

BMM150

Handling, soldering & mounting instructions



BMM150 HSMI

Document revision 1.4

Document release date December 2019

Document number BST-MCS-HS000-04

Technical reference codes 0 273 141 157

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1 Purpose of this document

This document provides practical recommendations for handling, placement and mounting of Bosch Sensortec geomagnetic sensors in hardware designs.

1.1 Who should read this manual?

This information is intended for practical guidance during hardware design including a Bosch Sensortec geomagnetic sensor, in terms of device handling, mounting, placement and environmental influences in the target system. This document also focuses on environmental disturbing magnetic effects. Also, it will explain which phenomena can be compensated for by software and which ones can not. Note: Earth magnetic field basics are explained in application note BST-MCS-AN000. PCB placement guidelines for geomagnetic sensors can be found in application note BST-MCS-AN002.

1.2 Glossary

In this document, these terms will be used:

Magnetic sensor, magnetometer

Sensor, which can measure magnetic fields

Geomagnetic sensor

Here: 3-axis magnetic sensor optimised for measurement of the earth magnetic field

Electronic compass

Here: 3-axis geomagnetic sensor and 3-axis accelerometer in one package

Earth magnetic field, geomagnetic field:

The magnetic field that is present around earth

Geographic north, true north, geographic North Pole

The northern place where earth's rotation axis crosses earth's surface

Geographic south, geographic South Pole

The southern place where earth's rotation axis crosses earth's surface

North magnetic pole, magnetic north, magnetic North Pole

The location near the geographic North Pole where the inclination of earth's magnetic field is +90° and the magnetic field lines cross earth's surface.

This is the physical south pole of the earth magnetic field.

South magnetic pole, magnetic south, magnetic South Pole

The location near the geographic South Pole where the inclination of earth's magnetic field is – 90° and the magnetic field lines crosses earth's surface.

This is the physical north pole of the earth magnetic field.

Geographic equator

The imaginary line drawn around earth halfway between the geographic north and South Pole Magnetic equator

The imaginary line near the geographic equator connecting all points where the magnetic field inclination is 0°

1.3 Important notes

- ▶ In order to avoid any damages of the geomagnetic sensor devices and resultant loss of warranty please strictly keep with the instructions described within this document.
- ▶ It is also strongly recommended to study the BMM geomagnetic sensor data sheets prior to handling the sensor device.
- ▶ In case you have any questions, please do not hesitate to contact your nearest Bosch Sensortec representative for further advice.

2 General placement and mounting recommendations

2.1 Introduction

MEMS sensors in general are high-precision measurement devices, which consist of electronic as well as mechanical silicon structures. Bosch Sensortec MEMS sensor devices are designed for precision, efficiency and mechanical robustness.

However, in order to achieve best possible results for your design, the following recommendations should be taken into consideration when mounting the sensor on a printed-circuit board (PCB).

The scenarios described below - given as examples - may lead to a bending of the PCB, which as a consequence, might influence the performance of the sensor mounted on the PCB.

In order to evaluate and to optimize the considered placement position of the sensor on the PCB it is recommended to use additional tools during the design in phase, e.g.:

- ▶ regarding thermal aspects: infrared camera
- ▶ regarding mechanical stress: warpage measurements and/or FEM-simulations

Unless stated otherwise all recommendations are valid for LGA (land grid array) and WLCSP (wafer level chip scale package).

2.2 Recommendations

- ▶ It is generally recommended to keep a reasonable distance between the sensor mounting location on the PCB and the critical points described in the following examples. The exact value for a "reasonable distance" depends on many customer specific variables and must therefore be determined case by case.
- ▶ It is generally recommended to minimize the PCB thickness (recommended: ≤ 0.8 mm), since a thin PCB shows less intrinsic stress, e.g. while being bent.
- ▶ It is not recommended to place the sensor directly under or next to push-button contacts as this can result in mechanical stress.
- ▶ It is not recommended to place the sensor in direct vicinity of extremely hot spots regarding temperature (e.g. a μController or a graphic chip) as this can result in heating-up the PCB and consequently also the sensor nearby.
- ▶ It is not recommended to place the sensor in direct vicinity of a mechanical stress maximum (e.g. in the center of a diagonal crossover, refer to 2.3.4). Mechanical stress can lead to bending of the PCB and also of the sensor, nearby.
- ▶ Do not mount the sensor too closely to a PCB anchor point, where the PCB is attached to a shelf (or similar) as this could also result in mechanical stress. To reduce potential mechanical stress, minimize redundant anchor points and/or loosen respective screws (refer to 2.3.3).
- ▶ It is not recommended to mount the sensor in areas where resonant amplitudes (vibrations) of the PCB are likely or to be expected.

- ▶ Please avoid partial coverage of the sensor by any kind of (epoxy) resin, as this can possibly result in mechanical stress.
- ▶ Avoid mounting (and operation) of the sensor in the vicinity of strong magnetic, strong electric and/or strong infrared radiation fields (IR).
- ▶ Avoid electrostatic charging of the sensor and of the device wherein the sensor is mounted.

In case you have any questions with regard to the mounting of the sensor on your PCB, or with regard to evaluate and/or to optimize the considered placement position of the sensor on your PCB, do not hesitate to contact us.

If the above mentioned recommendations cannot be realized appropriately, a specific in-line offset-calibration after placement of the device onto your PCB might help to minimize potentially remaining effects.

2.3 Recommendation details

2.3.1 Push-button contacts

Keep a reasonable distance to push-button contacts, when placing the sensor device. Do not position the sensor directly beneath a push-button contact.

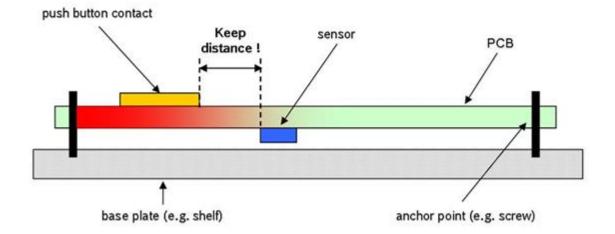


Figure 1: Distance to push buttons

2.3.2 Thermal hot-spots on the PCB

Keep a reasonable distance from any thermal hot spots, when placing the sensor device. Hot spots can for example be other integrated circuits with high power consumption.

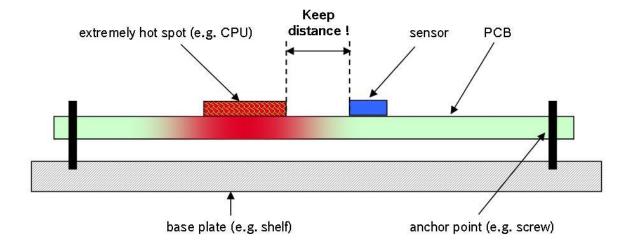


Figure 2: Distance to hot spots

2.3.3 Redundant PCB anchor points

It is recommended to unscrew or remove any redundant PCB anchor points. In theory, an ideal flat plane is determined by 3 anchor points, exclusively. Any further anchor point will over-determine the ideal flat plane criteria. If these redundant anchor points are out of plane position (which means not 100% exact in plane position) the ideal flat criteria is infringed, resulting in mechanical stress.

The below given figure describes an expected stress maximum in the center of the diagonal crossover, assuming that the 4 anchor points are not 100% exact in plane (over-determined ideal flat plane criteria). Unscrewing or removing one of the redundant anchor points can minimize mechanical stress, significantly.

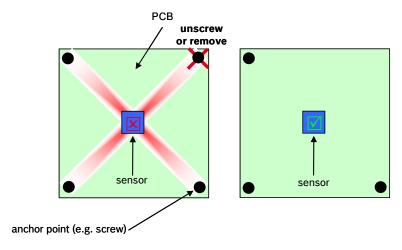


Figure 3: Redundant PCB anchor points

2.3.4 Mechanical stress maximum on the PCB

It is recommended to keep a reasonable distance from any mechanical stress maximum, when placing the sensor device. Mechanical stress can be induced for example by redundant anchor points, as described in 2.3.3.

The below given example will show a stress maximum in the center of the diagonal crossover of the 4 anchor points. It is good manufacturing praxis to always avoid or reduce the mechanical stress by optimizing the PCB design first, then to place the sensor in an appropriate low stress area.

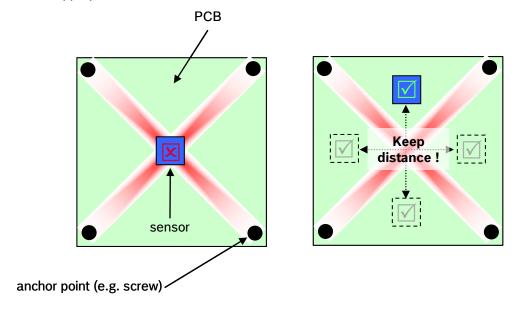


Figure 4: Stress maximum

2.3.5 Distance to PCB anchor points

Please keep a reasonable distance from any anchor points, where the PCB is fixed at a base plate (e.g. like a shelf or similar), when placing the sensor device.

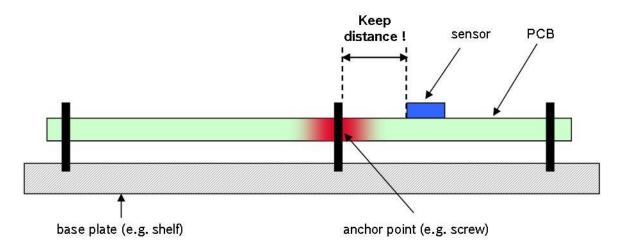


Figure 5: Distance to PCB anchor points

2.3.6 Vibrating PCB

Do not place the sensor in areas where resonant amplitudes (vibrations) of the PCB are likely to occur or to be expected.

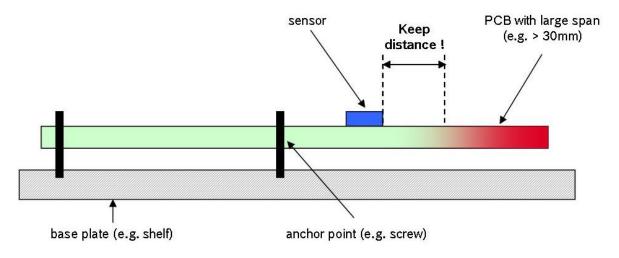


Figure 6: Vibrating PCB

2.3.7 Resin coatings

Please avoid partial covering of the sensor with any protective material like for example epoxy resin.

As shown in the below figure, please take care that the sensor (if at all) is not only partially covered and also not in contact with any (epoxy) resign material leading to an un-symmetric stress distribution over the sensor package.

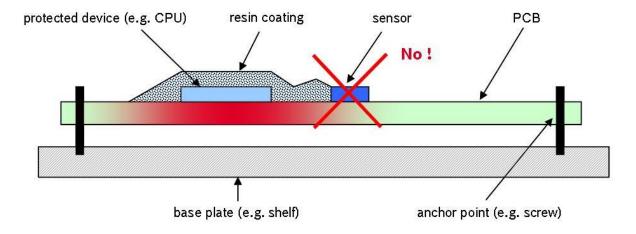


Figure 7: Resin coatings

2.3.8 Underfiller

Due to the very small size of the BMM products there is no need for any underfill material to increase mechanical reliability. All specified parameters are tested and verified without any underfill material. Using underfills may lead to performance loss of WLCSP products. It is strongly recommended to mount the package without any underfills.

3 Multiple reflow soldering cycles

BMM150 geomagnetic sensor devices can withstand in total up to 3 reflow soldering cycles.

This could be a situation where a PCB is mounted with devices from both sides (i.e. 2 reflow cycles necessary) and where in the next step an additional re-work cycle could be required (1 reflow).

3.1 Component removal instructions WLCSP

The WLCSP rework is same to that of a BGA. Prior to rework, the board should be baked to make the assembly moisture-free. The board should not be tilted since this can result in solder bridging.

Zero-force vacuum pick-up tool is recommended during cooling down to avoid bridging of the balls.

4 Further important mounting and assembly recommendations

This device has built-in protections against high electrostatic discharges or electric fields (2kV HBM); however, antistatic precautions should be taken as for any other CMOS component.

Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the supply voltage range. Unused inputs must always be connected to a defined logic voltage level.

4.1 Wafer Level Chip Scale Package Handling

Since BMM products in Wafer Level Chip Scale Package have no EMC mold protection they should be handled with great care. The devices should remain secure in their carriers except during unloading or inspection operations at dedicated ESD-safe workplaces. WLCSP parts should not be handled with bare hands, even wearing gloves or finger cots.

In cost driven assembly builds like low volume productions and engineering runs, manual handling of the devices may be necessary. In these cases it is mandatory that tweezers of any form are not used to pick up, transfer or place the WLCSP. Tweezers often cause mechanical damage to the WLCSP, either to the top surface or to the silicon. Scratches chip-out and micro-cuts are hard to avoid using tweezers of any form. This kind of damage maybe visible but often does not manifest until electrical testing. Therefore it is recommended that any manual handling is done by using suitable designed tools such as vacuum pencils with PTFE tips for sawn-edge pick-up.

For automatic pick and place equipment a soft silicon/rubber tip of suitable size should be used. These tips should be inspected and cleaned in well defined periods to avoid mechanical damage to the chip. The operating pressure of the pick and place tool should be minimized.

5 PCB placement guideline based on magnetic influences

5.1 Non-geomagnetic field sources

For basics of earth magnetic field refer to application note "Earth magnetic field basics". The magnetic field measured by a geomagnetic sensor is a superposition of earth magnetic field and other environmental influences such as adjacent magnetic materials or fields induced by electric currents.

In this chapter, two other sources will be named, their strength will be compared to that of the geomagnetic field, and the implications for geomagnetic sensor applications will be explained.

The sources relevant for geomagnetic sensor applications are hard ferromagnetic materials and electric currents. Other sources do exist, but are not relevant for geomagnetic sensor applications. Please note that the majority of disturbances stemming from the device (adjacent magnetic materials) are effectively compensated by the Bosch Sensortec eCompass software.

5.1.1 On-board: Hard ferromagnetic materials

A hard magnetic material possesses a strong intrinsic magnetisation, which hardly reacts to external fields. These materials are typically used in speaker magnets and electrical motors (which are used for vibration alarm). Many different hard magnetic materials alloys exist. Some low-cost materials are: ferrites (BaFeO, SrFeO, ...) and AlNiCo; high-performance materials are for example SmCo and NdFeB.

The field strength of these fields is temperature-dependent. For the popular low-cost ferrite magnets, the field decreases on rising temperature at a rate of typically 0.2 %/K; most other materials have a lower temperature coefficient. When operating a geomagnetic sensor in a ferrite-caused offset field of 500 μ T, the offset will shift by 10 μ T on a change of 10°C (18°F). If not detected, this will cause a major miscalculation of heading.

5.1.2 On-board: Current-induced fields

Magnetic fields occur around electrical currents. The field direction follows the right-hand rule, which is depicted in Figure 8.

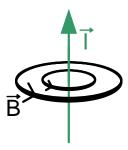


Figure 8: The right-hand rule for current-induced magnetic fields

The absolute magnetic field strength B at a given point outside of the wire depends on the current flowing through the wire and the distance to its centre according to the following formula:

$$B=\mu_0\cdot\mu_r\cdotrac{l}{2\pi r}$$
, where
$$\mu_r= ext{relative permeability}\approx 1 ext{ for air, and} \ \mu_0= ext{vacuum permeability}=4\pi\cdot10^{-7} H/m$$
 Equation 1

As an example, a power line on a mobile phone PCB could carry a current of 100 mA. At a distance of 5 mm from this line, the magnetic field strength equals:

$$B = \mu_0 \cdot \mu_r \cdot \frac{l}{2\pi r} = 4\pi \cdot 10^{-7} \frac{H}{m} \cdot 1 \cdot \frac{100 \text{ mA}}{2\pi \cdot 5 \text{ mm}} = 4 \text{ } \mu\text{T}$$
 Equation 2

As a typical value for the horizontal geomagnetic field strength is 20 μ T, a current-induced field can strongly influence heading calculation results, so that some distance must be kept. However, this is only the case for high-current lines, signals lines (e.g. an SPI bus) do not cause distortions.

5.1.3 Comparison of geomagnetic field strength to other fields

The geomagnetic field is very weak compared to other sources of magnetism. A typical speaker magnet can generate a field of 11 000 μ T, which by far exceeds the strength of the earth magnetic field. The calculation above shows that, at least at close distances, current-induced fields can generate fields with strengths similar to the geomagnetic field.

5.2 Distortion and shielding by soft magnetic materials

The measurement of the earth magnetic field is not only affected by the existence of the other field sources named in chapter 5.1. Instead, there are also materials that can distort the surrounding fields. These materials are called soft magnetic materials. Unlike hard magnetic materials, these materials easily change their magnetization based on the surrounding fields and attract the magnetic field lines. This leads to two phenomena: distortion and shielding.

5.2.1 On-board: Distortion

For a geomagnetic sensor, distortion is the effect that the field lines near soft magnetic materials are 'bent', so that their direction is changed from large-scale geomagnetic field direction. An example is given in Figure 9, where this field visible to the sensor is not pointing in the direction of magnetic north anymore. In addition, many soft magnetic materials are anisotropic, which means that the behavior depends on the direction of the field applied.

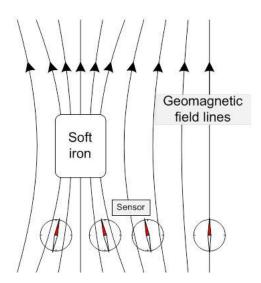


Figure 9: Magnetic field distortion due to soft iron effects

Software compensation of this effect is very difficult. For maritime applications, geomagnetic sensors are calibrated to correct the soft magnetic effects of the ship's iron. If no precise calibration is possible, such as in consumer applications, soft magnetic materials should be avoided in the vicinity of geomagnetic sensors.

5.2.2 On-board and external: Shielding

If a space is surrounded by soft magnetic material (solid or framework), this surrounding will absorb all of the magnetic field lines. This is depicted in Figure 10. As a result, there will be virtually no remaining field within the structure. If this effect is desired, the materials like the commercially available Mu-metal can be used as magnetic shielding.

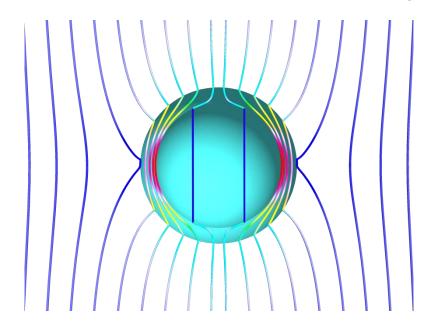


Figure 10: Magnetic shielding within a soft magnetic sphere (source: Institute for Theory of Electrical Engineering, Universität Stuttgart)

A geomagnetic sensor cannot work without the external magnetic field. Hence, the better the shielding is, the less signal is available for the geomagnetic sensor to work with. Especially the iron frame of buildings can be an unwanted cause of magnetic shielding. This explains why geomagnetic sensor performance can suffer within a building containing steel.

5.2.3 Overview of external influences

In this chapter, many possible external influences to geomagnetic sensor performance have been discussed. For a better overview, the impact on geomagnetic sensor input will now be given in Figure 11, in which the field in X and Y direction over a 360° geomagnetic sensor rotation is depicted. A centered circle depicts ideal geomagnetic sensor input; the distortions are clearly visible.

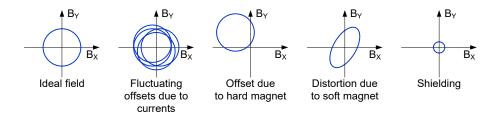


Figure 11: Overview of the effects of external influences on geomagnetic sensor input

5.3 Possibilities and limitations of software compensation

The effects mentioned in the previous chapter can partially be corrected by software.

On-board hard magnetic offsets are almost unavoidable in the environment of a mobile phone. They are the reason that mobile phone geomagnetic sensors always need a calibration phase. In this calibration, the offset is estimated so that it can be subtracted from further measurements. This initial calibration is depicted in Figure 12.

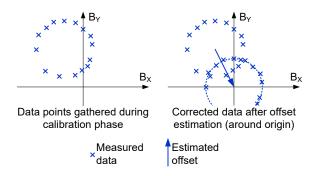


Figure 12: Offset estimation in calibration phase

However, if the hard magnetic offsets exceed the sensor range, the sensor will become saturated and heading can not be measured at all anymore.

The temperature dependence of the hard magnetic offsets will cause the originally estimated offset to change when temperature changes. If the sensor does not see many different orientations after the original calibration, this change may go unnoticed and result in a significant error (e.g. $\sim 15^{\circ}$ heading error on 5°C change of a 500 μ T offset magnet).

Figure 13 illustrates this. The center of the blue circle is the offset caused by permanent magnets. The radius of the blue circle equals the magnitude of the earth magnetic field.

The blue x marks the measured field strength. This is going directly in +y direction from the circle's center. The correct heading can only be estimated after the circle's center has been moved to the axes' origin (second image). When the offset changes (third image), while the offset compensation still subtracts the same value, the estimated heading is again wrong.

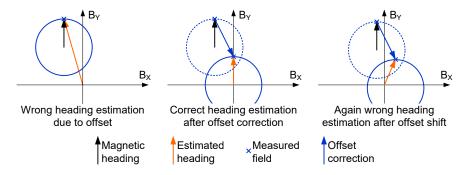


Figure 13: Errors caused by changing magnetic offsets

On-board current-induced fields change unpredictably (e.g. on display brightness change, during network activity ...). Because of this, their effects can not be compensated and the fields will appear to add small varying offsets (appearing like noise) or large offsets to the sensor signal.

On-board soft magnetic effects are very difficult to compensate for. Since soft magnetic materials can distort or bend the geomagnetic field in different directions, depending on temperature, field strength and magnetic history of the material involved, a very large data set would be required to estimate all magnetic effects.

For these reasons, soft magnetic materials must (and can) be avoided in the vicinity of an geomagnetic sensor instead of being compensated in software.

On-board or external shielding due to on-board soft magnetic cover or external iron in buildings can attenuate the earth magnetic field so much that it becomes almost immeasurable. External effects can not be estimated by the compass software and there can not be compensated. On-board shielding will still dampen the signal so much that reliable heading estimation becomes impossible.

5.4 PCB placement advice

In order to achieve optimum geomagnetic sensor performance, several rules need to be kept in order to avoid the disturbances mentioned above.

5.4.1 Hard magnetic offsets

Hard magnetic offsets must be as limited as much as possible. Ideally, the offset should be below 100 μ T, maximum 200 μ T. If this is not possible, please refer to the following two rules:

Sensor range may not be exceeded over entire temperature and magnet variation range.

To keep to this rule, the offset at the proposed location should be measured. Then, using information about sample spread and temperature dependence of the magnet(s) that cause(s) this field, the effects over temperature can be estimated.

Example: A ferrite magnet has a temperature dependence of -0.2 %/K. A field of 600 μ T measured at 20 °C will grow to (-0.002 x (-40 - 20) + 1) x 600 = 1.12 x 600 = 672 μ T at a temperature of -40 °C. In order to accommodate for magnet variance as well, we recommend not using more than 75 % of the magnetic sensor range at room temperature. For example this results for BMM150 in the following rule:

$$B_{x}, B_{y}, B_{z} < 0.75 \cdot 1300 \mu T$$
 Equation 3

Not following this rule means that in some conditions and in some samples, the sensor range will be exceeded and geomagnetic sensor functionality will be lost.

External field temperature effects must be minimized. Even if the range of the sensor in large enough to cope with the offset present, its temperature dependence will still impact geomagnetic sensor performance. Our advice is to have no more than $200\mu\text{T}$ absolute field strength (i.e. $\sqrt{(X^2+Y^2+Z^2)}$) assuming a temperature coefficient of -0.2 %/K. if the temperature coefficient is lower, the value of 200 μT can be increased accordingly (e.g. 400 μT for a coefficient of 0.1%/K). This results in the following rule:

$$\sqrt{B_{x}^{2} + B_{y}^{2} + B_{z}^{2}} \cdot TC_{magnet} < 200\mu T \cdot 0.2 \%$$
 Equation 4

Not following this rule can result in noticeable temperature dependence of the geomagnetic sensor. This is strongly influenced by the speed of temperature change of the permanent magnet.

5.4.2 PCB Currents

Constant currents on the PCB cause a constant offset on the sensor signal and are compensated by software. However, if fluctuating currents are routed closely to the magnetic sensor, then the changing field strength caused by such a current should not exceed $0.5~\mu T$, while lower numbers are better. Following equation 5, for a given current l_{fluc} , the required distance equals:

$$r = \frac{\mu_0 \cdot \mu_r}{2\pi \cdot B} \cdot I_{fluc} = 0.4 \cdot I_{fluc}, \text{ using}$$

$$\mu_r = \text{relative permeabili ty} \approx 1 \text{ for air,}$$

$$\mu_0 = \text{vacuum permeabili ty} = 4\pi \cdot 10^{-7} \ H/m, \qquad \text{Equation 5}$$

$$I_{fluc} = \text{fluctuatin g current, and}$$

$$B = \text{allowed fluctuatin g field strength } (0.5 \, \mu T)$$

Please use the following table to estimate the required distance between the current line and the geomagnetic sensor:

Current change (max-min) [mA]	Required distance [mm]
1	0.4
2	0.8
5	2.0
10	4.0
20	8.0
50	20.0

Table 1: Required distance between magnetic sensor and current lines

5.4.3 Soft magnetic effects

The usage of soft magnetic materials close to the geomagnetic sensor must be avoided. The presence of soft magnetic materials at the sensor can be estimated by rotating the PCB on a nonmagnetic table (free of iron). Ideally, the measured data points will all be in a circle. In usual cases, soft magnetic effects are visible as distortion of this circle into an ellipse as visible in Figure 14.

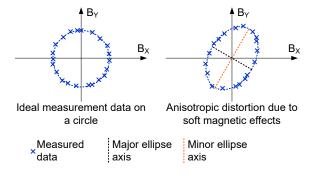


Figure 14: Quantifying soft magnetic distortion

If the distortion can be approximated by an ellipse, the ratio between major and minor ellipse axis defines the soft magnetic effect. The mismatch should be below 3 %, resulting in the last rule:

$$\frac{L_{major_axis}}{L_{minor_axis}} < 1.03$$
 Equation 6

5.4.4 Overview

In the following, an overview of the previously presented rules is given:

Table 2 : Overview of placement guidelines

Hard magnetism				
Ideal:	External field < 100 μT			
Second best:	External field < 200 μT			
Otherwise:	External field < 0.75 x sensor range (room temperature), and sqrt(BX²+BY²+BZ²) x TCext. field < 0.40 µT x %/K			
Fluctuating PCB currents				
Distance r [mm]	Distance r [mm] > 0.4 x Ifluc [mA]			
Soft magnetism				
Ratio major axis / minor axis < 1.03				

6 Legal disclaimer

i. 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.

ii. 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.

iii. 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 modification

Rev. No	Chapter	Description of modification/changes	Date
1.0	All	Initial release	April 2011
1.2	2.3.8	Chapter "underfiller" added	
	3	Valid for BMM/BMC	
	3.1	Chapter 3.1 "Component removal instructions WLCSP"	
	4.1	Chapter "Wafer Level Chip Scale Package Handling" added	20 January 2013
	5.4	Magnetic measurement range updated to 1300µT	
	All, 2.1	Valid for all geomagnetic sensors (BMC in LGA package and	
		BMM in WLCSP)	
1.3	5.4.4	Formular for fluctuating PCB currents adapted	14 May 2013
1.4	All	Update to new template	13 December 2019
		BMC taken out (discontinued products)	
	6	Update of legal disclaimer	



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