

# Bosch Sensortec Inertial Measurement Units

## Handling, Soldering and Mounting Instructions



### HSMI for BMI2xy/BMI3xy IMUs

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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. The technical details and legal disclaimer of the respective product data sheet apply.

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## 1 Purpose of this document

This document describes the recommended conditions and parameters to be applied when handling, soldering, and mounting Bosch Sensortec's Inertial Measurement Units (IMUs, incl. programmable IMUs) to a PCB. This document applies to all Sales Part Numbers mentioned on the cover sheet. In case the Sales Part Number of your Bosch Sensortec device is not listed, contact your Bosch Sensortec representative.

Important:

- To avoid damage to the sensor and the loss of warranty, strictly follow the instructions described in this document.
- It is strongly recommended to study the sensor datasheet before handling the sensor device.
- In case you have any other questions, do not hesitate to contact your Bosch Sensortec representative.

## 2 Package outline

Please refer to the latest version of the corresponding product datasheet or preliminary datasheet.

## 3 Landing pattern

Refer to the latest version of the corresponding product datasheet or preliminary datasheet.

## 4 Moisture sensitivity level (MSL)

The moisture sensitivity level of the device corresponds to JEDEC Level 1. Also, see the following standards:

- IPC/JEDEC J-STD-020E "Joint Industry Standard: Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices."
- IPC/JEDEC J-STD-033D "Joint Industry Standard: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices."

Both standards are available on [JEDEC's website](#).

The sensor fulfills the lead-free soldering requirements of the IPC/JEDEC standard mentioned above, i.e., reflow soldering with a peak temperature  $T_p$  up to 260°C.

## 5 RoHS compliance/halogen content

The sensors meet the requirements of the EC restriction of hazardous substances (RoHS) directive. Also, see the following directive:

RoHS-Directive 2011/65/EU and its amendments, including the amendment 2015/863/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

As listed on the cover sheets, the devices (Sales Part Numbers) are also halogen-free. For more details on the corresponding analysis results, contact your Bosch Sensortec representative.

Corresponding chemical analysis certificates are available as separate documents from Bosch Sensortec.

## 6 Mounting recommendations

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

However, to achieve the best possible results for your design, the following recommendations should be considered when mounting the sensor on a printed circuit board (PCB).

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

It is recommended to use additional tools during the design-in phase to evaluate and optimize the considered placement position of the sensor on the PCB, for example:

- infrared camera regarding thermal aspects
- warpage measurements and/or FEM simulations regarding mechanical stress
- drop tests of the device after soldering on the target application PCB regarding shock robustness

It is generally recommended to keep a reasonable distance between the sensor mounting location on the PCB and the critical locations described in the following examples. The exact value for a "reasonable distance" depends on the individual design and, therefore, must be determined case by case.

Contact us if you have questions regarding the mounting of the sensor on your PCB or about evaluating and/or optimizing the considered placement position of the sensor on your PCB. If the recommendations mentioned above cannot be met, a specific in-line offset calibration after device placement onto your PCB might help minimize the potential remaining effects.

### 6.1 External loads/forces

In certain applications, circuit boards may feature an array of functional buttons or connection points. External loads or forces applied to these points can transmit stress through the board to the MEMS sensor, potentially causing mechanical damage. It is advisable to position MEMS sensors at a distance from these force-prone areas. See Figure 1.

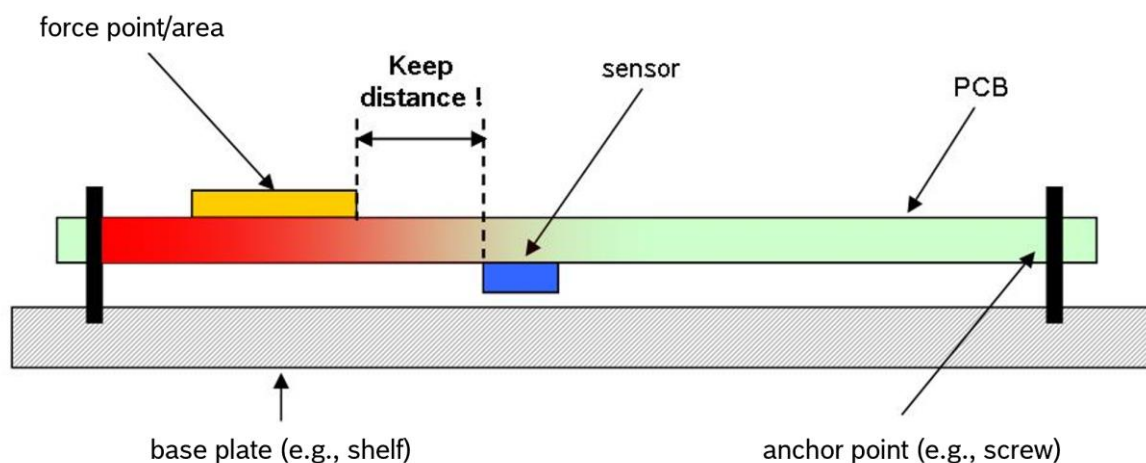


Figure 1: External loads/forces

## 6.2 Thermal hot spots on the PCB

It is recommended to keep a reasonable distance from any thermal hot spots when placing the sensor device to achieve higher accuracy measurements. Hot spots can include a  $\mu$ Controller or a graphic chip, other integrated circuits with high power consumption, processors, batteries, power management circuitry, or high-current devices.

The hot spots on the PCB will have two effects: temperature rise will affect the performance of IMU series sensors, including the impact on the sensitivity and zero-g offset of the acceleration and gyroscope. Additionally, the rise in temperature will cause the PCB to deform, generating additional mechanical stress. See Figure 2.

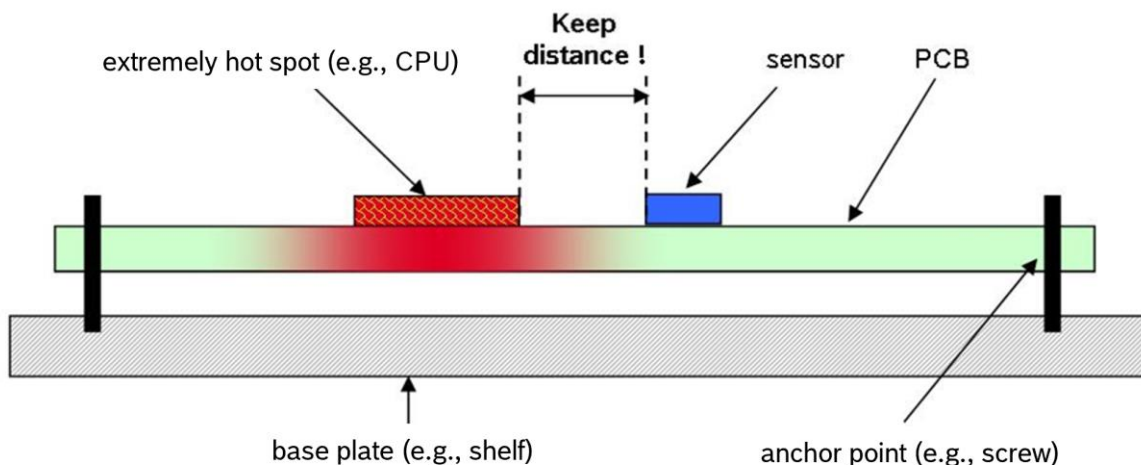


Figure 2: Thermal hot spots on the PCB

Prevent any contact between heat sinks or other external structures and the sensor, which may also create thermal conduction and mechanical stress. See Figure 3.

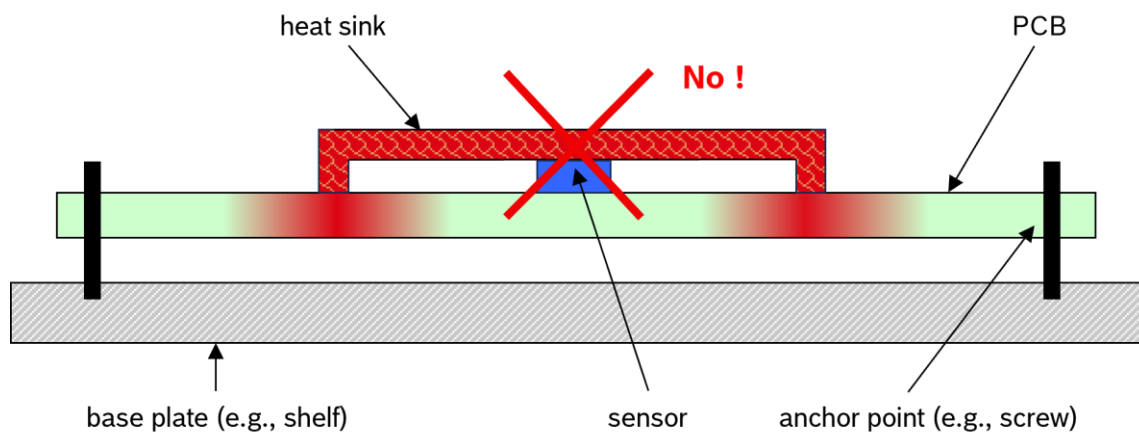


Figure 3: Heat sinks

### 6.3 Mechanical stress maximum on the PCB

It is recommended to keep a reasonable distance from any mechanical stress maximum when placing the sensor device.

Figure 4 shows a stress maximum in the center of the diagonal crossover of the four anchor points. It is good manufacturing practice to always avoid or reduce mechanical stress by optimizing the PCB design first, then placing the sensor in an appropriate low-stress area.

A best practice is to place MEMS components on the PCB in locations where the stress value is not exceeding 500  $\mu$ strain.

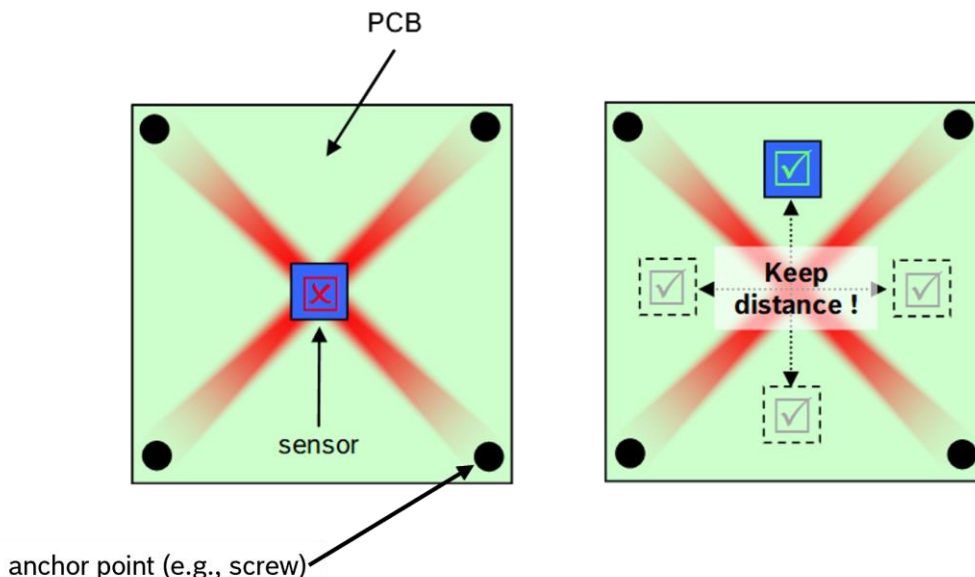


Figure 4: Mechanical stress maximum on the PCB

### 6.4 Distance to PCB anchor points

When placing the sensor device, keep a reasonable distance from anchor points where the PCB is fixed at a base plate (e.g., a shelf or something similar). See Figure 5.

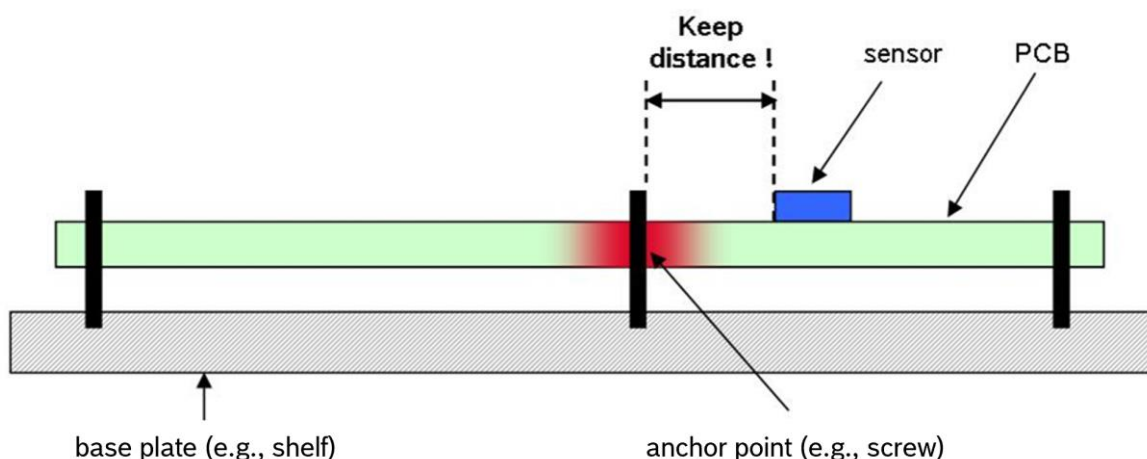


Figure 5: Distance to PCB anchor points



## 6.5 Vibrations on the PCB

Various measures can be applied to minimize vibration transmission. Passive damping can be achieved by adding damping washers or foam pads at anchor points, while active damping can be accomplished by adjusting the placement of the IMU.

It is recommended to position the IMU away from other Sub-systems/Modules (from top and bottom side) on the PCB to mitigate or prevent the impact of vibrations from these parts to the sensor. MEMS gyroscopes and accelerometers have multiple internal eigenmodes. In the case of a resonant match between an external aggressor and an eigenmode of the sensor, even rather low vibration amplitudes might cause damage to the MEMS structures. The system-level design should avoid vibrations that align with the resonant frequencies of the IMU.

External vibrations that coincide with the sensor's eigenfrequencies may introduce extra noise or even damage the sensor. It is recommended to contact your Bosch Sensortec representative in case interference sources with resonant frequencies are used.

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

The predominant vibration sources at the PCB board level are those listed below. Measures must be taken to avoid their impact on the sensor.

### 6.5.1 Mechanical vibration sources

Vibrating components not intended for measurement, such as speakers, vibration/haptic motors, fans, etc., should be mechanically isolated from the IMU.

### 6.5.2 Electrical sources

A switched-mode power supply (SMPS) has the potential to induce vibrations. If the SMPS's specific switching frequencies (including harmonic frequencies) coincide with the sensor's specific eigen frequencies (including harmonic frequencies), it could result in increased noise and offset in the sensor gyroscope.

### 6.5.3 MLCCs

MLCCs (multilayer ceramic chip capacitors) are commonly employed in wireless and fast-charging ICs and DC-DC conversion circuits. Some ceramic capacitors may exhibit vibration or low-frequency buzzing, known as "singing capacitors," due to imbalances in the power circuit. This phenomenon, attributed to the piezoelectric effect, can induce vibrations overlapping with the resonant frequency of the IMU, thereby impacting sensor performance. Furthermore, prepolarization from DC bias enables AC voltages to generate mechanical stresses, resulting in the deformation of the MLCC and the attached PCB substrate. See Figure 6.

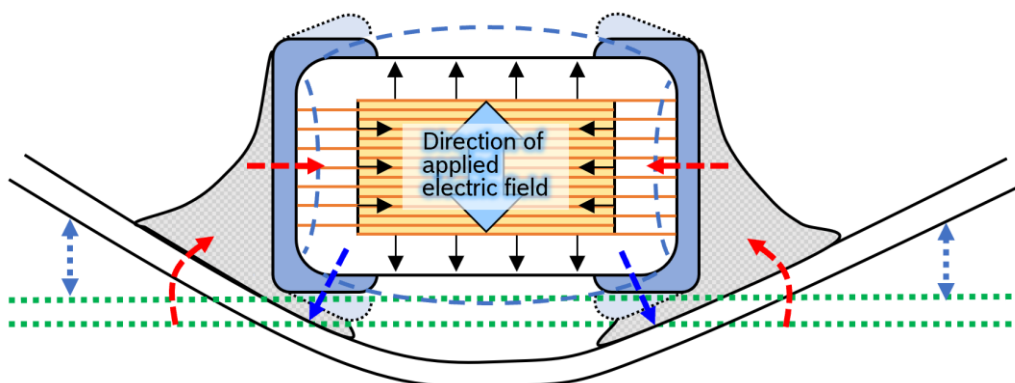


Figure 6: Deformation of MLCC affected by electric field

Recommendations for PCB material and thickness:

- Increasing PCB thickness resists deformation and reduces sound pressure level (SPL).

Optimize the layout of MLCCs on the PCB:

- MLCCs are placed as far away from the sensor as possible.
- Prioritizing placing MLCCs on PCB edges produces a lower SPL.
- When MLCCs are placed symmetrically on opposite sides of a PCB, the vibrations generated by each other can often be canceled out.
- When placed in an L-shape or T-shape layout configuration, the vibrations of the two MLCCs are orthogonal to each other and provide a certain level of cancellation. See Figure 7.

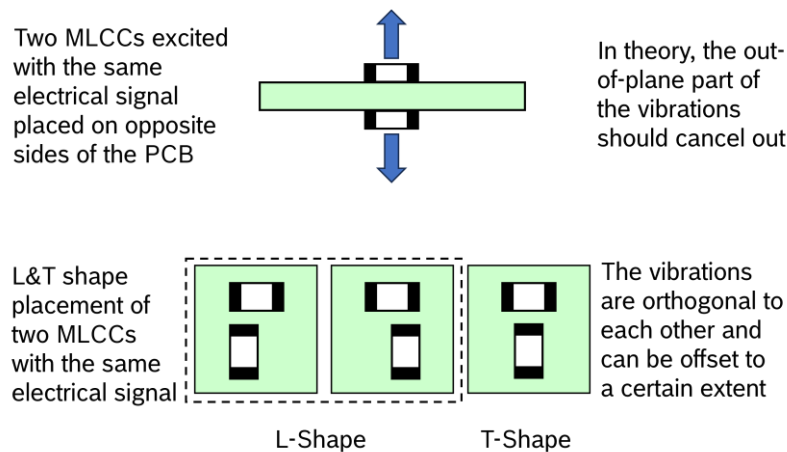


Figure 7: Placement of MLCCs to significantly reduce vibration

- MLCCs can be replaced with tantalum capacitors; the structural composition of tantalum capacitors prevents them from generating vibration and deformation effects similar to those of MLCCs on the PCB board.

It is recommended that the impact of MLCCs on IMUs can be reduced or avoided in the early design-in phase from the following aspects:

- Provide aggressor frequencies (e.g., frequency of fast charging and/or wireless charging ICs). Ideally, test more than one fast-charging IC frequency (consider fallback options to primary IC frequency, etc.).
- Invest in Laser Doppler Vibrometer (LDV) measurements to scan the vibration profile of the target PCB and assess expected load (g's) at available placement position (s) of IMU.
- Perform finite element modeling (FEM) simulations to understand the impact of aggressors better.
- Qualify the IMU based on HSMI recommendations.

By implementing best practices, vibrations caused by MLCCs can be reduced but not entirely prevented. If switching the frequency hits an eigenmode of the IMU, vibration reduction alone cannot guarantee the absence of interference. If you have any questions about the placement of MLCCs, contact your Bosch Sensortec representative.

### 6.5.4 PCB with large span

Avoid placing the IMU on the end of a long hanging beam or the PCB with a large span. See Figure 8.

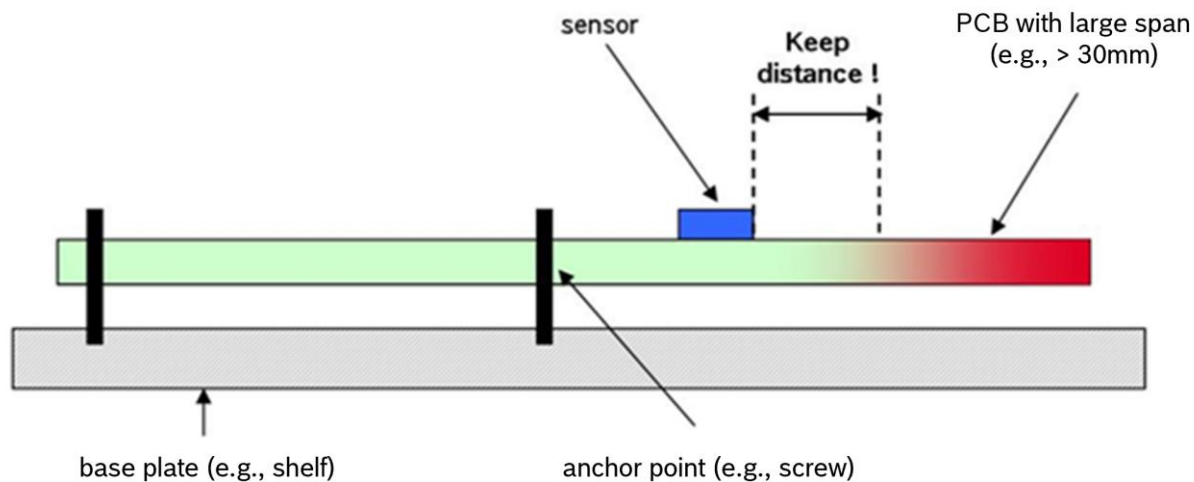


Figure 8: Long hanging beam or large span PCB

## 6.6 Resin coatings and shields

### 6.6.1 Resin coatings

Avoid partially covering the sensor with any protective material, such as epoxy resin.

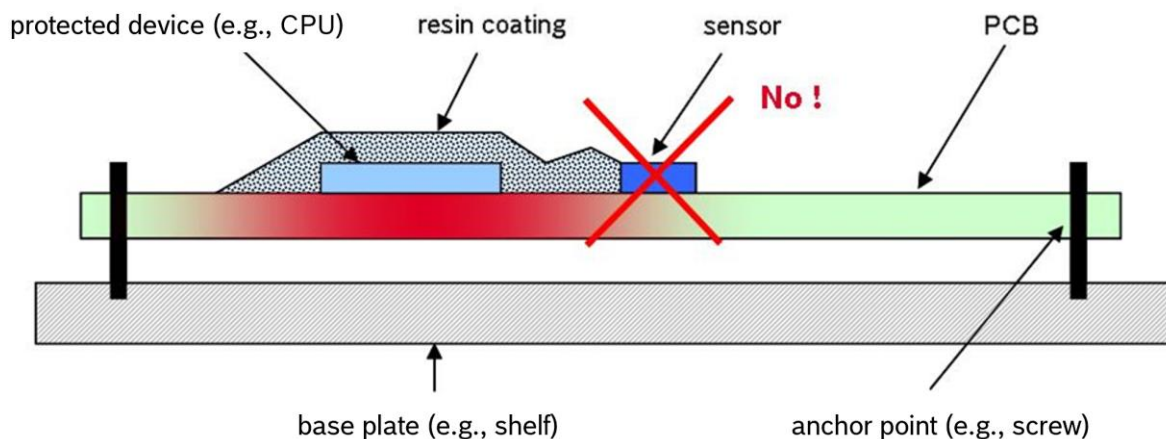


Figure 9: Resin coatings

As shown in Figure 9, while ensuring the sensor is not partially covered (if at all), also ensure it is not in contact with any (epoxy) resin material, leading to an un-symmetric stress distribution over the sensor package.

### 6.6.2 Shields

A shield can cause mechanical stress on the PCB, which may have the effect of causing additional offset of sensors located close to the shield. Keep the sensor away from the shield, including the opposite side of the shield. See Figure 10.

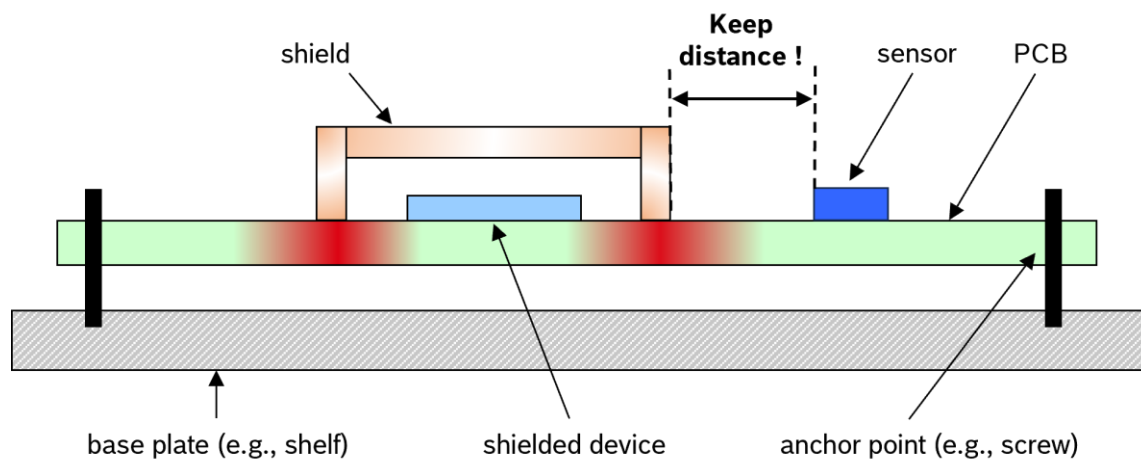


Figure 10: Shields

### 6.7 Edge of PCB

Keep the IMU away from PCB edges and bridges or V-Grooves (see Figure 11), as deflection caused by milling drills or saws when separating the PCB can damage the MEMS device, and avoid dull milling cutters and saw blades, which can cause excessive mechanical vibration. Do not break the panel. Severe bending force and mechanical shock may damage the IMU.

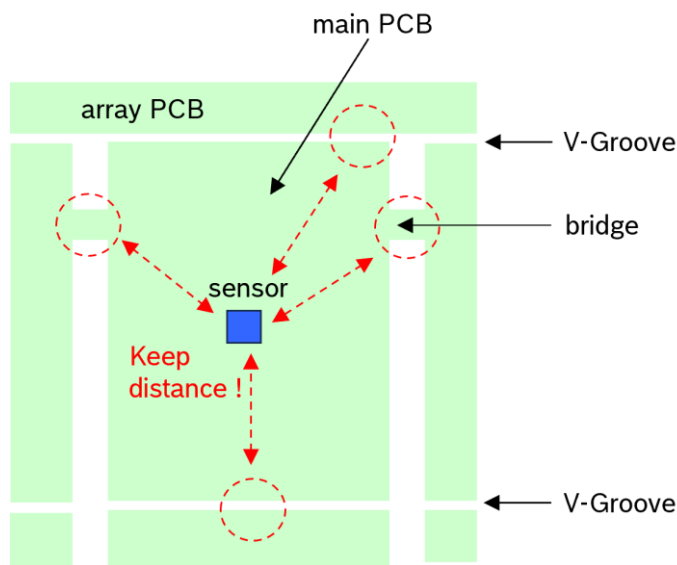


Figure 11: Edge of PCB

### 6.8 Magnetic, Electric, Infrared (IR) and Radio Frequency (RF)

Avoid mounting (and operating) the sensor in the vicinity of strong magnetic, electric, infrared (IR), and radio frequency (RF) radiation fields.

### 6.9 Electrostatic charging

Avoid electrostatic charging of the sensor and of the device wherein the sensor is mounted.

## 7 PCB Design Guidelines

- For the solder mask design of each pin, it is recommended to use Non-Solder Mask Defined (NSMD) pads.
- Placing any structure or routing on the top layer of the PCB below the sensor is strictly prohibited.
- The symmetry of the traces connected to the pads can optimize component self-alignment and promote improved solder paste reduction after reflow, so it is recommended to maintain symmetry and balance of traces on the pads as much as possible.
- Keep the distance between the screw hole and the sensor greater than 2mm for best performance.
- Confirm that the pin #1 indicator is unconnected and must remain unconnected to avoid affecting sensor functionality.

### 7.1 Footprint design rules

All lands are required to be of equal size and do not need to be large. General recommendations for PCB pads and solder mask layers are illustrated in Figure 12. Refer to the datasheet for specific pad count, size, and pitch.

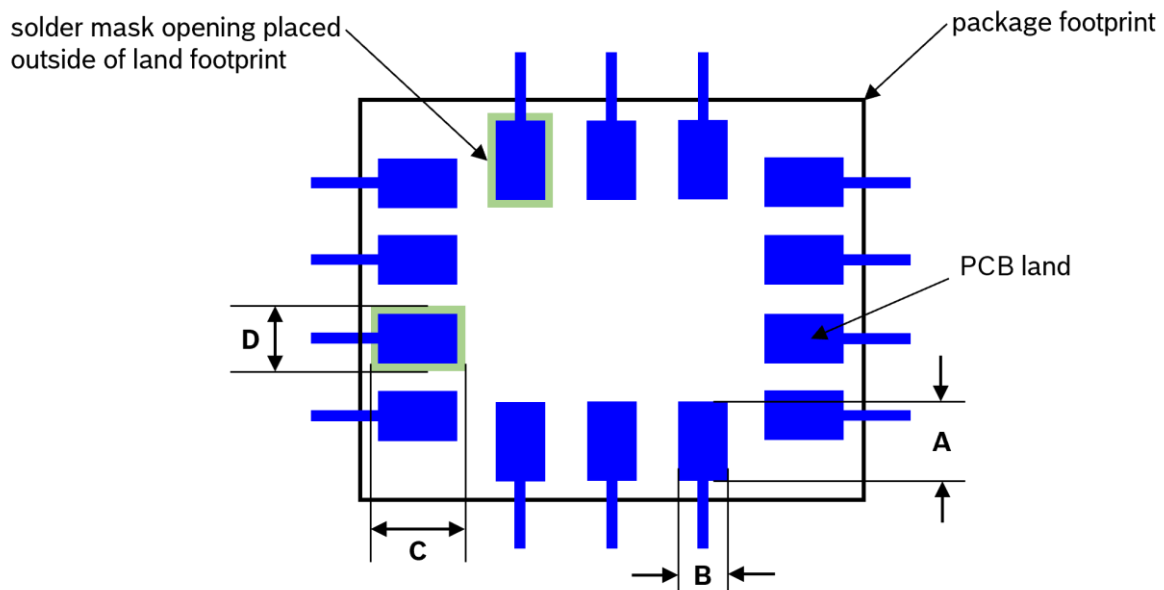


Figure 12: Footprint design rules

PCB land and connecting traces should be designed symmetrically.

- A = PCB land length = LGA solder pad length
- B = PCB land width = LGA solder pad width
- C = Solder mask opening length (Longer than A)
- D = Solder mask opening width (Wider than B)

## 7.2 Stencil design

The stencil design is very important for sensor soldering.

- It is recommended to use a stainless-steel stencil to apply solder paste.
- Stencil thickness will result from pad size, aspect, and area Ratio.
- The stencil opening dimensions need to follow the general best practices for stencil design.
- Aspect ratio of stencil openings: Aperture width/stencil thickness =  $W/T > 1.5$
- Area ratio of stencil openings: Aperture area/aperture wall cross-sectional area =  $(W \times L) / [2 \times (W+L) \times T] > 0.66$

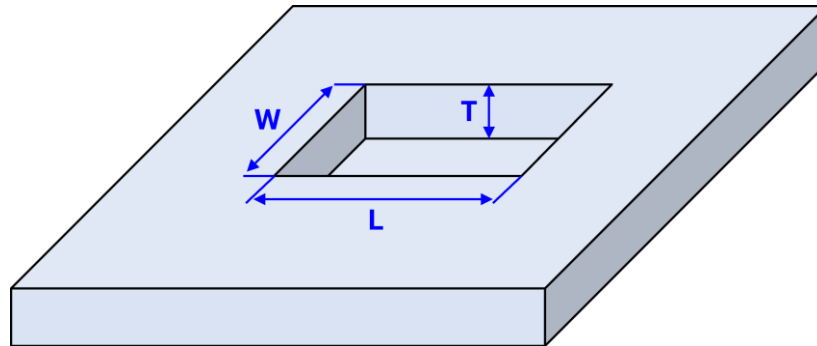


Figure 13: Stencil opening dimensions

## 7.3 PCB design rules for the traces

All traces should flow outside the component, remain symmetrical, and be parallel to the long sides of the pads.

The traces must remain the same thickness; power signals do not require thicker traces because the current flowing into them is very low, thus avoiding potential mechanical stress.

The ground plane should not be connected directly to the package pad. It is better connected via standard traces. See Figure 14.

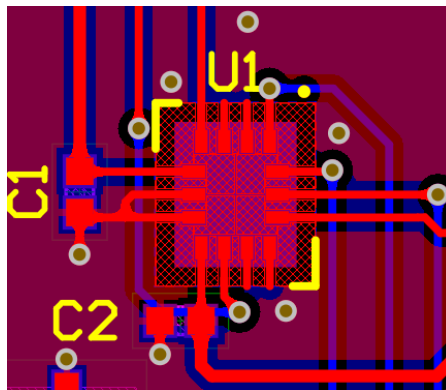


Figure 14: Correct traces

High-frequency communication lines (as SCx or OSCx) should only be routed around the sensor with enough distance to the sensor: the connection lines to the clock pads should run perpendicular to the package outline as long as possible; several millimeters are recommended.

When designing the layout, as much as possible, ensure that VDD, VDDIO, and serial interface traces are isolated from any components and signals related to battery charging and DC-DC switching power regulation. The substantial energy carried by power signals can induce significant noise or spikes.

If the above requirements cannot be met during actual wiring, the 3W principle can be followed, where the center spacing of high-speed signal traces is not less than three times the line width. See Figure 15.

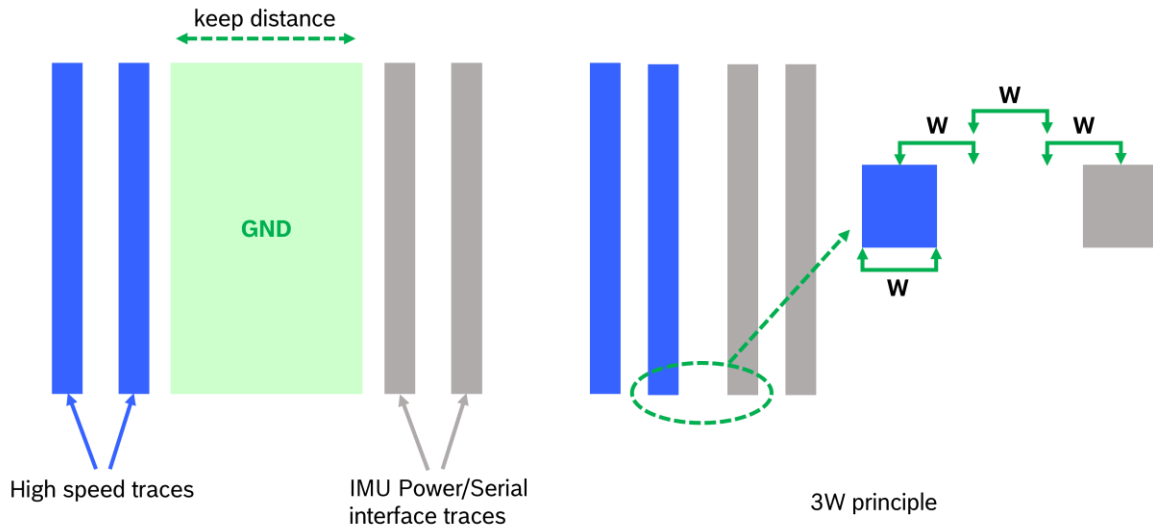


Figure 15: High-speed traces

### 7.4 Placement rules for the top layer

For all MEMS devices, soldering takes place exclusively on the top layer. Avoid positioning any routing or vias directly under the device on the top side. See Figure 16.

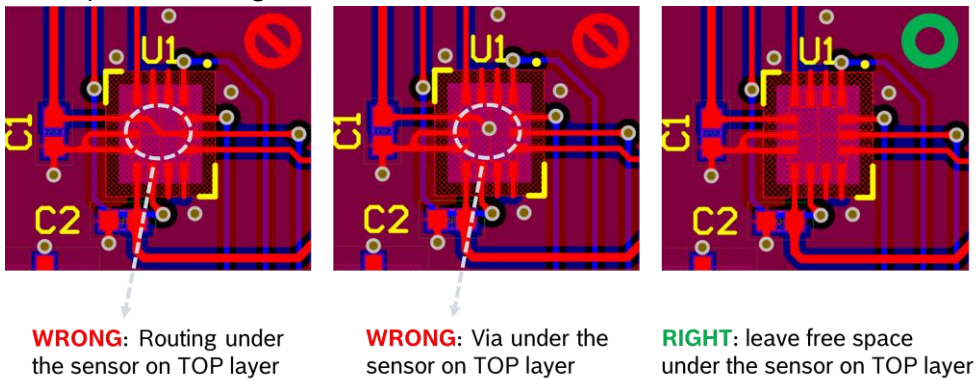


Figure 16: Top layer placement examples

### 7.5 Placement rules for the middle and bottom layer

Power plane or signal routing can be done on the middle and the bottom layer below the sensor. See Figure 17. Note that this bottom placement rule only applies to MEMS accelerometers, gyroscopes, and pressure sensors.

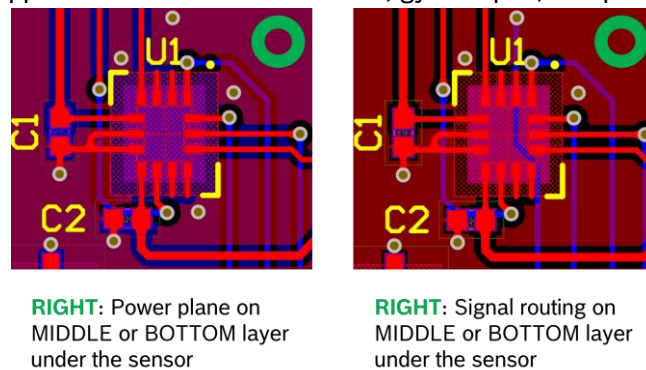


Figure 17: Middle and bottom layer placement examples

In the sensor package footprint area on the PCB, through holes are prohibited, buried vias can be placed in the middle and bottom layer below the sensor, blind vias can only be placed on the side that does not lead to the sensor, they are not allowed on the sensor side.

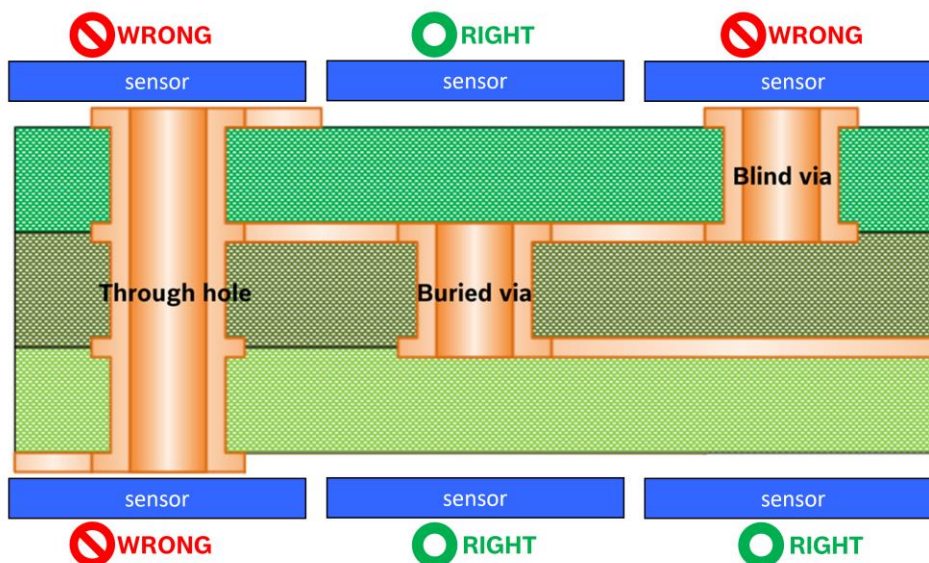


Figure 18: Three types of vias and top layer placement examples

## 8 Note on internal package structures

Within the scope of Bosch Sensortec's ambition to improve its products and secure the product supply while in mass production, Bosch Sensortec qualifies additional sources for the LGA package of its sensors.

While Bosch Sensortec took care that all of the technical package parameters as described above are 100% identical for both sources, there can be differences in the chemical analysis and internal structure between the different package sources.

However, as secured by the extensive product qualification processes at Bosch Sensortec, this has no impact on the usage or the quality of the sensor.

## 9 Device marking

Refer to the latest version of the corresponding product data sheet or preliminary data sheet.

## 10 Reflow soldering

### 10.1 Recommendation for soldering of sensors in the LGA package

Ensure that the edges of the LGA substrate of the sensor are free of solder material. It is not recommended to allow solder material to form a high meniscus covering on the edge of the LGA substrate (see Figure 19).



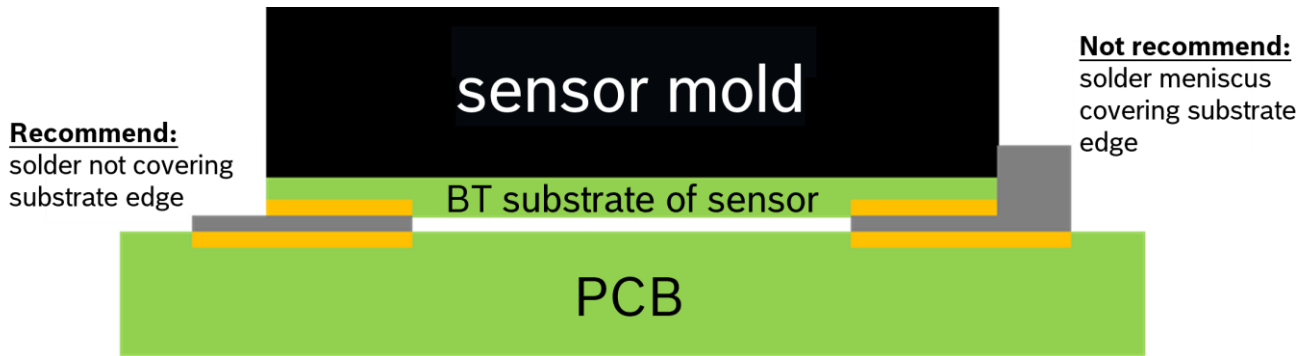


Figure 19: Recommendation to keep the side of LGA free from solder material

Using underfill (e.g., copper underfill) for the LGA package is forbidden. See Figure 20.

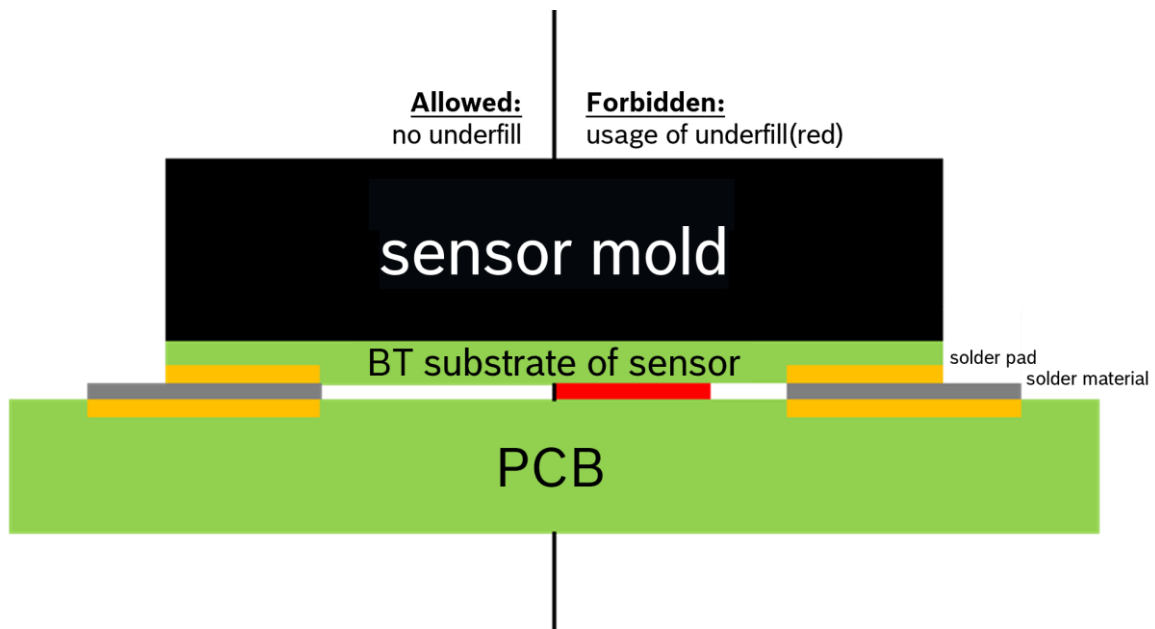


Figure 20: Recommendation not to use underfill for LGA packages

## 10.2 Classification reflow profiles

The sensor fulfills the JEDEC and lead-free soldering requirements described in Chapter 4, i.e., reflow soldering (after MSL1 pretreatment) with a peak temperature  $T_p$  up to 260°C.

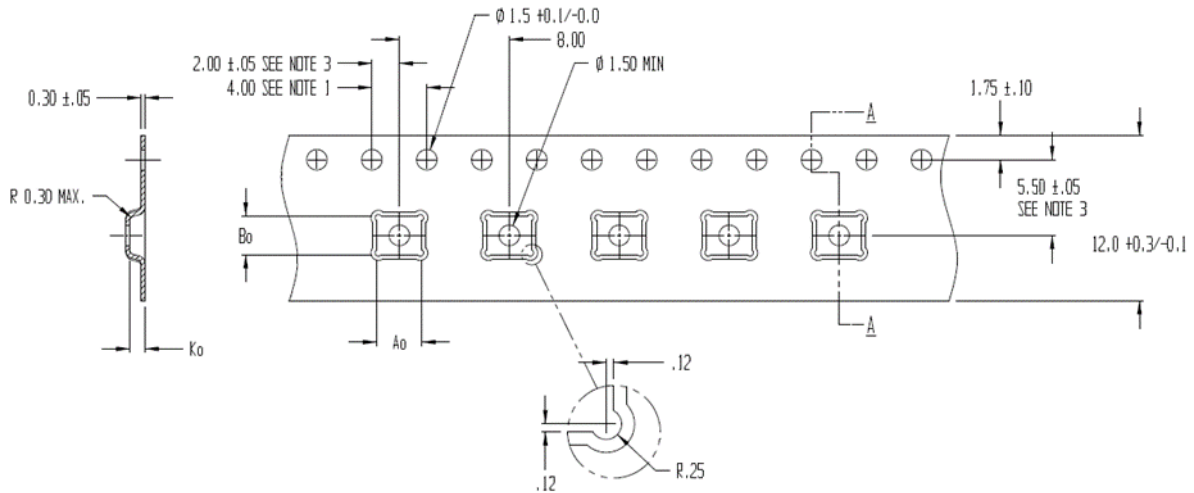
## 10.3 Multiple reflow soldering cycles

The product can withstand up to 3 reflow soldering cycles in total. In case 5 cycles are required, contact your local Bosch Sensortec representative.

There 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).

## 11 Tape & reel

### 11.1 Tape & reel specification



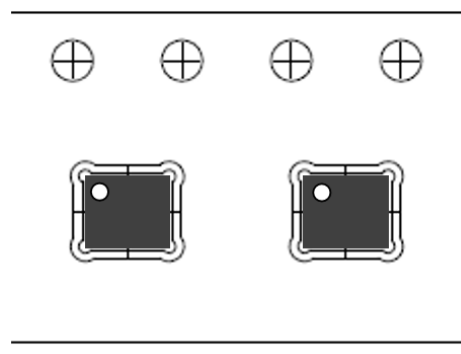
$A_0 = 3.30\text{mm}$ ,  $B_0 = 2.80\text{mm}$ ,  $K_0 = 1.10\text{mm}$

Note:

- Tolerances unless noted:  $\pm 0.1\text{mm}$
- Sprocket hole pitch cumulative tolerance  $\pm 0.1\text{mm}$
- Camber in compliance with EIA481
- Pocket position relative to sprocket hole measured as true position of the pocket, not the pocket hole
- $A_0$  and  $B_0$  are calculated on a plane at a distance "R" above the bottom of the pocket.

### 11.2 Orientation within the reel

→ Processing direction →



## 12 Further important mounting, assembly & handling recommendations

Bosch Sensortec's IMUs are designed to sense acceleration and rate of rotation with high accuracy, even at low amplitudes, and contain highly sensitive structures inside the sensor element. The MEMS sensor can tolerate mechanical shocks up to several thousand g's. However, these limits might be exceeded in conditions with extreme shock loads, such as a hammer hitting the sensor or next to the sensor, dropping the sensor onto hard surfaces, etc.

We strongly recommend avoiding any g-forces beyond the limits specified in the datasheet during the sensors' transport, handling, and mounting in a defined and qualified installation process.

The IMUs have built-in protections against high electrostatic discharges or electric fields (2kV HBM); however, anti-static precautions should be taken 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.

Ultrasonic cleaning and welding are not recommended.

## 13 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).

Bosch Sensortec products are released on the basis of the legal and normative requirements relevant to the Bosch Sensortec product for use in the following geographical target market: BE, BG, DK, DE, EE, FI, FR, GR, IE, IT, HR, LV, LT, LU, MT, NL, AT, PL, PT, RO, SE, SK, SI, ES, CZ, HU, CY, US, CN, JP, KR, TW. If you need further information or have further requirements, please contact your local sales contact.

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.

## 14 Document history and modification

Rev. No	Chapter	Description of modification/changes	Date
0.5	all	Document creation	3 Apr 2018
0.5.1	Cover 9.2 10	Updated Part# Updated Table + Graphic Spec, Graphic + Definition included	18 Sep 2018
0.5.2	all	Document name change to MIS-HS001	28 Nov 2018
1.0	Cover 4 5 6.2.6 9.2 11	Included Part# 0.273.017.003, -.004, -.008 Updated to latest JEDEC STD Sentence rephrased Updated content Shortened content Sentence rephrased Updated Legal Disclaimer	09 Oct 2019
1.1	All Cover Cover Cover 1 5 6.1 6.2.4 9.3 11	Updated template Legal Disclaimer replaced by reference page 1 "Notes" Included BMI32x, Part# 0 273 017 018, 0 273 017 028 Excluded Part# 0 273 017 002, 0 273 017 003, 0 273 017 004 (EOL) Sentence rephrased Updated directive Radio frequency environments + other components included Updated content 5 cycles included Sentence rephrased	17 Feb 2022
1.2	all Cover	Updated template Included Part# 0.273.017.037, -.039, added BHI3xx in title	19 Dec 2022
1.3	Cover	Included Part# 0.273.017.029	06 Oct 2023
1.4	Cover Cover Cover Cover All All 6 7	Document title changed Cover image changed Included Part# 0 273 017 056 Excluded Part# 0 273 017 037, 0 273 017 039 Cover and header subtitles changed Grammar modification Content merged from Rev 1.3 and updated Added content	25 Apr 2024

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