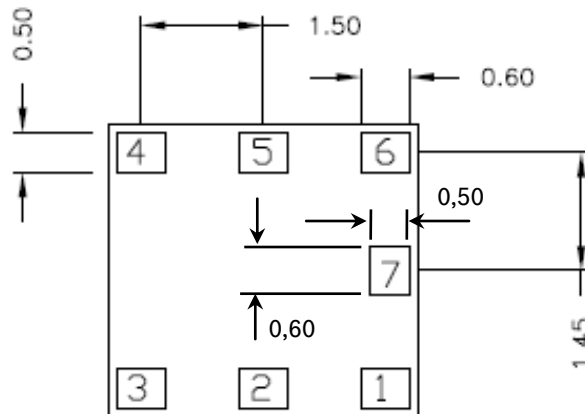
All pins have to be soldered to the PCB for symmetrical stress input even though they are not connected internally.

## 6.2 Outline dimensions

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

Note: All dimensions are in mm.

### 6.2.1 Bottom view



BOTTOM VIEW

Figure 11: Bottom view BMP180

**6.2.2 Top view**

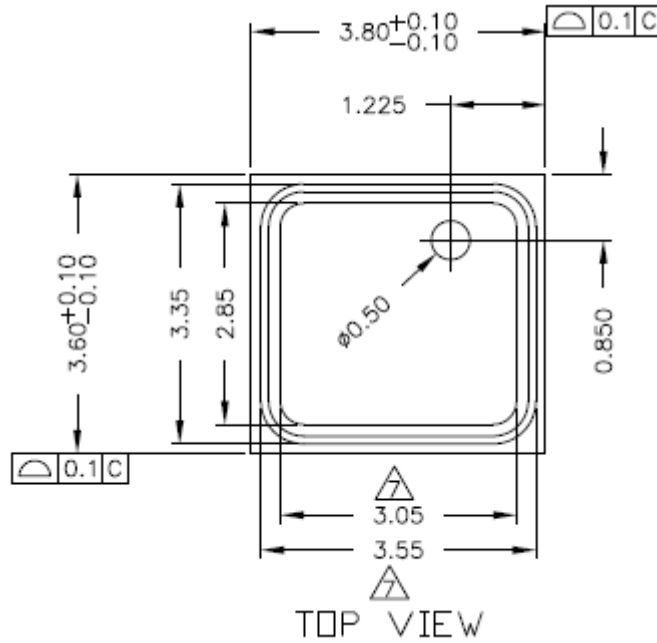


Figure 12: Top view BMP180

**6.2.3 Side view**

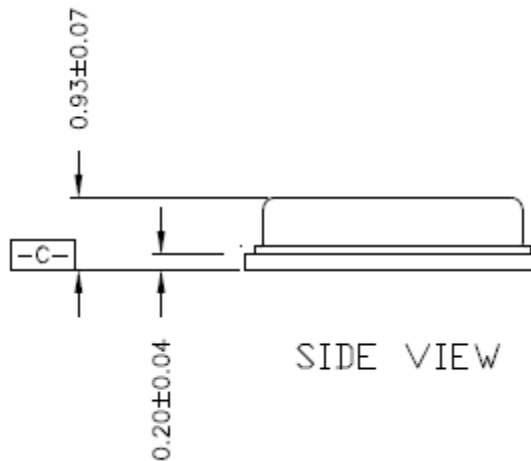


Figure 13: Side view BMP180