Application Note

BMP280
End-of-line Offset Calibration

Bosch Sensortec

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BMP280: Application Note (End-of-line Offset Calibration)

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1. About this application note

This document describes how an additional post-soldering offset calibration step (end-of-line calibration) can improve the accuracy of the barometric sensor. It describes how the end-of-line calibration is performed with the aid of a reference sensor and the requirements to the production environment. This application note applies to all pressure sensors referenced in the field *technical reference codes* on the previous page.

Important guideline: Please wait at least 24 hrs after soldering before applying the end-of-line calibration. This is to minimize additional solder drift. Otherwise, there is the high probability of significant drift after calibration. General guideline also indicates that longer relaxation time of more than 24 hrs is optional and could lead to optimized calibration results.

2. Warnings

Performing offset correction on a pressure sensor is a complex task. An improvement of sensor performance is only possible in a very well-controlled production environment, where no fast pressure changes (e.g. blowing winds, doors being opened or closed) occur. Highly accurate reference sensors (typically priced over $10,000) are required. The reference sensor must be constantly checked for sudden failures and recalibrated regularly.

Ensuring the accuracy and reliability of the end-of-line calibration is the task of the user. Bosch Sensortec cannot guarantee the accuracy of the modified parameters. Depending on the user's implementation, there may be a loss of accuracy.

3. Concept of end-of-line calibration

The BMP280 is delivered in a completely calibrated form. However, the soldering process generates additional offsets. Typically, the soldering induces a change in pressure output of +1 hPa. For this reason, the default offset trimming is −1 hPa, so that the offset of the distribution is centered close to 0 Pa after soldering. However, there is a certain spread in soldering related offsets which are visible as an offset error of sensor measurements. By adding an additional offset compensation step after the soldering process, the absolute accuracy may be improved, especially close to the temperature, pressure and humidity level at which the end-of-line calibration was performed. The accuracy over temperature changes will not increase by offset correction.

4. Reference sensor requirements

The reference sensor should have an absolute precision of below ±0.1 hPa in order to get a noticeable accuracy gain.

5. Environmental requirements

For the end-of-line calibration, the environment needs to be free of pressure peaks and offsets. These can be caused by wind gusts, steady winds, closing doors or windows and other events. The reference sensor must be positioned at the same height as the sensors which are recalibrated. If they cannot be positioned at the same height, a pressure correction is required. The correction depends on absolute pressure, air temperature, and air humidity. A rough estimation can be made using the table below. The values used must however be verified in the actual production environment.

Table 1: indication of barometric height steps; to be verified at production site

	Barometric height step [m/hPa]			
height [m]	−15 °C	0 °C	15 °C	30 °C
0	7.5	7.9	8.3	8.8
500	7.9	8.3	8.7	9.2
1000	8.3	8.7	9.2	9.6
2000	9.3	9.7	10.1	10.6

6. Estimation on accuracy gain

When performed properly, a gain in accuracy at room temperature can be expected over the entire pressure range, i.e. from 300 to 1100 hPa. The pressure during calibration is not important for the final result, but temperature should be as close as possible to the temperature at which the sensor is intended to be used (i.e. should be done at room temperature in order to increase accuracy at room temperature).

To give an idea of the possible improvements, an example of how a distribution after soldering could look like, is plotted in a distribution diagram and can be seen in Figure 1.

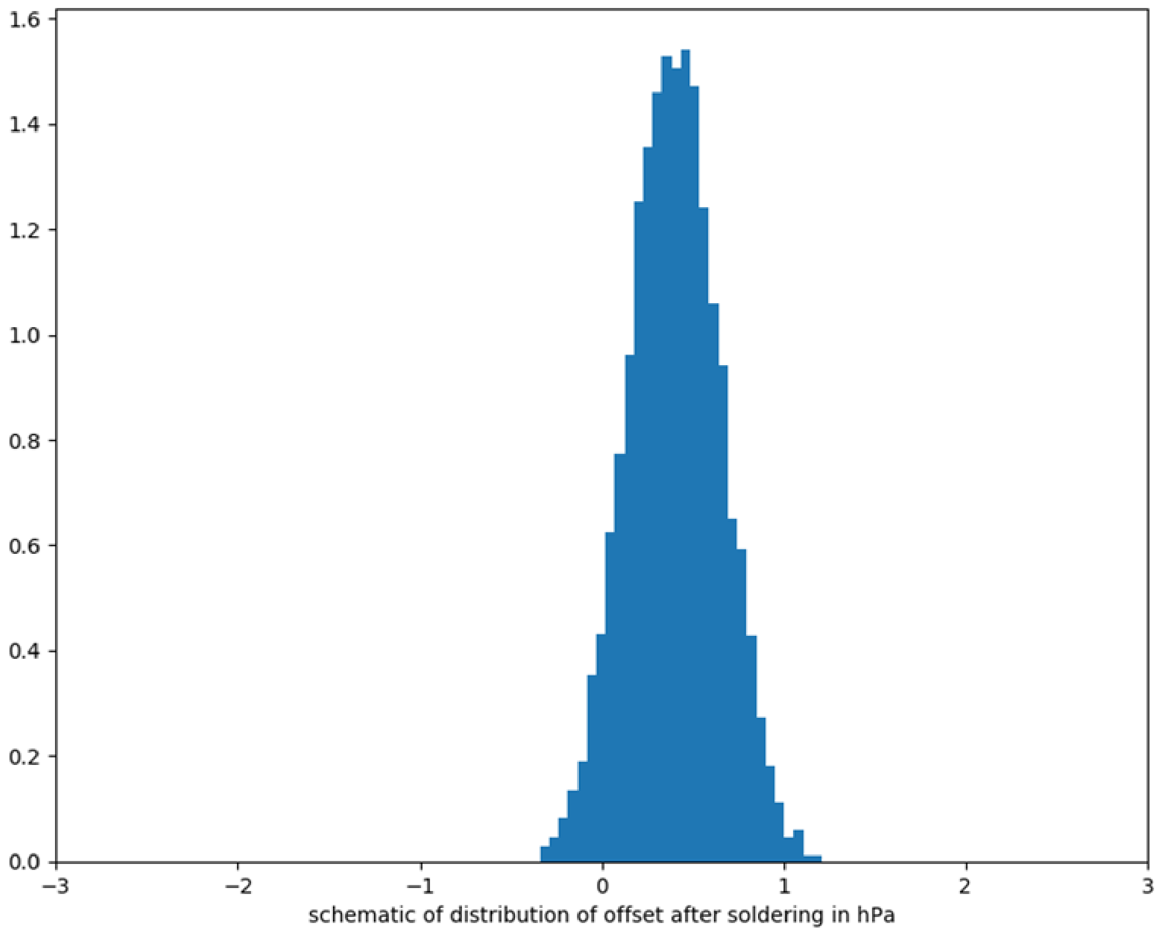

Figure 1: an example of offset distribution after soldering (in hpa)

The values will depend on many influences such as PCB properties, soldering process and mounting stress and cannot be generalized. They do however give an idea of how a distribution can look after soldering.
If the offset, as an example, has a mean error of 0.37 hPa and a standard deviation of 0.34 hPa, it can be reduced to almost zero if an additional offset compensation step is applied to each sensor (depending on the reference sensor and the production environment).

7. Implementation

7.1 Sensor measurement

The sensor should be operated in ultra high resolution mode. Even though the sensor noise is so low that a single measurement would suffice to estimate the offset, it is recommended to take several measurements (e.g. 16) and use the average result. This is done in order to compensate for a possibly noisy environment. Based on reliability of the measurements at the production site, the number of measurements used to compute the average can be reduced. A good way to assess the amount of disturbance is to calculate the standard deviation of the measurement points. If an unexpected result is seen here (standard deviation of the measurement points > 0.06 hPa), the measurement was probably disturbed and should be repeated.

7.2 Offset estimation and limits

The offset can be calculated as *offset = mean(sensor measurements) − reference*. If the *offset* is larger than the data sheet maximum deviation (4 hPa) the measurement should be repeated to make sure than it was not wrong due to a disturbance. If the offset continues to be this large on several parts, the customer should ensure that the reference sensor is still working correctly and that the parts are not mounted under excessive stress.

7.3 Implementation of the correction

The correction of the offset should be applied after the normal sensor compensation formula. This will lead to ideal performance; there is no advantage in interfering in the compensation formula. The recommended way of compensation is depicted in Figure 2.

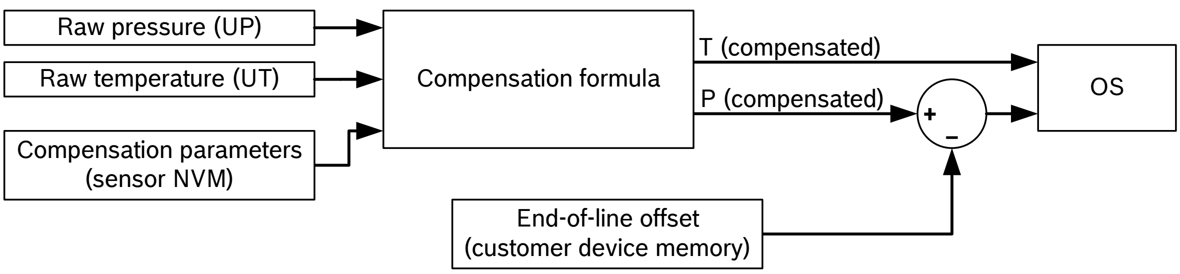

Figure 2: Implementation of end-of-line correction

7.4 Details of the implementation

1. SMT
    a. Soldering sensor to the board (PCB)
    b. Check basic function in production line via self-test (basic operation check (on/off function; barometric pressure check, temperature sensor check; pcb has to be connected to pc via USB cable
        i. Pass if the measured value is between 990 and 1030 hPa)
        ii. Pass if internal temperature output values is between -40 and 85 °C
2. Set level test after device assembly, compare pressure value of BMP280 against golden sample
    a. Simple process test after device assembly; optional connection of the device to a PC or direct readout of pressure value on device.
    b. Check if measured pressure values is in the range of +/- 7 hPa
        i. Pass if measure values is +/- 7 hPa

This step is to sort out bad parts (wrong soldering or HW problem). This topic has nothing to do with accuracy limit

3. Inline calibration (Important: It has to be in controlled environment → constant pressure and temperature to add compensated pressure output value to the devices memory compared to the reference equipment
        i. Example 1: Reference equipment or golden sample shows 1000 hPa
            1. Device pressure output is 995 hPa
            2. + 5 hPa is saved to #1 device's memory
        ii. Example 2: Reference equipment or golden sample shows output values of 1001 hPa
            1. Device pressure output shows value of 1003 hPa
            2. – 2 hPa is saved to the device's memory
    b. No more steps needed, optional the customer can make a validation check, because setup has some inaccuracies
        i. Measure directly after inline calibration
        ii. Pass if +/- 1 hPa compared to reference sensor

4. OQC before packing the device into box

Random samples to check if it is in the +/- 3 hPa range (considering TCO, long term stability, reference machine deviation, margin deviation and dispersion error).

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.

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8.3 Application examples and hints

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9. Document history and modifications

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