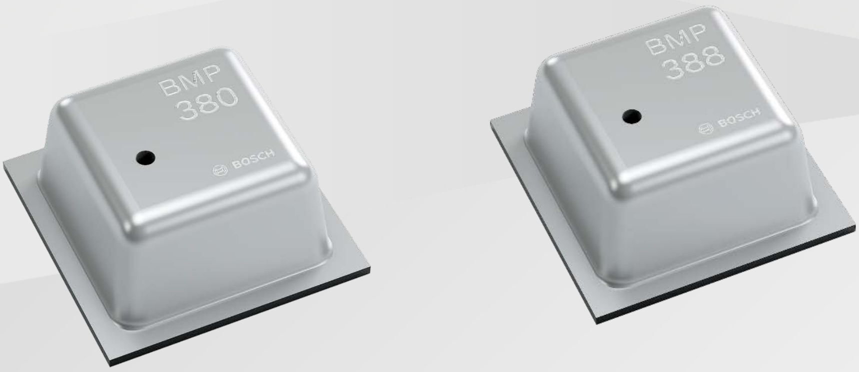
Application Note

High-resolution pressure measurement for enhancement of GPS navigation



Application Note

Document revision	1.1
Document release date	October 2019
Document number	BST-BMP38x-AN001-01
Technical reference code(s)	
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.

BMP38x
Digital pressure sensor

The BMP38x 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 mm^2 and max 0.8 mm package height. Its small dimensions and its low power consumption of 3.4 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

- Package: 2.0 mm x 2.0 mm x 0.8 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: 1.71 V to 3.6 V
  V_{DDIO} interface voltage range: 1.2 V to 3.6 V
- Relative accuracy: typ. ± 8 Pa, equiv. to ± 0.66 m
  (700 … 900 hPa, 25 . . . 40 °C)
- Absolute accuracy: typ. ± 50 Pa
  (300 ...1100 hPa, 0 ...+65 °C)
- Temperature coefficient offset: typ. ± 0.75 Pa/K
  (-20 … 65°C @700 -1100 hPa)
- Current consumption: 3.4 µA at 1 Hz pressure and temperature
  2.0 µA in sleep mode
- Operating range: -40 – +85 °C, 300–1250 hPa
- The product is RoHS compliant, halogen-free, MSL1

BMP38x enables accurate altitude tracking and is specifically suited for drone applications. The best-in-class TCO between 0-65°C for accurate altitude measurement over a wide temperature range of the BMP38x greatly enhance the drone flying experience by making accurate steering easier. It is compatible for use with other Bosch sensors, including the new BMI088 for better performance, robustness and stability. The new BMP38x sensor offers outstanding design flexibility, providing a single package solution that can also be easily integrated into other existing and upcoming devices such as smart homes, industrial products and wearables.

The sensor is more accurate than its predecessor BMP38x, 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 BMP38x is ideally suited for fitness and navigation applications which require highly accurate, low power and low latency sensor data fusion.
The new interrupt functionality provide 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.
BMP38x 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.

Table of contents

1 Abstract

This application note describes how to use the Bosch Sensortec BMP38x pressure sensor in navigation context and shows the impact of enhancing GPS-based navigation systems by BMP38x.

2 General descriptions

Pressure sensors can be used to measure the barometric pressure respectively the pressure change enabling altitude measurements. The BMP38x fits ideally in such applications as its comprehensive package size and electrical parameters are specially targeted for portable and ultra-low power applications. The BMP38x is fully calibrated and temperature compensated. The current consumption is around 2.7µA at a read-out rate of 1 sample/s. The device communicates via an I^2C interface.

Bosch is leading edge provider for pressure sensors with an experience of 450 million pressure sensors in the field.

3 Detection of GPS Signal Reflections

When a GPS signal is reflected by a skyscraper or high buildings, its signal propagation delay increases and the GPS receiver assumes a larger distance from that satellite. Therefore, vertical and horizontal accuracy drops.

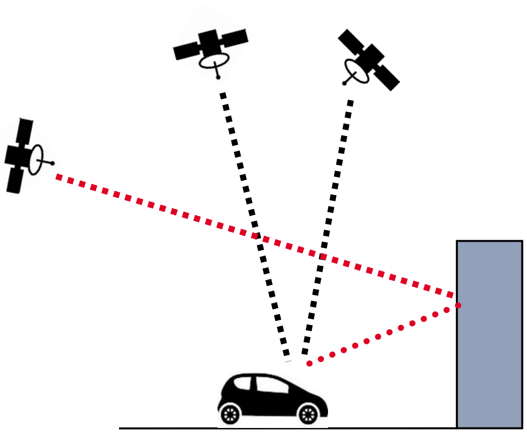


Figure 1: GPS signal reflection and true position of GPS receiver

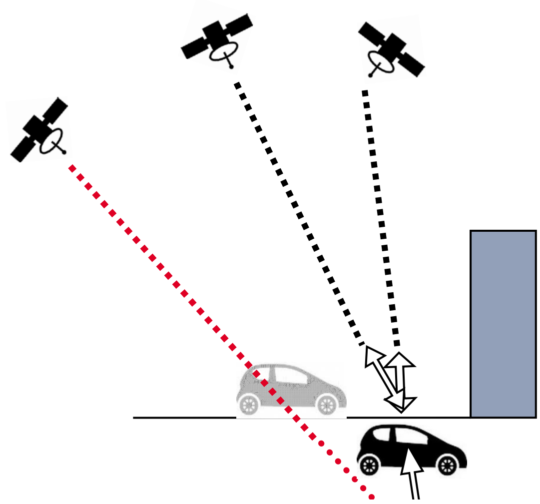


Figure 2: Position calculated by GPS receiver, the arrows indicate the minimized deviation errors

With the BMP38x pressure sensor multi-path GPS signal detection and suppression is possible:

A simple method is to compare the altitude change of GPS and BMP38x. If it does not correlate (see Figure 3), the navigation system can assume that GPS signal reflections occurred and mark the GPS position as invalid.

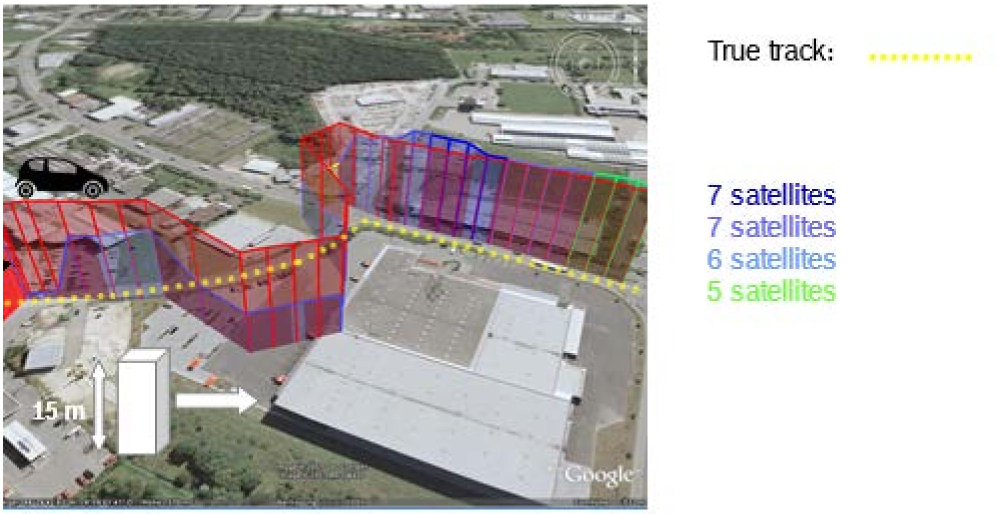


Figure 3: GPS altitude (blue) does not correlate with BMP38x altitude (red) due to GPS signal reflection; here the maximum vertical GPS error is about 45 m.

If a tight integration in the GPS algorithm is possible, three methods for increasing accuracy are suggested:

- Find the set of satellites, which matches best the altitude of the pressure sensor by calculating the position for each combination of satellites. Multi-path signals are thus suppressed, since they would have pushed the calculated position underneath the true position, see Figure 2.

- If computing power is limited, perform a three step calculation:

  1. Calculate position based on all satellites available, see Figure 2.
  2. Adjust vertical position with altitude from the BMP38x, see Figure 5. The deviation between non-multi-path and multi-path GPS signals thus differs significantly.
  3. Ignoring satellites with a too high deviation re-perform position calculation, see Figure 5.

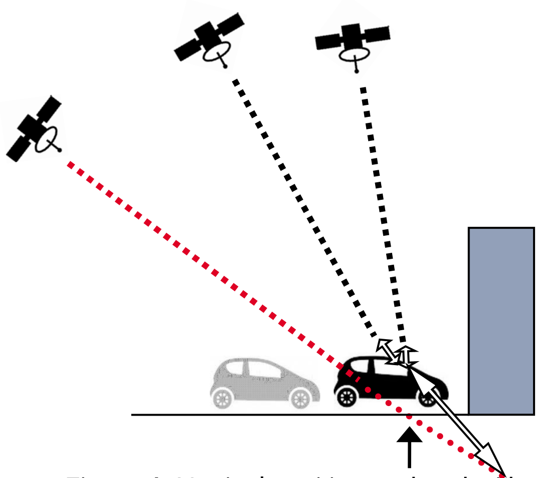


Figure 4: Vertical position updated with the altitude from the BMP38x, the arrows indicate the minimized errors for each signal

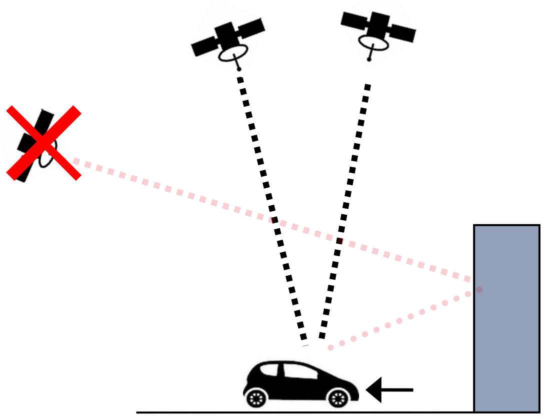


Figure 5: Position calculated by GPS receiver, if the multi-path GPS signal is ignored

- Reduce the degree of freedoms in the calculation of the mathematically most probable position by forcing it on the surface of the earth's ellipsoid that is enlarged by the altitude provided by the BMP38x. Besides the fact that this suppresses multi-path signals to a certain degree, horizontal accuracy will significantly increase if only three satellites are in view.

We emphasise that the suggested methods work even without having calibrated the pressure sensor to the exact pressure at sea level – just look at the altitude changes: For example, instead of finding the set of satellites that matches best the altitude of the BMP38X, find a combination, whose altitude difference to the last GPS position matches best the difference of the two corresponding altitudes provided by the BMP38x:

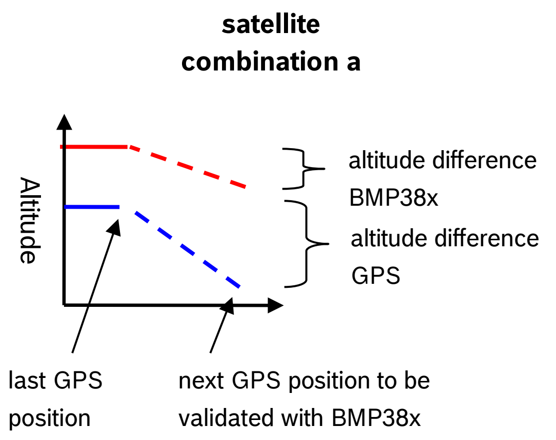


Figure 6: As altitude differences do not match, this combination of satellites contains multi-path GPS signals

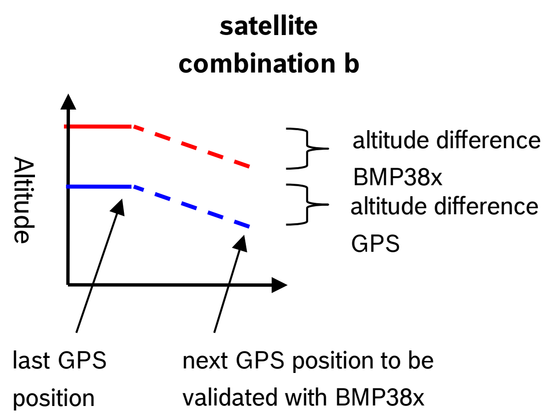


Figure 7: Altitude differences match, multi-path GPS signals are suppressed

Note: Due to weather change, a reliable altitude should be provided about every minute - either by GPS or by 3D map information - to recalibrate the pressure sensor if the absolute altitude is desired.

4 Distance estimations in tunnels

As navigation systems cannot receive GPS signals in tunnels and reacquisition takes up to 15 seconds, distance estimation is required if intersections are located inside or directly after the tunnel. In this section we suggest a method for distance estimation with the BMP38x used as altimeter.

4.1 Tunnels with slope

The approach is to measure the exact altitude difference between tunnel entrance and the actual altitude of the car. Three-dimensional map information enables the navigation system to accurately estimate the distance covered in the tunnel.
In contrast to conventional distance estimation based on the assumption that the velocity before and inside the tunnel is identical, this method is invulnerable to velocity changes.

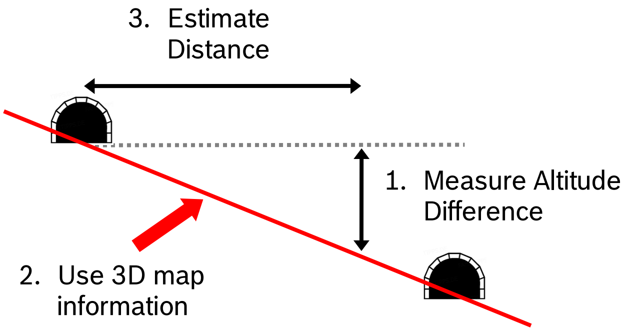


Figure 8: Tunnels with slope

The following examples demonstrate the efficiency of this method.

4.1.1 Tunnel in the Black Forrest (Germany)

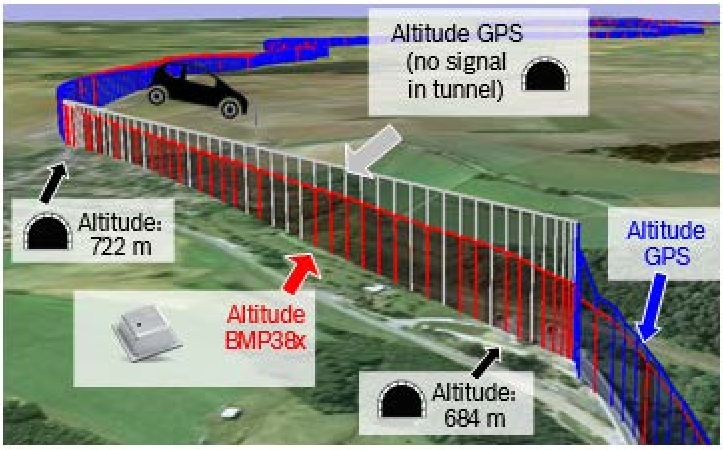


Figure 9: Altitude profile of BME38x (red) and GPS (blue) in a tunnel in the Black Forest

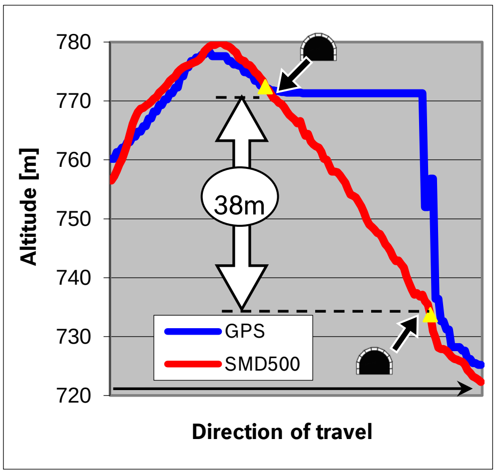


Figure 10: Altitude difference between tunnel entrance and exit

- Altitude difference: 38m
- Altitude resolution: 0.3m
- Tunnel length: 1100m

⇨ **If the slope is linear, the distance resolution is < 10m !**

Assuming a constant slope, distance resolution may be estimated with the following formula:

$$Distance\_Resolution = \frac{Length\_of\_tunnel}{Altitude\_Difference} * Altitude\_Resolution$$

4.1.2 Tunnel in Stuttgart (Germany)

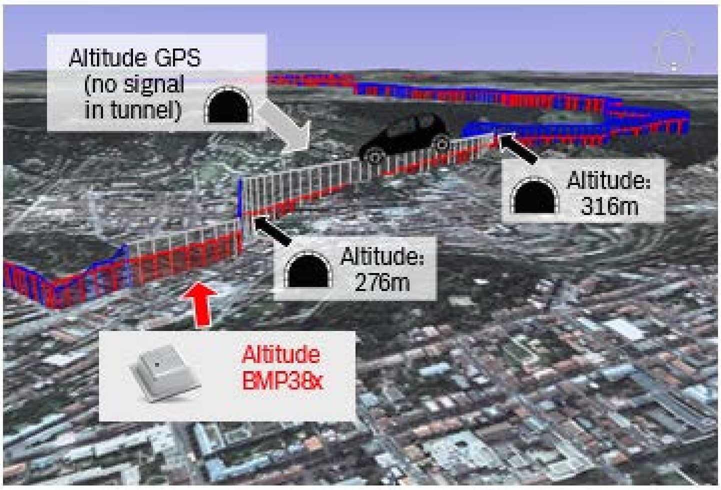


Figure 11: Altitude profile of BMP38x (red) and GPS (blue) in a tunnel in Stuttgart

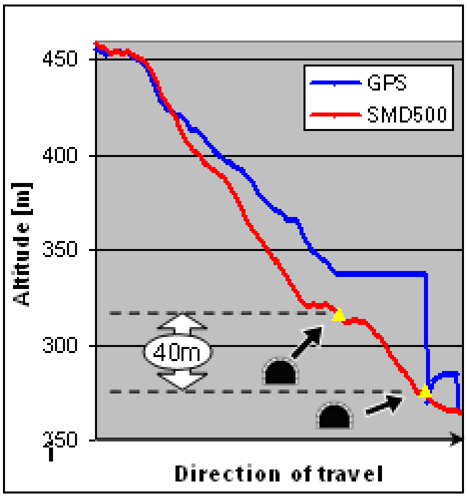


Figure 12: Altitude difference between tunnel entrance and exit

Note: deviation between GPS and BMP38x before the tunnel entrance is due to limited visibility of satellites in steep and woody area.

- Altitude difference: 40m
- Altitude resolution: 0.3m
- Tunnel length: 1200m

=> **If slope is linear, distance resolution is < 10m !**

4.2 Tunnels without slope

4.2.1 Tunnel without slope

Urban tunnels without slope inside mostly pass underneath ground. Therefore, they probably have a slope before its entrance and after its exit, e.g see Figure 10.

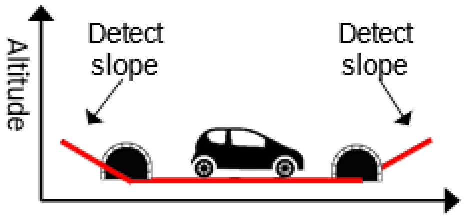


Figure 13: Tunnels without slope

These slopes can be detected with the BMP38x pressure sensor used as altimeter. The tunnel exit is thus determined much faster than with a GPS receiver, since reacquiring the GPS signal may take several seconds.

Figure 3: Slope after tunnel exit

5 Recognition of slip roads for entering or leaving the motorway

Due to its poor horizontal accuracy, roads passing very close to each other are indistinguishable with (civil) GPS.

In case of slip roads for entering or leaving the motorway, the BMP38x provides the navigation system with the essential information by indicating the slope of the road:

If the car proceeds on the local lane (case a, see Figure 11) altitude change is negligible.
By contrast, if it enters the motorway (case b), the altitude change is very reliably detectable with the BMP38x pressure sensor.

Note: Even though GPS provides altitude information, it is not consistent and accurate enough to reliably detect the slopes.

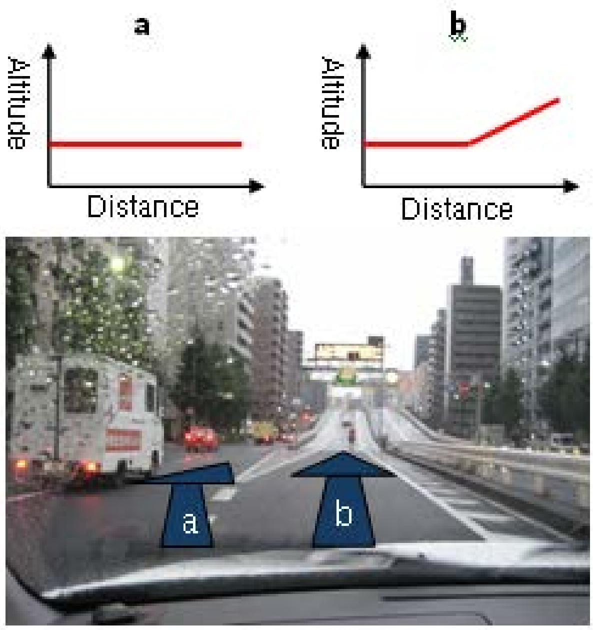


Figure 15: Slip road for entering a motorway in Tokyo (Japan)

6 Legal disclaimer

6.1 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.

6.2 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.

6.3 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.

7 Document history and modifications

Rev. No	Chapter	Description of modification/changes	Date
1.0		Initial release	April 2018
1.1	6	Updated legal disclaimer	October 2019

Bosch Sensortec GmbH
Gerhard-Kindler-Straße 9
72770 Reutlingen / Germany

www.bosch-sensortec.com

Modifications reserved | Printed in Germany
Preliminary - specifications subject to change without notice
Document number: BST-BMP38x-AN001-01
Revision_1.1_102019