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BMP085
Digital pressure sensor

Bosch Sensortec

BOSCH

Invented for life

BMP085: Data sheet

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BMP085

DIGITAL PRESSURE SENSOR

Key features

- Pressure range: 300 ... 1100hPa (+9000m ... -500m above sea level)
- Supply voltage: 1.8 ... 3.6V (V_{DDA})
                          1.62V ... 3.6V (V_{DDD})

- LCC8 package: Robust, ceramic lead-less chip carrier (LCC) package
                          Small footprint: 5.0mm x 5.0mm
                          Super-flat: 1.2mm height

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

- Low noise: 0.06hPa (0.5m) in ultra low power mode
                          0.03hPa (0.25m) ultra high resolution mode
                          down to 0.1m (rms noise) possible

- Temperature measurement included
- I^{2}C interface
- Fully calibrated
- Pb-free, halogen-free and RoHS compliant,
- MSL 1

General Description

The BMP085 is the fully pin- and function compatible successor of the SMD500, a new generation of high precision digital pressure sensors for consumer applications. The universal C-code SMD500/BMP085 ("BMP085_SMD500_API") is fully upward compatible to SMD500 and recognizes automatically the device ID. Customers already working with the SMD500 pressure sensor are invited to contact Bosch Sensortec as soon as they intend to switch-over to the BMP085 sensor for getting first-hand support.

The ultra-low power, low voltage electronics of the BMP085 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 BMP085 offers superior performance. The I^{2}C interface allows for easy system integration with a microcontroller.

The BMP085 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 200 million pressure sensors in the field, the BMP085 continues a new generation of micro-machined pressure sensors.

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)

New features comparison

	BMP085	SMD500
Smaller package height	1.2mm	1.55mm
Faster conversion time (standard mode each)	7.5ms (max.)	34ms
Faster I^2C data transfer	max. 3.4MHz	max. 400kHz
Extended min. supply voltage	min. 1.8V	min. 2.2V
Lower stand-by current (typ.)	0.1µA	0.7µA
External clock	not necessary	necessary

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1. Electrical characteristics

If not stated otherwise, the given values are maximum values over temperature/voltage range in the given operation mode.

Table 1: Electrical 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
Peak current	I_{peak}	during conversion		650	1000	µA
Standby current	I_{DDSBM}	at 25°C		0.1		µA
Serial data clock	f_{SCL}				3.4	MHz
Conversion time temperature	t_{C_temp}	standard mode		3	4.5	ms
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
Absolute accuracy pressure V_{DD} = 3.3V		700 . . . 1100 hPa 0 . . . +65 °C	-2.5	±1.0	+2.5	hPa
		300 . . . 700 hPa 0 . . . +65 °C	-3.0	±1.0	+3.0	hPa
		300 . . . 1100 hPa -20 . . . 0 °C	-4.0	±1.5	+4.0	hPa
Resolution of output data		pressure		0.01		hPa
		temperature		0.1		°C
Relative accuracy pressure V_{DD} = 3.3V		700 . . . 1100 hPa @ 25 °C		±0.2		hPa
		0 . . . 65 °C @ p const.		±0.5		hPa

Noise in pressure		see table on page 12				
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
Solder drifts		Minimum solder height 50µm		±1.0		hPa
Long term stability		12 months		±1.0		hPa

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 BMP085 has to be handled as Electrostatic Sensitive Device (ESD).

Figure 1: ESD

3. Operation

3.1 General description

The BMP085 is designed to be connected directly to a microcontroller of a mobile device via the I^2C bus. The pressure and temperature data has to be compensated by the calibration data of the E^2PROM of the BMP085.

3.2 General function and application schematics

The BMP085 consists of a piezo-resistive sensor, an analog to digital converter and a control unit with E^2PROM and a serial I^2C interface. The BMP085 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)

Typical application circuit:
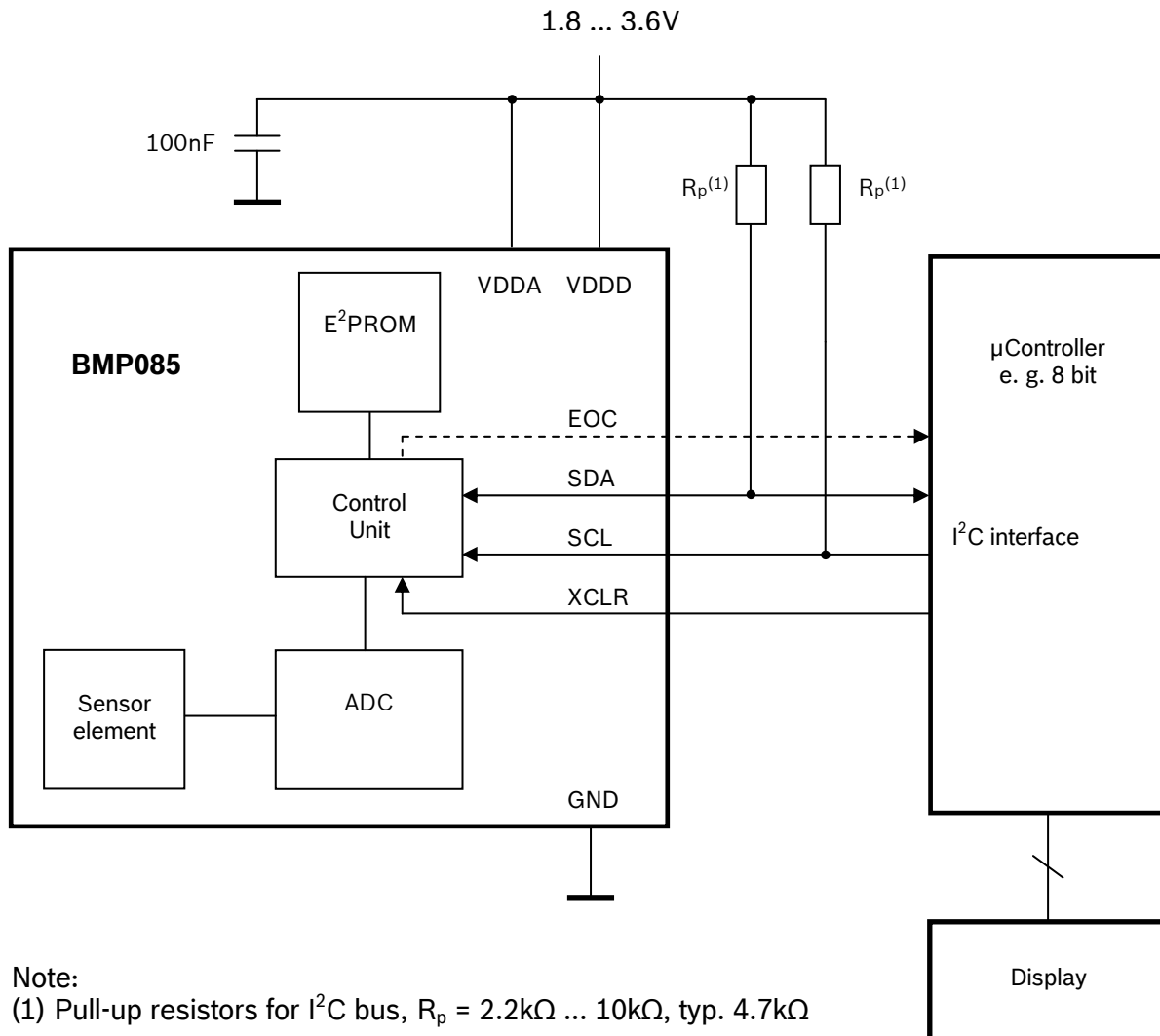
Note:
(1) Pull-up resistors for I^2C bus, R_p = 2.2kΩ ... 10kΩ, typ. 4.7kΩ

Note:
The BMP085 can be supplied independently with different levels of V_{DDA} and V_{DDD}, which is not possible with the SMD500. In case of different voltage levels, V_{DDA} and V_{DDD} shall have a 100nF decoupling capacitor each.

3.3 Measurement of pressure and temperature

For all calculations presented here an ANSI C code is available from Bosch Sensortec ("BMP085_SMD500_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^2C 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 BMP085 E^2PROM via the I^2C 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.

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

```
                    ┌─────────────┐
                    (    Start    )
                    └──────┬──────┘
                           │
                    ┌──────▼──────┐
                    │    Start    │
                    │ temperature │
                    │ measurement │
                    └──────┬──────┘
                           │  wait 4.5ms
                    ┌──────▼──────┐
                    │   Read UT   │
                    └──────┬──────┘
                           │
                    ┌──────▼──────┐
                    │    Start    │
                    │  pressure   │
                    │ measurement │
                    └──────┬──────┘
                           │  wait (depends on mode, see below)
                    ┌──────▼──────┐
                    │   Read UP   │
                    └──────┬──────┘
                           │
                    ┌──────▼───────────┐
                    │ Calculate        │
                    │ pressure and     │
                    │ temperature in   │
                    │ physical units   │
                    └──────────────────┘
```
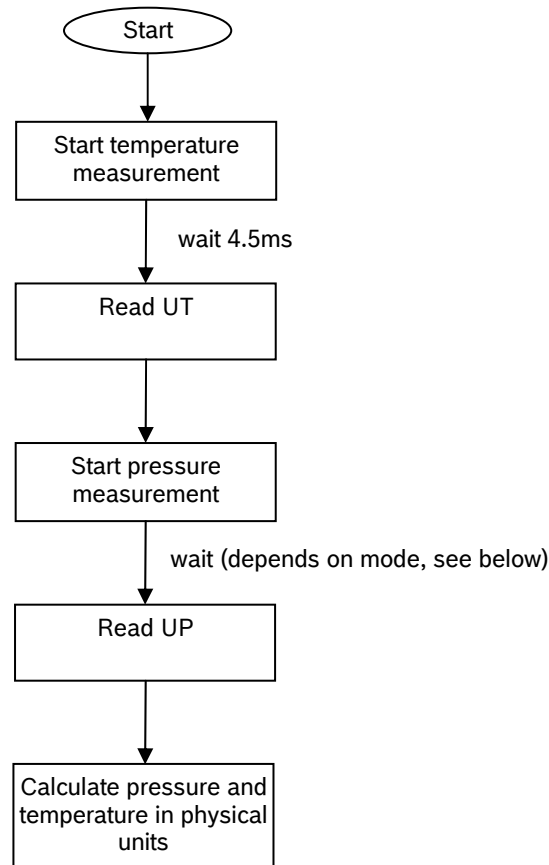
Figure 2: Measurement of pressure and temperature

Table 3: Overview of BMP085 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

The noise data is calculated as standard deviation of 10 data points. 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. This way the noise can be decreased further by software averaging.

3.4 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 4: Calibration coefficients

Parameter	BMP085 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 Calculation 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.

The universal code SMD500/BMP085 is fully upward compatible to SMD500 and recognizes automatically the device ID. Thus, the SMD500 can be replaced "on the fly" by the BMP085 without changing hardware or software.

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 ("BMP085_SMD500_API") from Bosch Sensortec and via its sales and distribution partners. **Please contact your Bosch Sensortec representative for details.**
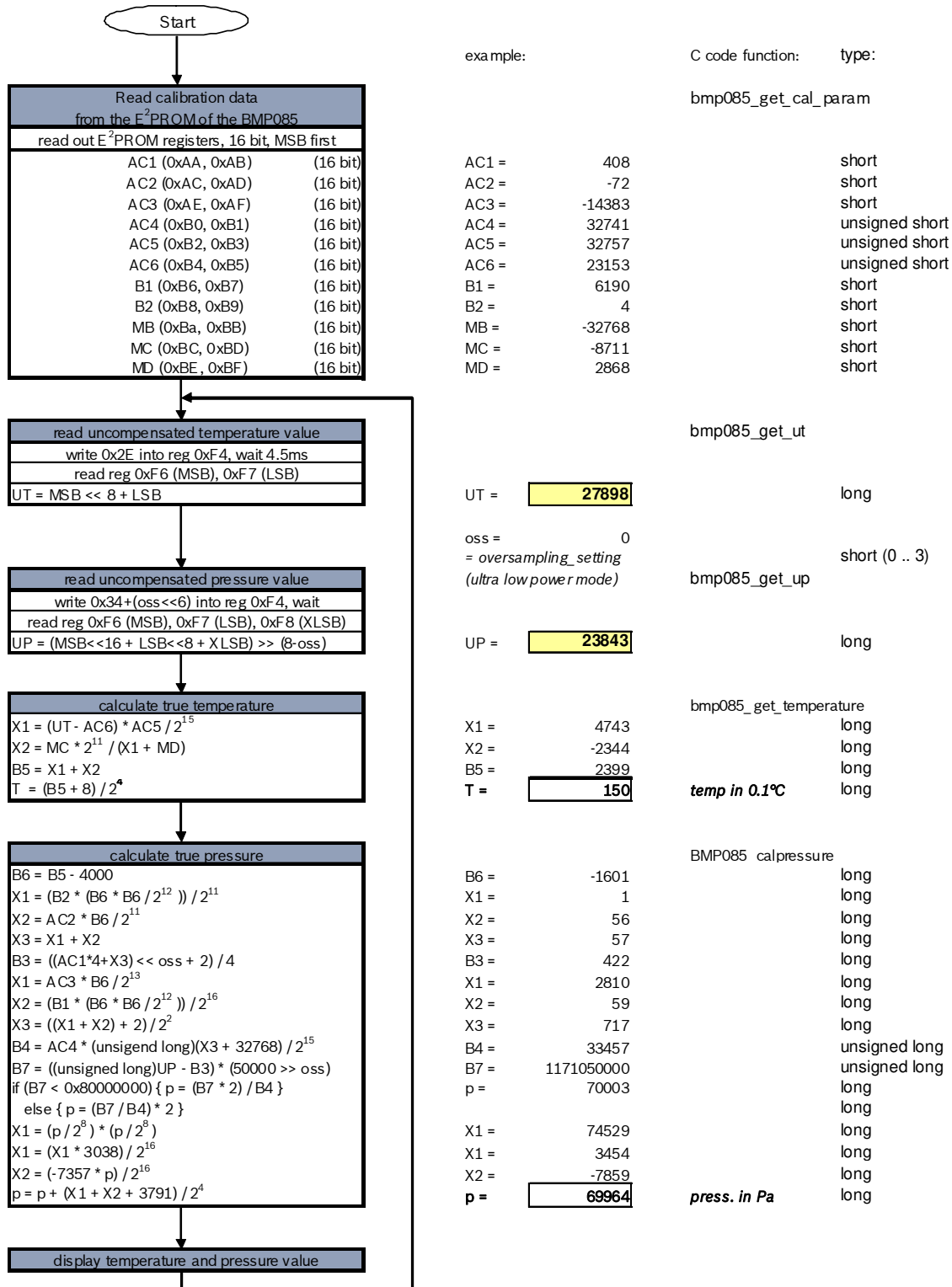
Calculation of pressure and temperature for BMP085

Start

flow	example:	C code function:	type:

Read calibration data from the E^{2}PROM of the BMP085

bmp085_get_cal_param

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

Register		example		type
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 =	-32768	short
MC (0xBC, 0xBD)	(16 bit)	MC =	-8711	short
MD (0xBE, 0xBF)	(16 bit)	MD =	2868	short

read uncompensated temperature value

bmp085_get_ut

write 0x2E into reg 0xF4, wait 4.5ms
read reg 0xF6 (MSB), 0xF7 (LSB)

$UT = MSB << 8 + LSB$

UT = **27898** long

oss = 0
= *oversampling_setting* short (0 .. 3)
(ultra low power mode) bmp085_get_up

read uncompensated pressure value

write 0x34+(oss<<6) into reg 0xF4, wait
read reg 0xF6 (MSB), 0xF7 (LSB), 0xF8 (XLSB)

$UP = (MSB<<16 + LSB<<8 + XLSB) >> (8\text{-}oss)$

UP = **23843** long

calculate true temperature

bmp085_get_temperature

equation	example	type
$X1 = (UT - AC6) * AC5 / 2^{15}$	X1 = 4743	long
$X2 = MC * 2^{11} / (X1 + MD)$	X2 = -2344	long
$B5 = X1 + X2$	B5 = 2399	long
$T = (B5 + 8) / 2^4$	**T = 150**	*temp in 0.1°C* long

calculate true pressure

BMP085 calpressure

equation	example	type
$B6 = B5 - 4000$	B6 = -1601	long
$X1 = (B2 * (B6 * B6 / 2^{12})) / 2^{11}$	X1 = 1	long
$X2 = AC2 * B6 / 2^{11}$	X2 = 56	long
$X3 = X1 + X2$	X3 = 57	long
$B3 = ((AC1*4+X3) << oss + 2) / 4$	B3 = 422	long
$X1 = AC3 * B6 / 2^{13}$	X1 = 2810	long
$X2 = (B1 * (B6 * B6 / 2^{12})) / 2^{16}$	X2 = 59	long
$X3 = ((X1 + X2) + 2) / 2^2$	X3 = 717	long
$B4 = AC4 * (unsigend long)(X3 + 32768) / 2^{15}$	B4 = 33457	unsigned long
$B7 = ((unsigned long)UP - B3) * (50000 >> oss)$	B7 = 1171050000	unsigned long
if (B7 < 0x80000000) { p = (B7 * 2) / B4 }	p = 70003	long
else { p = (B7 / B4) * 2 }		long
$X1 = (p / 2^8) * (p / 2^8)$	X1 = 74529	long
$X1 = (X1 * 3038) / 2^{16}$	X1 = 3454	long
$X2 = (-7357 * p) / 2^{16}$	X2 = -7859	long
$p = p + (X1 + X2 + 3791) / 2^4$	**p = 69964**	*press. in Pa* long

display temperature and pressure value

Figure 3: Calculating pressure and temperature for BMP085

3.6 Calculation 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:

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

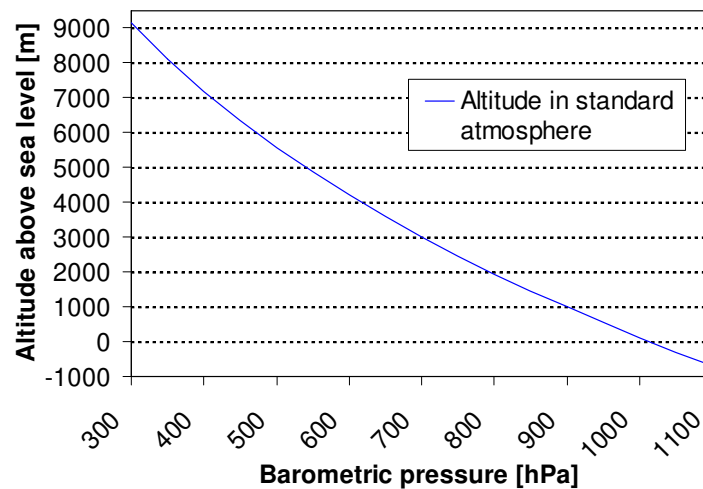Thus, a pressure change of Δp = 1hPa corresponds to 8.43m at sea level

Figure 4: Calculation absolute altitude

3.7 Calculating pressure at sea level

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

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

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

4. I²C Interface

- I²C is a digital two wire interface
- Clock frequencies up to 3.4mBit/sec (I²C standard, fast and high-speed mode supported)
- SCL and SDA needs a pull-up resistor, typ. 4.7 kOhm to V_{DDD} (one resistor each for all the I²C bus)

The I^2C 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. SDA (serial data) and SCL (serial clock) have open-drain outputs.

For detailed I^2C-bus specification please refer to:
http://www.nxp.com/acrobat_download/literature/9398/39340011.pdf

The BMP085 has a master clear (XCLR) low-active input that is used to reset the BMP085 and initializes internal registers and counters. The device is automatically reset by power on reset (POR) circuitry. XCLR can be left floating if not used. The pad has an internal pull-up resistor of typ. 120kOhm.

4.1 I²C specification

Table 5: Electrical parameters for the I^2C interface

Parameter	Symbol	Min.	Typ	Max.	Units
Clock input frequency	f_{SCL}			3.4	MHz
Input-low level	V_{IL}	0		$0.2 * V_{DDD}$	V
Input-high level	V_{IH}	$0.8 * V_{DDD}$		V_{DDD}	V
SDA and SCL pull-up resistor	$R_{pull-up}$	2.2		10	kOhm
SDA sink current @ V_{DDD} = 1.62V, V_{OL} = 0.3V	I_{SDA_sink}		9		mA
EOC sink current @ V_{DDD} = 1.62V, V_{OL} = 0.3V	I_{SDA_sink}		7.7		mA
EOC source current @ V_{DDD} = 1.62V, V_{OH} = 1.32V	I_{SDA_source}		1.5		mA
XCLR pulse length	t_{XCLR}	1			µs
Start-up time after power-up, before first communication	t_{Start}	10			ms

4.2 Device and register address

The BMP085 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).

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

There is an easy way to connect two BMP085 to the same I^2C bus: You can use the XCLR input of BMP085 to set one BMP085 part silent while you communicate with the other BMP085 part via I^2C and vice versa. The signals can be provided by two digital outputs of the microcontroller, or one digital output and one inverter.

4.3 I²C protocol

The I^2C 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.
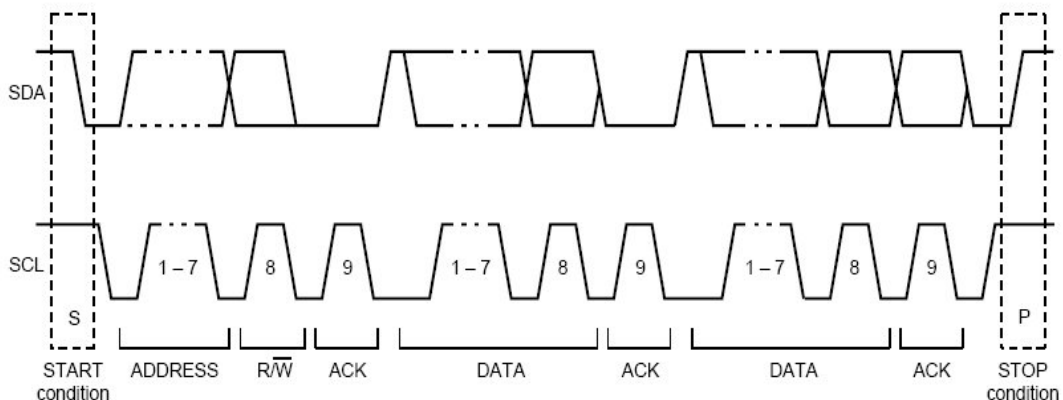
Figure 5: I²C protocol

4.4 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 BMP085 sends an acknowledgement (ACKS) every 8 data bits when data is received. The master sends a stop condition after the last ACKS.
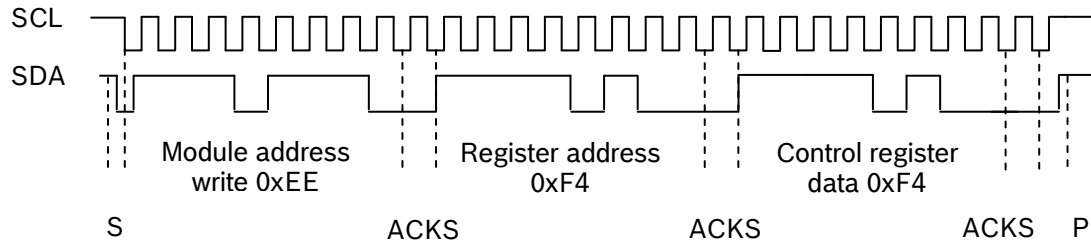
Figure 6: Timing diagram for starting pressure measurement

Abbreviations:

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

Table 6: Control registers values for different internal *oversampling_setting* (osrs)

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

Instead of waiting for the maximum conversion time, the output pin EOC (end of conversion) can be used to check if the conversion is finished (logic 1) or still running (logic 0). After the conversion is finished BMP085 switches automatically in standby mode.

4.5 Read A/D conversion result or E²PROM data

To read out the temperature data word UT (16 bit), the pressure data word UP (16 to 19 bit) and the E^2PROM 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^2PROM 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 BMP085 (ACKS). The BMP085 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 ("BMP085_SMD500_API", available from Bosch Sensortec).
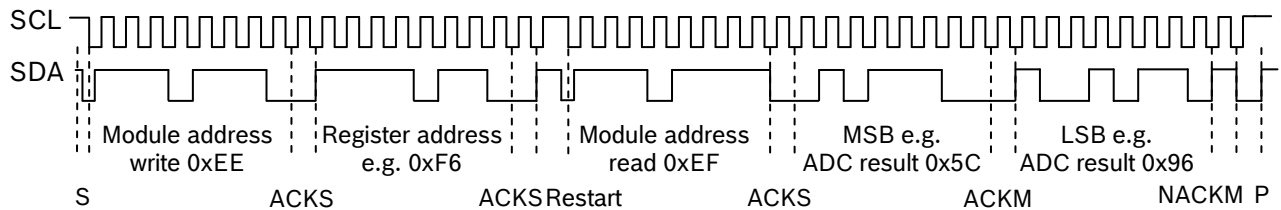
Figure 7: Timing diagram read 16 bit A/D conversion result

5. Package

5.1 Pin configuration

Picture shows the device in top view. Device pins are shown here transparently only for orientation purposes.
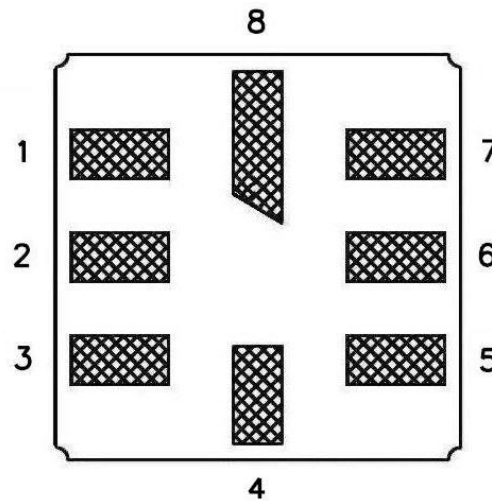
Figure 8: Pin configuration

Table 7: Pin configuration

Pin No.	Name	Function	Type
1	GND	Ground	Power
2	EOC	End of conversion	Digital output
3	V_{DDA}	Power supply	Power
4	V_{DDD}	Digital power supply	Power
5	NC	no internal connection	-
6	SCL	I^2C serial bus clock input	Digital input
7	SDA	I^2C serial bus data	Digital bi-directional
8	XCLR	master clear (low active) input	Digital input

5.2 Outline dimensions

The sensor housing is a standard 8-pin lead-less chip carrier (LCC8) ceramic package. Its dimensions are 5.0mm x 5.0mm (±0.25mm) x 1.2mm (±0.12mm).
Package weight is approximately 0.09grams.

Note: All dimensions are in mm.

5.2.1 Top view

Device pins are shown here transparently only for orientation purposes.
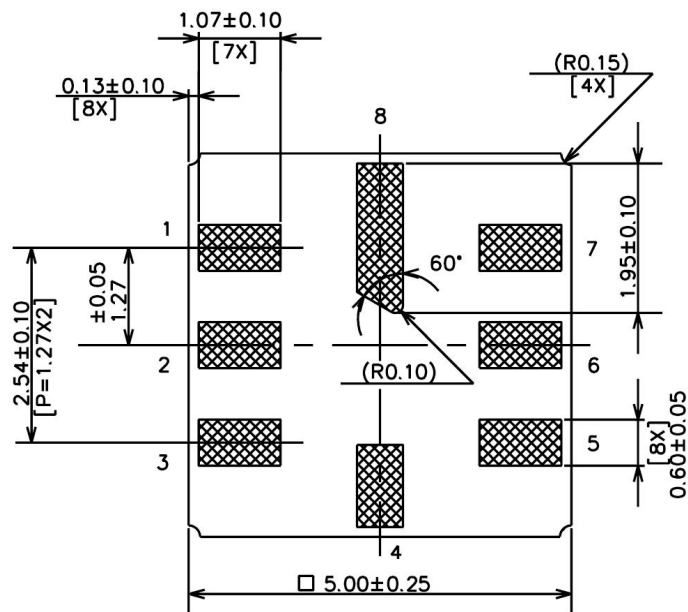
Figure 9: Top view

5.2.2 Top view with lid
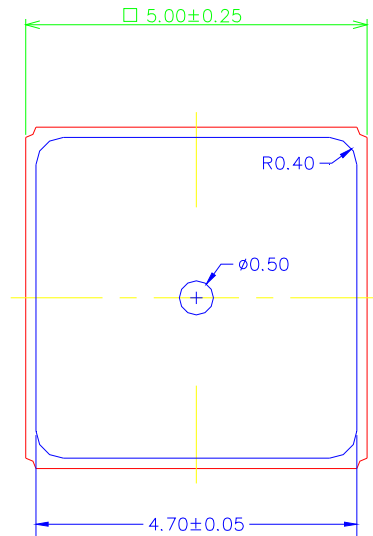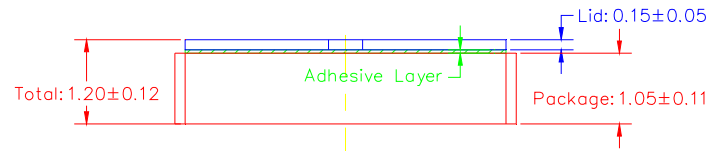

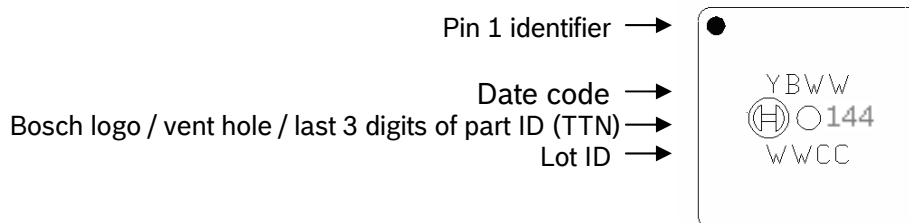Figure 10: Top view with lid

5.2.3 Side view with lid

Figure 11: Side view with lid

5.3 Device marking

The device lid shows the following laser-marking:

Pin 1 identifier →

Date code →
Bosch logo / vent hole / last 3 digits of part ID (TTN) →
Lot ID →

The vent hole (diameter 0.5mm) is in the center of the lid, between the Bosch logo and the part ID code (144).

5.4 Tape on reel

Number of parts per reel: 3,000
Orientation of the parts inside the reel is according to EN60286-3.
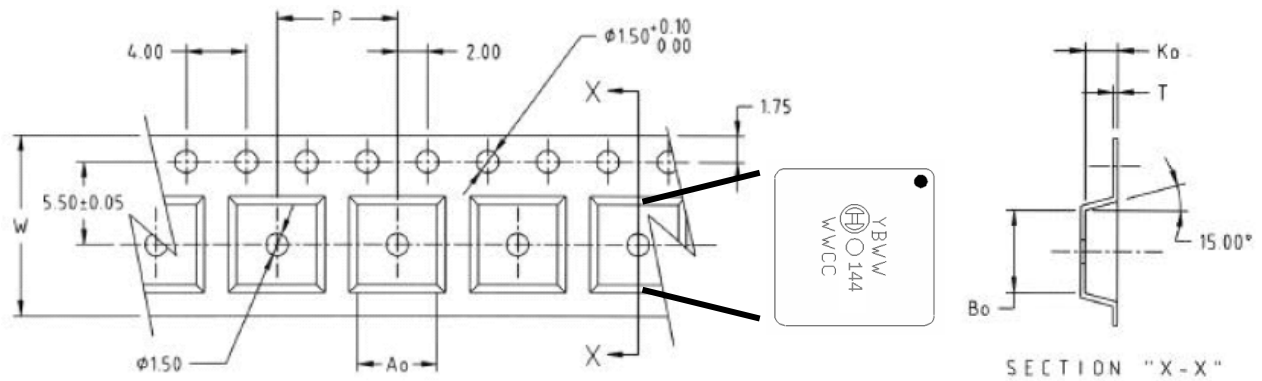
Carrier tape material: Conductive polystyrene C 100, $10^3 - 10^6$ Ohm/sq.

Dimensions are in mm:

A_0 = 5.30 ± 0.10
B_0 = 5.30 ± 0.10
K_0 = 2.10 ± 0.10
P = 8.00 ± 0.10
W = 12.00 +0.30 / -0.10
t = 0.30 ± 0.05

The bars between the cavities are embossed about 0.2mm into the direction of K_0. All other dimensions and tolerances follow the EIA 481 standard.

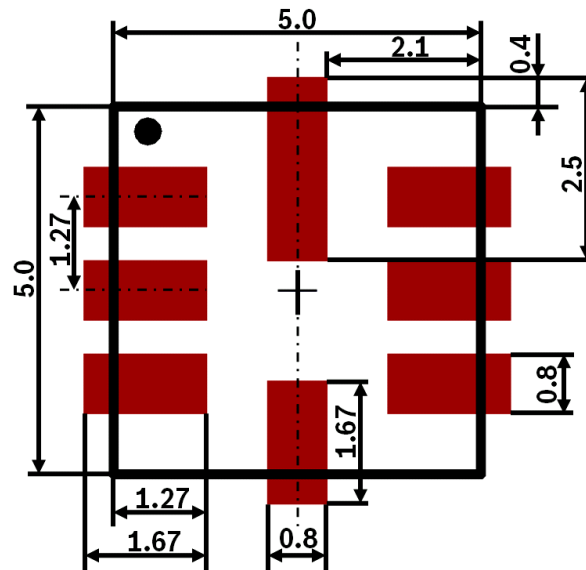## 5.5 Printed circuit board (PCB) design

Figure 12: Recommended PCB design (top view)

5.6 Moisture sensitivity level and soldering

The BMP085 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).

The BMP085 devices have to be soldered within 6 months after shipment (shelf life). To ensure good solder-ability, the devices shall be stored at room temperature (20°C).

The soldering process can lead to an offset shift of typically 1hPa.

5.7 RoHS compliancy

The BMP085 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 BMP085 sensor is also halogen-free. Please contact your Bosch Sensortec representative for the corresponding analysis report.

5.8 Mounting and assembly recommendations

Please read the following recommendations carefully.

- 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; if waterproof packaging is needed, venting can be accomplished by a vent element with a membrane like Gore-Tex$^{(TM)}$

- 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); therefore, the hole in the top lid shall not be exposed to direct light during operation

- The BMP085 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

- For further details, please refer to the BMP085 handling, soldering & mounting instructions manual that is also available from Bosch Sensortec