TN0018

Technical note

Handling, mounting, and soldering guidelines for MEMS devices

Introduction

This document provides preliminary information and general guidelines for handling, soldering, PCB design, and mounting microelectromechanical systems (MEMS) inertial sensors from STMicroelectronics.

MEMS inertial sensors, such as accelerometers, gyroscopes, and compasses, are highly sensitive devices that require careful handling during manufacturing processes to prevent any issues and ensure that customers receive high-quality sensors that meet their performance requirements.

MEMS devices contain movable microelectromechanical structures. They may exhibit displacement of inertial masses and transient behavior when subjected to acceleration stress, caused by handling, soldering, or mounting operations, or any combination of these. They are different from common discrete electronics components or IC-only devices, where no movable element is present. Therefore, they require a set of special precautions during their usage in customer manufacturing lines, especially when they are handled by:

- Human operators
- High-speed or high-pressure automatic machinery, like pick and place, transfers, seeders, and similar equipment

This technical note describes the precautions recommended by ST for each step of the customer's manufacturing process.

For further information, contact your local STMicroelectronics sales office.

1 Handling and storage of outer box, inner box, base packing (reel and tray)

1.1 Outer box

The outer box is the ST standardized container utilized for shipments that can include different inner boxes.

Precautions in handling the outer box are shown below, indicating:

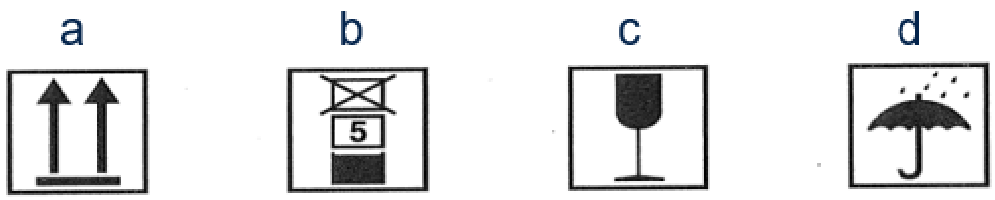
a. The correct vertical orientation of the box

b. To stack a maximum number of boxes on top of each other

c. To handle the box with caution because of a fragile contents

d. To protect the box from water and moisture

Figure 1. **Possible pictograms on outer box**



1.2 Inner box

The inner box is the ST standardized container that contains a defined number of base containers of the same product. The standard inner box labels are depicted in the figure below along with the mandatory information printed on them.

Figure 2. **Example of tape and reel packing inside the inner box**

The following figure shows two examples of the correct or incorrect appearance of the inner boxes.

Figure 3. Examples of correct or damaged aspect of the inner box

	Inner Box	Remarks
GOOD		No defect/anomalies on packing materials
NOT GOOD		Minor dent on the box

1.3 Base packing (reel and tray)

The base packing is the ST standard elementary packing container that contains a defined quantity of product. Typically, the base packing consists of a reel or tray. The contents core of the base packing can vary depending on the thickness of the device.

Figure 4. Example of reel and tray base packing

Figure 5. From reel to inner box

The standard base packing label is depicted in the figure below along with precautions to be taken because of the presence of moisture-sensitive devices. Shelf life and floor life indications are listed as well.

Figure 6. Details of the caution label placed on the base packing

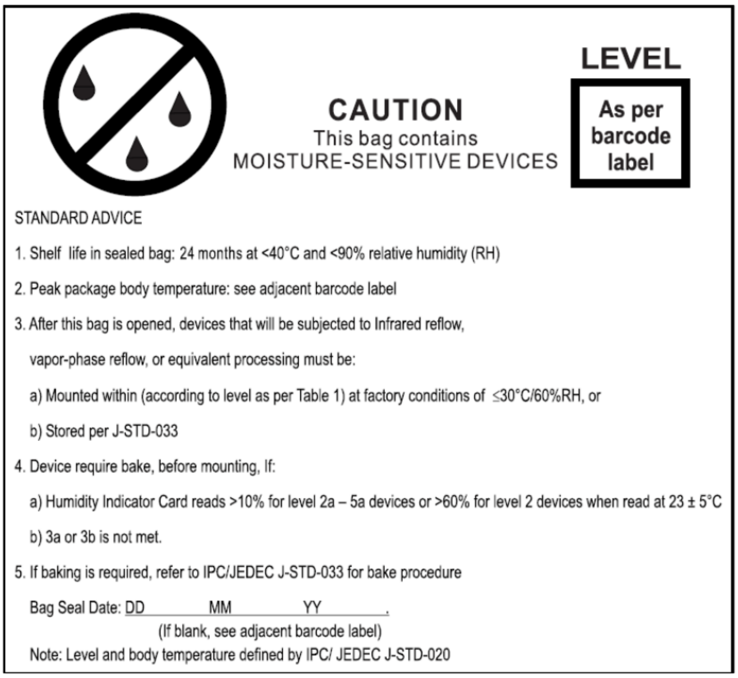
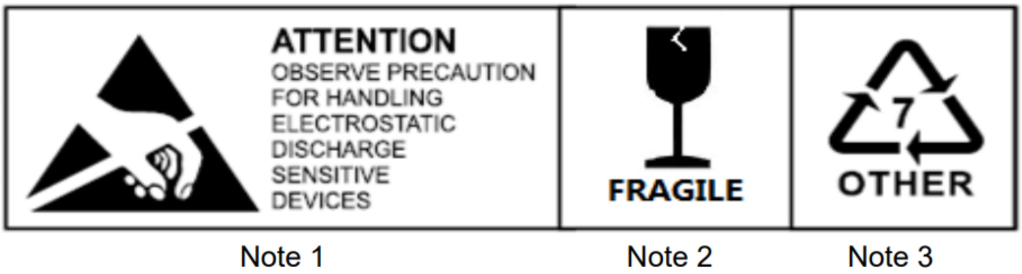


Figure 7. Description of the levels of floor life

LEVEL	FLOOR LIFE (OUT OF BAG) AT FACTORY Ambient ≤30°C/60%RH or as stated
1	UNLIMITED at ≤30°C/85% RH
2	1 YEAR
2a	4 WEEKS
3	1 WEEK
4	72 HOURS
5	48 HOURS
5a	24 HOURS
6	EXTREMELY Moisture-sensitive devices. Mandatory bake before use: Once baked, must be reflowed within 6 hours.

Figure 8. Additional pictograms on the base packing



Note1: Handling Discharge Sensitive Device Symbol
Note 2; Fragile Contents Symbol
Note 3; Material Recycle symbol follow ISO/IEC Standard.

1.4 Handling the reel after bag removal

Handling of reels, when removing them from the carton box and vacuum bag, can be potentially critical for the MEMS devices contained inside. Some best practices and actions should be taken to minimize the risk of sensor damage. Some examples are indicated below:

- Perform a visual inspection of the outer box upon reception.
- Perform a visual inspection of the inner box before opening it.
- Perform a visual inspection of the reel after removing it from the sealed bag.
- De-reel the initial part of the reel just in front of the SMT equipment and avoid accidentally dropping the reel tail on the floor (even if there are no components in the reel tail).
- Avoid any drop or accidental fall, during the entire assembly line process or during transportation.
- In the event of a fall or drop, intended or unintentional, caused by a human being or a machine, track the dropped material (box, reel, or device) and avoid mounting it and delivering to a third party. It is recommended to track any accident (due to mishandling) using a dedicated manufacturing traveler document for reel handling.

1.5 Handling MEMS sensors

Handling MEMS sensors can be potentially critical for the mechanical structure inside.

Some general guidelines to avoid risks are as follows:

- Store MEMS sensors in a clean, dry environment to prevent contamination or damage.
- Avoid touching the sensing elements or leads of the MEMS sensors with bare hands to prevent damage from oil or moisture.
- Use appropriate ESD precautions when handling inertial sensors to prevent damage from electrostatic discharge.
- Use appropriate handling tools. When handling inertial sensors, it is important to use appropriate tools, such as tweezers (preferably made of plastic) or vacuum pick-up tools, to avoid applying excessive force or pressure.
- Avoid bending or twisting the leads. The leads of inertial sensors are fragile and can be easily damaged by excessive force or pressure.
- Train personnel on proper handling techniques to avoid an excessive force or pressure to be applied during placement or testing. This can include training on the use of appropriate handling tools, the importance of a controlled placement process, and the risks associated with bending or twisting the leads.

1.6 Conclusion

MEMS devices during qualification are subjected to:

- Shock tests up to 10000 - 25000 *g*
- Drop (tumble) tests, where accelerations are not deterministic since the falling direction and the interaction with the surface can vary

These shocks are conceived as extreme single-drop falls as required by specific customers, but they are not intended to be sustained along normal manufacturing processes, handling, and PCB mounting operations or shocks occurring during transportation. Users or customers should avoid dropping individually packaged sensors (LGA or ceramic), trays, or reels containing sensors, especially on rigid surfaces (metal, marble, concrete or similar hardness), since accelerations can be in the order of >10x of qualification limits in those cases. The manufacturer shall take into consideration that any impact on the packing (outer/inner box or reel/tray) is considered a major event and that any sign of mishandling could be considered as a potential source of damage for the inertial devices. Therefore, the manufacturer must avoid accidental falls throughout the manufacturing process, regardless of the type of packing.

2 Pick and place guidelines

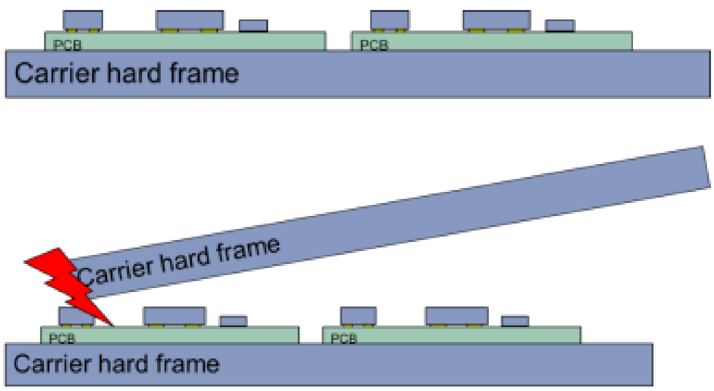
The assembly of the printed circuit boards (PCB) is a fully automated process where high-speed, high-precision machines guarantee the placement of electronic components on the relevant board. These systems normally use pneumatic suction cups, and at the end, a nozzle accurately picks the device from a predetermined area.

This process must be rigorously controlled since the position of the nozzle, the force involved in the pick and place, and the mechanical parameters can damage the structure of the MEMS sensor being picked up.

Some guidelines for the pick and place process are as follows:

- Ensure that equipment can raise an alarm if a false pick or an out-of-control of pick height occurs.
- Avoid any impact of hard material on the PCB area close to the component or on the component itself as depicted in the following example:

Figure 9. Hitting the component or PCB with a hard tool can damage it



- Operator awareness of the possibility of this failure mode
- Remove dangerous tools (screwdrivers, scissors) from the line where not necessary in normal operations.
- Protecting the PCB panel with foam during nonthermal operation and transportation can be an optimal solution even if it impacts line productivity
- Report any accident that occurs on the SMT line.

3 Surface mounting guidelines

3.1 General guidelines for soldering surface-mount MEMS sensors

The following elements must be considered in order to adhere to common PCB design and good industrial practices when soldering MEMS sensors:

- PCB design should be as symmetrical as possible.
  - Large traces on VDD or GND lines are not required (very low power consumption).
  - No vias or traces below the sensor footprint
- Solder paste must be as thick as possible (after soldering) in order to:
  - Reduce the decoupling stress from the PCB to the sensor
  - Avoid that the PCB solder mask touches the device package
- Solder paste thickness must be as uniform as possible (after soldering) to avoid uneven stress:
  - Final volume of soldering paste within 20% among lands is possible using the SPI (solder paste inspection) control technique.
- Avoid placement of the sensor on the PCB in locations close to hot spots (microprocessors, graphic controllers, batteries, …), close to pushbuttons, screws and/or PCB anchor points since these locations can produce mechanical stress affecting sensor precision.
- High-amplitude resonances (vibrations) of the PCB, both those caused by a source external to the PCB and those originating from another device mounted on the PCB itself, should be avoided.
- Sensors should be placed in positions in which the effects of such disturbing frequencies are minimized, or the component should be placed on a separate board to decouple its effects from the rest of the system.
- As MEMS devices have a mechanical structure with its own resonant and operating frequencies, the use of ultrasonic processes for cleaning and soldering is NOT recommended due to potential damage to the internal MEMS structure.

3.2 PCB design guidelines and recommendations

General recommendations for PCB land and solder mask design are shown in Figure 13. Refer to the device datasheet for pad count, size, and pitch.

- It is recommended to place the solder mask opening outside the PCB land.
- It is strongly recommended not to place any structure on the top metal layer underneath the sensor (on the same side of the board). This must be defined as a keepout area.
- Traces connected to pads should be as symmetric as possible. Symmetry and balance for pad connection help component self-alignment and lead to better control of solder paste reduction after reflow.
- For optimal performance of the device, it is strongly recommended to place screw mounting holes at a distance greater than 2 mm from the sensor.
- If present, the pin #1 indicator must be left unconnected to ensure proper device functionality.
- In order to prevent noise coupling and thermomechanical stress, following standard industry design practices for component placement is advised.

3.3 Stencil design and solder paste application

The thickness and the pattern of the soldering paste are important for the proper MEMS sensor mounting process.

- Stainless steel stencils are recommended for solder paste application.
- A stencil thickness of 90 - 150 μm (3.5 - 6 mils) is recommended for screen printing.
- The openings of the stencil for the signal pads should be between 70% and 90% of the PCB pad area.
- Optionally, for better solder paste release, the aperture walls should be trapezoidal and the corners rounded.
- The fine pitch of the IC leads requires accurate alignment of the stencil to the printed circuit board. The stencil and printed circuit assembly should be aligned to within 25 μm (1 mil) prior to application of the solder paste.

3.4 Process considerations

The soldering profile depends on the number, size, and placement of components on the application board. For this reason, it is not possible to define a unique soldering profile for the sensor only. The customer should use a time and temperature reflow profile based on PCB design and manufacturing expertise.

- In order to reduce residual stress on the components, the recommended ramp-down temperature slope should not exceed -3°C/s.
- No solder material reflow on the side of the package is allowed since LGA packages show metal traces on the side of the package.
- If “self-cleaning” solder paste is not used, the board must be properly cleaned after soldering to eliminate any possible source of leakage between adjacent pads due to flux residues.
- The final volume of soldering paste applied to each PCB land is recommended to be within 20% among (all) the PCB land pads.
- Based on the JEDEC 9702 standard, a component shows negligible output variation up to stress intensity of 500 me (microstrain).

3.5 Solder heat resistance and environmental specifications

In order to meet environmental requirements, ST offers these devices in ECOPACK packages. These packages have a lead-free second level interconnect. The category of second level interconnect is marked on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label.

3.6 PCB layout and recommended distance

The following figures depict some guidelines for PCB layout.

Figure 10. PCB distance and no underfill

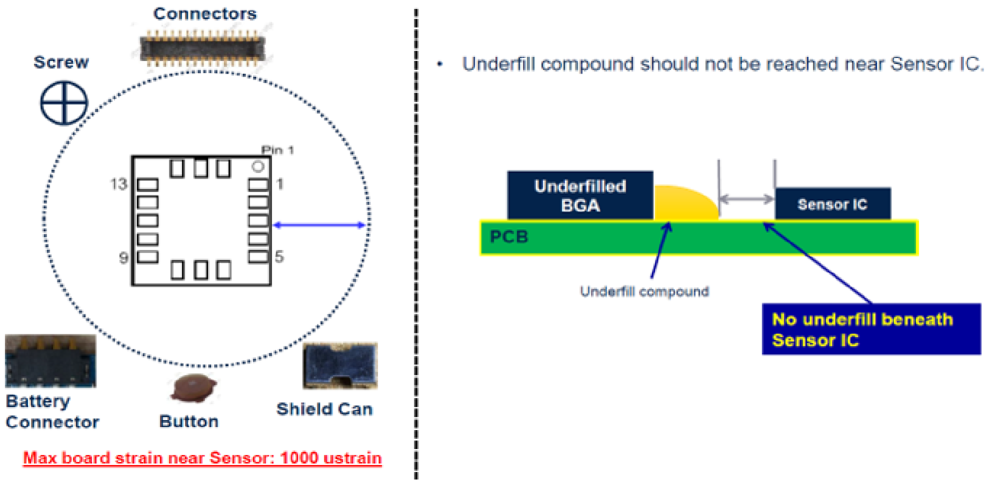


Figure 11. **PCB distance under IC**

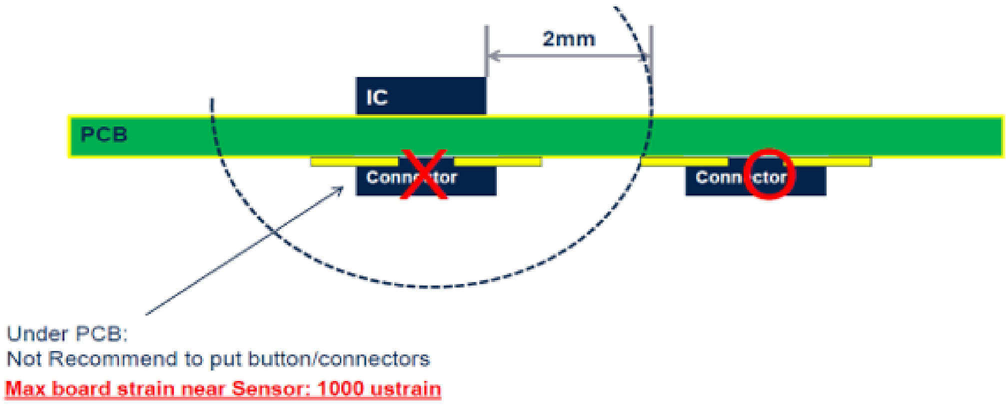
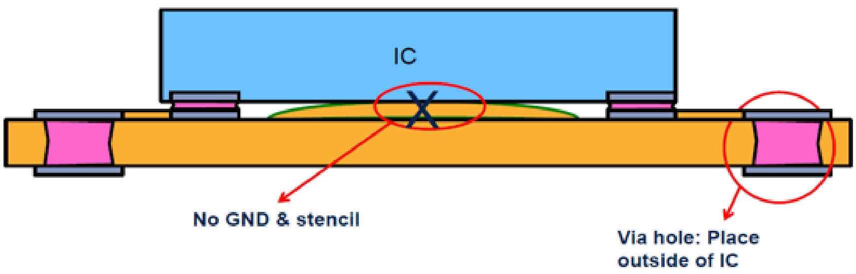


Figure 12. **PCB layout: side view**

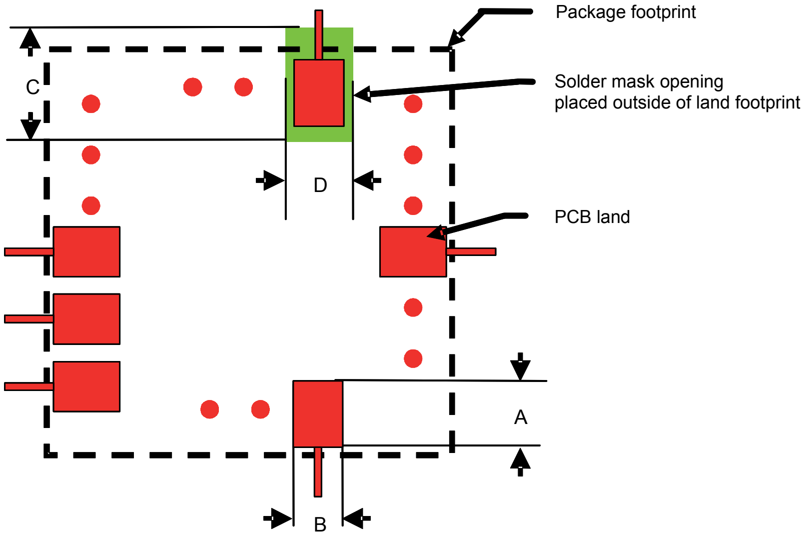


1. Top Layer placement is better than Bottom layer.
2. Via hole should be placed outside of IC
3. Keep out area beneath IC: Peel cut (No GND)

3.7 PCB design rules for the footprint

Note that all lands have to be the same size, no need for large lands.

Figure 13. **Footprint design rules**



PCB land design and connecting traces should be designed symmetrically.

For LGA pad spacing greater than 200 µm:

A = PCB land length = LGA solder pad length + 0.1 mm

B = PCB land width = LGA solder pad width + 0.1 mm

For LGA pad spacing equal to or less than 200 µm:

A = PCB land length = LGA solder pad length

B = PCB land width = LGA solder pad width

C = Solder mask opening length (where applicable) = PCB land length + 0.1 mm

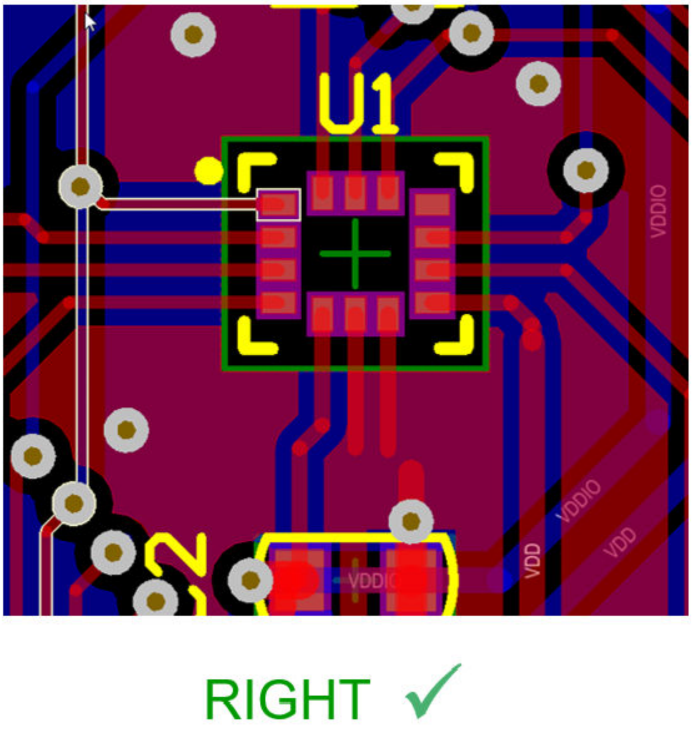
D = Solder mask opening width = PCB land width + 0.1 mm

3.8 PCB design rules for the traces

Connecting traces should be designed symmetrically.

The ground plane should not be connected directly to the footprint pads. It is better to connect it through a standard trace.

Figure 14. **Correct traces**

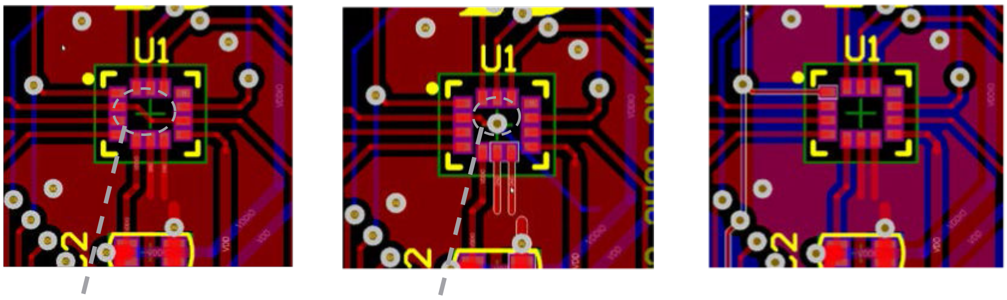


3.9 Placement rules for the top side

For all MEMS devices, the device is soldered on the top side.

Never place any routing or via on the top side under the device, refer to the following figure.

Figure 15. Examples of top side placement



WRONG: routing under the device on TOP side

WRONG: VIA under the device

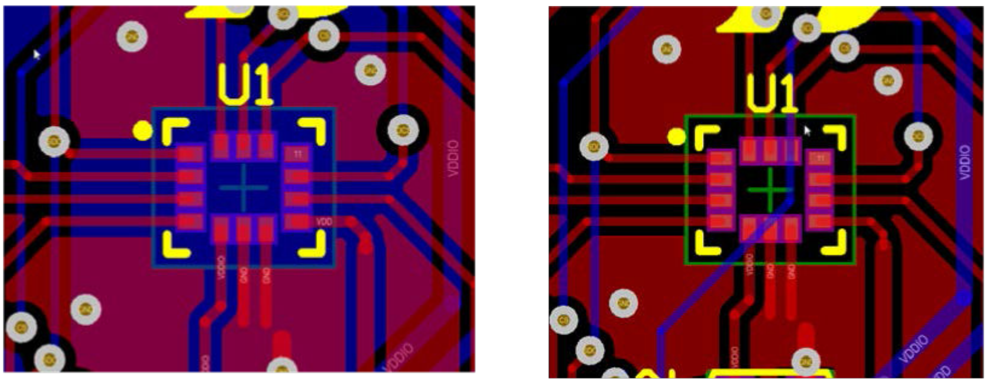
RIGHT: leave free space under the device on TOP side

3.10 Placement rules for the bottom side

Placement rules for the bottom side apply only to MEMS accelerometer, gyroscope, and pressure sensors.

It is possible to use the bottom side under the device for power plane or signal routing.

Figure 16. Examples of bottom side placement



RIGHT: power plane on BOTTOM side under the device

RIGHT: signal routing on BOTTOM side under the device

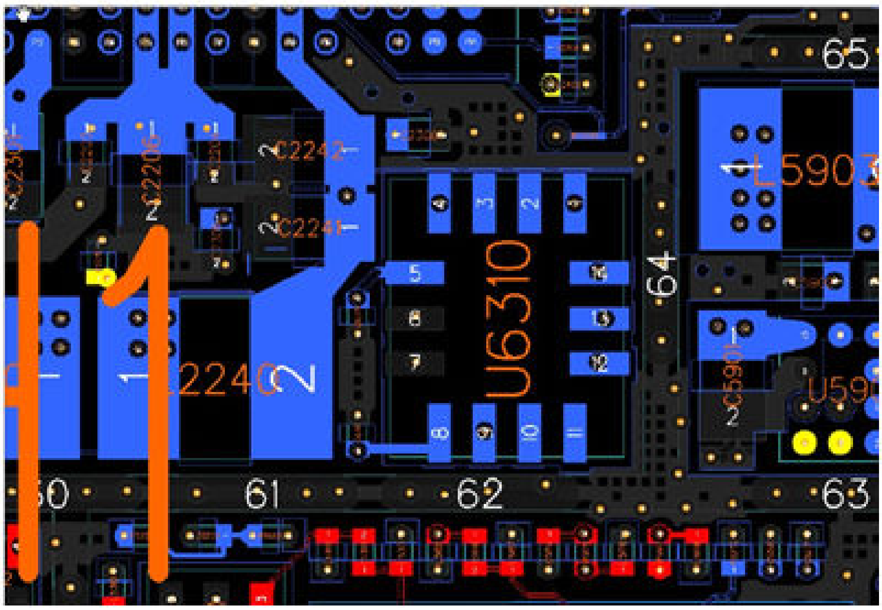
3.11 LGA package layout hints - extra tips

The following figure shows an actual case from the field.

The customer was facing a little offset shift on the zero-*g* and zero-rate level. The following points were identified as incorrect practices:

- Pins 6 and 7 are not soldered: this can cause mechanical stress on the inner sensors.
- Vias below pads: it is better to move these outside the component.
- Copper traces below the component have to be avoided (trace of pin 8 should flow directly outside the component).

Figure 17. Example of incorrect layout from a real case



3.12 Mounting recommendations vs. mechanical shock and thermal stress

The following figures depict some mounting recommendations regarding mechanical shock and thermal stress.

Figure 18. Mechanical shock

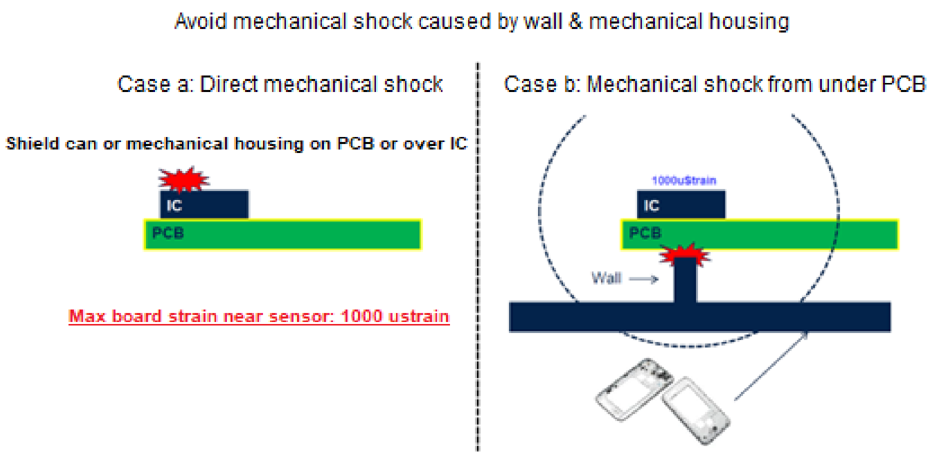


Figure 19. Thermal stress

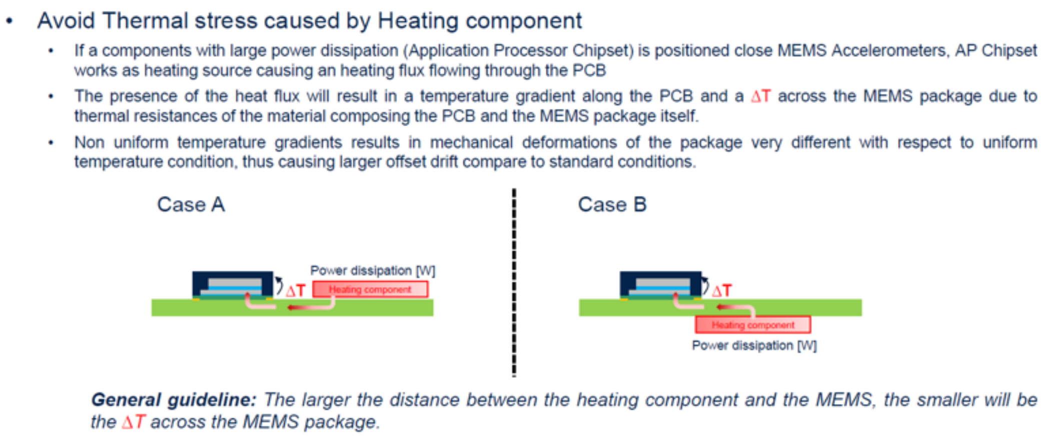
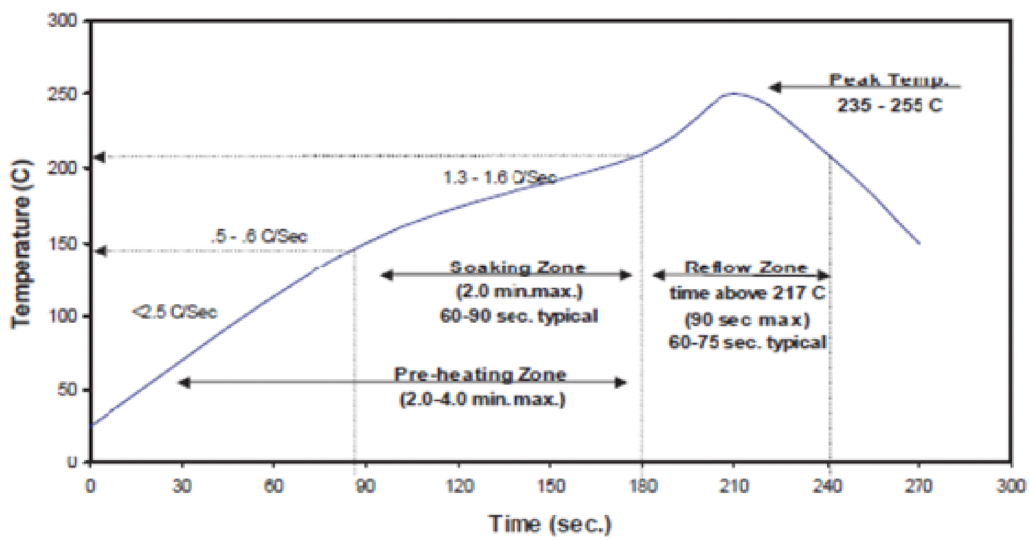


Figure 20. Typical reflow profile



3.13 Ultrasonic baths

Ultrasonic baths, usually performed before and after PCB mounting operations, are allowed but they can potentially damage MEMS devices if the bath energy level is too high and/or one or more resonant frequencies of the device is/are matched and forced.

4 Desoldering and resoldering

Guidelines for desoldering and resoldering devices

The desoldering process for MEMS products is highly critical. It is essential to follow the recommendations below to avoid damaging the device. Proper handling during desoldering ensures the integrity and performance of the components.

- **Desoldering**: The removal of components from customer PCBs should be performed at a maximum temperature of 270°C (maximum peak temperature profile). It is crucial that the desoldering tool used has a stable and controlled temperature, monitored through temperature sensor feedback, to prevent overheating and potential damage to the device.
- **Resoldering**: Do not proceed with the resoldering of components that have already been desoldered. Resoldering previously desoldered components can compromise their reliability and performance.

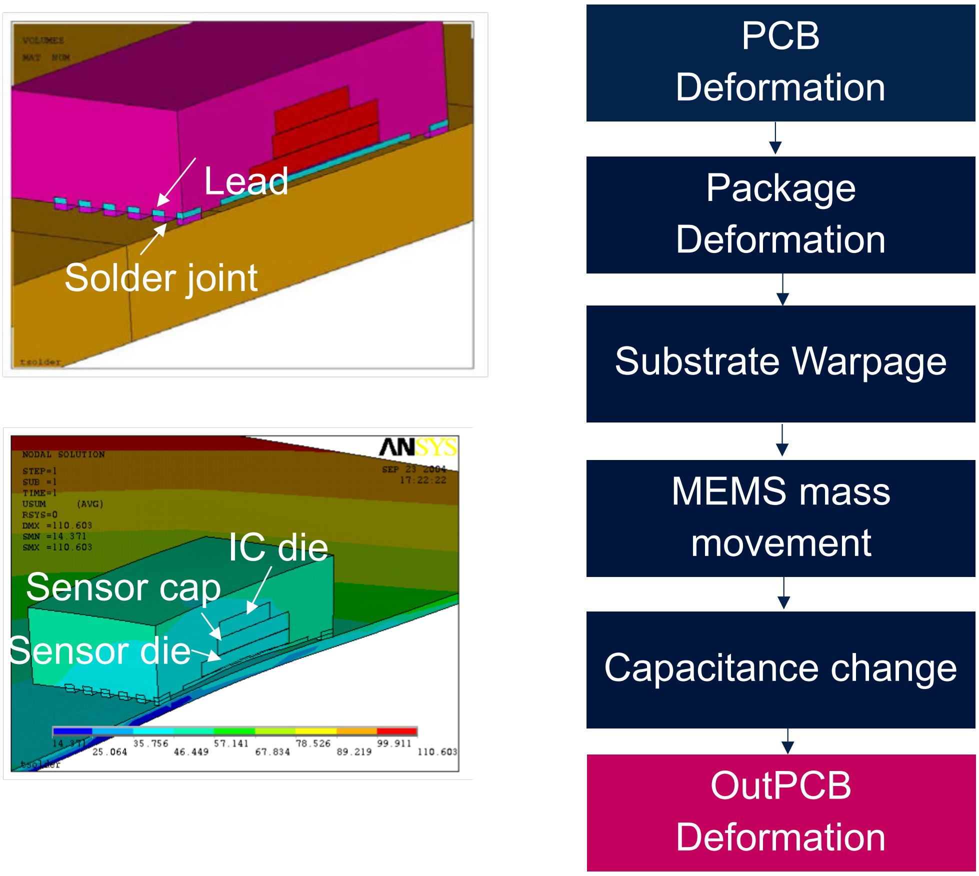
5 Effects of thermomechanical stress

5.1 Soldering effect on the MEMS

Assembly processes can induce thermomechanical stress to the sensor due to the interaction between the sensor die, package, and PCB.

Basically, the deformation of the PCB is transferred to the substrate and to the package of the sensor. Then the mechanical stress is transferred to the mechanical structure of the sensor through its anchors. This causes a deviation/drift of sensor parameters, such as offset, sensitivity, and self-test response. In the worst case, aggressive handling may lead to breakage of the structures of the sensor.

Figure 21. Consequences of thermomechanical stress

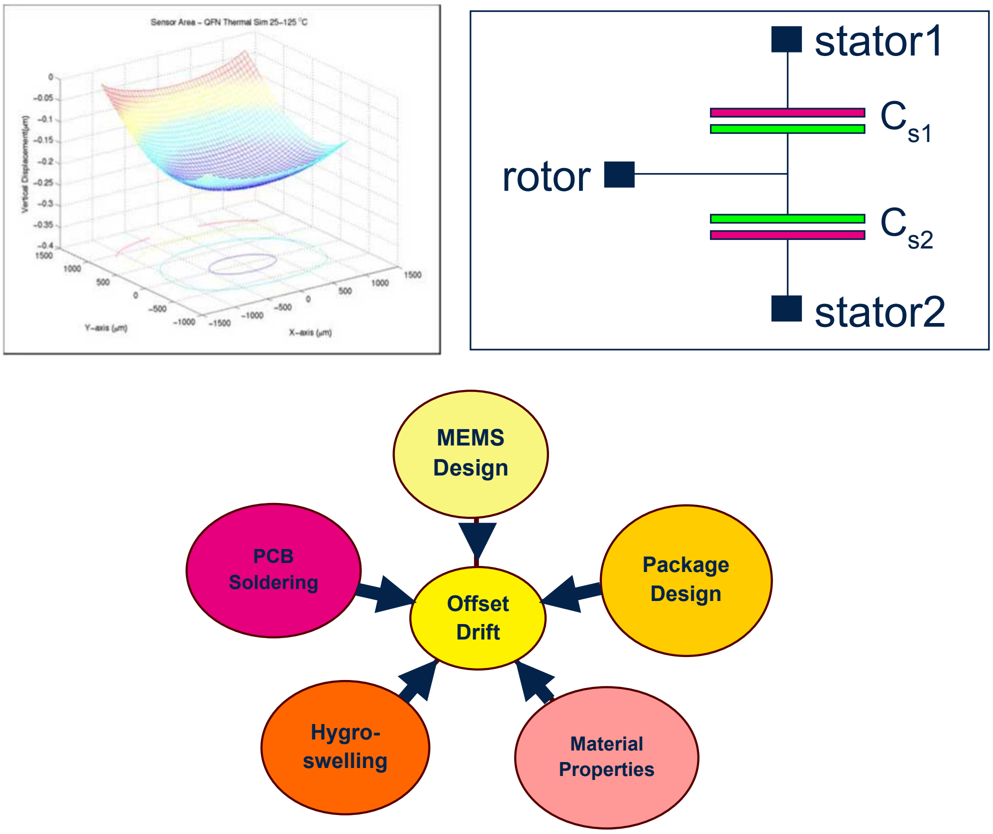


5.2 Effect of thermomechanical offset drift on the sensor

Thermomechanical stress causes a deformation of the silicon die of the sensor, which is converted into a relative displacement between the fixed and movable electrodes. For the sensors, this displacement produces a signal comparable to a real physical one. This produces, for example, a variation of the offset of the device.

The actual variation of the sensor parameters related to thermomechanical offset drift depends on several variables (package, materials, MEMS design, soldering process, and so forth).

Figure 22. Offset drift resulting from thermomechanical stress



5.3 Effect of thermomechanical stress: elastic vs. plastic

Thermomechanical stress, and related warpage, always happen when there are changes in temperature:

- It is usually an **elastic** effect.
- When the external force is removed, **warpage is relaxed**.
- Package materials have been selected and the sensor has been designed to **minimize this effect**.

During **soldering**, **plastic deformation** can happen in the package due to:

- Interaction with the **PCB**, **uneven force field**
- **Process not optimized**, for example, temperature ramp down in reflow oven

Plastic deformation does not relax back when the temperature stress is removed.

5.4 Mechanical stress factors

Uneven force field distribution is created by:

- Asymmetrical PCB layout, surrounding components, position of the vias (see Section 3: Surface mounting guidelines)
- Placement of MEMS component (see Section 6: Placement considerations for inertial MEMS sensors on the PCB)
- Usage and dispensing of filler
- Nonuniformity of solder paste thickness

Other factors to be considered for optimized performance are:

- Very thick solder paste reduces the level of warpage of the sensor.
- Slow cooling of the board after assembly (JEDEC specs) is recommended to avoid stress on the sensor.
- It is recommended to avoid *g*-forces exceeding the specified sensor limits during all handling operations, including transportation and assembly.

6 Placement considerations for inertial MEMS sensors on the PCB

6.1 Mechanical stress and layout tips

Thermomechanical stress is a normal process during component assembly and the effect is fully recovered once the stress conditions return to normal. In fact, even if the layout is symmetrical, the PCB and solder joints need time to relax the induced stress.

On the other hand, permanent unexpected levels of sensor output can be caused by anisotropic mechanical stress distribution on the PCB. This is typically generated by:

- Screw, holes, pillars
- Shields placed in close proximity to the device
- Underfill (when placed close or on the opposite side of the MEMS)

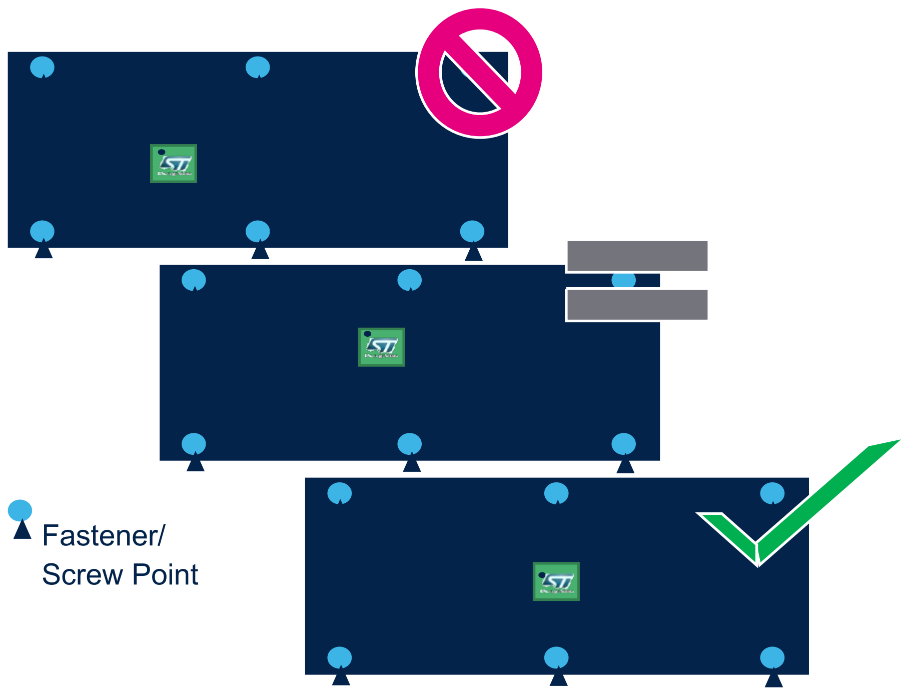
Moreover, in order to prevent high temperature gradients that could cause mechanical stress, ST recommends placing the sensor away from heat sources (such as batteries and power management integrated circuits).

All these elements should be carefully evaluated during the design of the PCB.

6.2 Fasteners on the PCB

PCB boards are generally housed and fixed in an enclosure. Inertial MEMS sensors should be located between fasteners so as to minimize and distribute homogenously the stress on the MEMS sensor as illustrated in the following figure. When this is not possible, the location that best meets this criteria is to be selected.

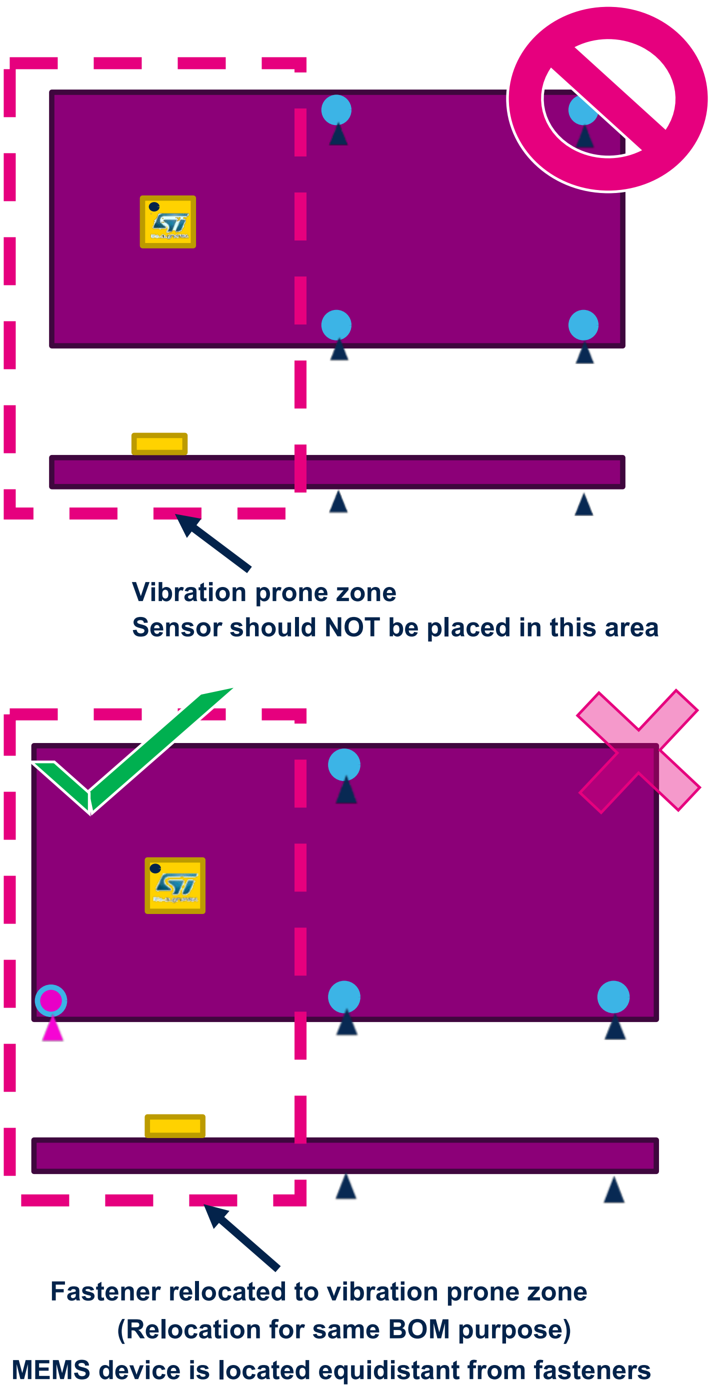
Figure 23. **Placement of sensor between fasteners**



6.3 Areas of stress on the PCB

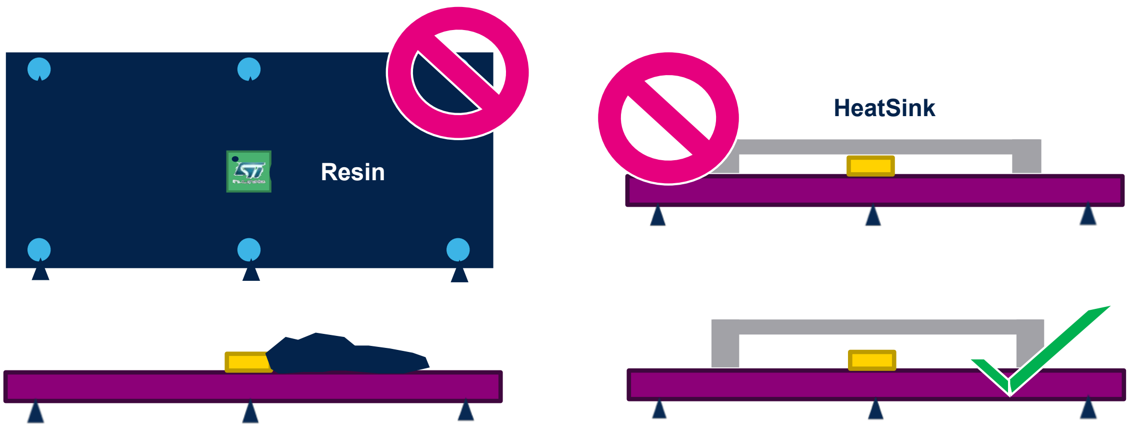
The PCB board illustrated in the previous Figure 1 is a symmetric rectangular board. In actual applications, the probability of having a symmetric board is unlikely. In most cases, PCBs have protruding sections and without fasteners. These locations are prone to vibrations that can provide false readouts and thus it is highly advisable that the MEMS sensor be located away from such areas.

Figure 24. Placement of sensor in area without vibrations



Sources of stress can be the use of epoxy resin materials to cover the CPU and the use of heat sinks or other foreign structures that are in contact with the MEMS sensors. These conditions are sources of high stress and need to be removed from the design.

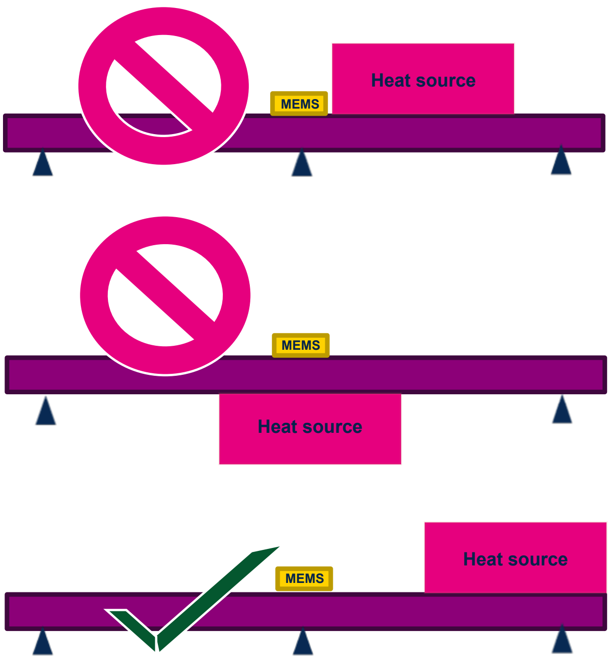
Figure 25. **Examples of sources of stress to the sensor**



6.4 Recommended placement of a heat source with respect to the MEMS sensor

The presence of a heat source in the surrounding area of the MEMS sensor causes undesired internal movement. In order to reduce the probability of mechanical stress, locating the heat source away from the MEMS sensor is recommended.

Figure 26. **Placement of the heat source far from the MEMS sensor**

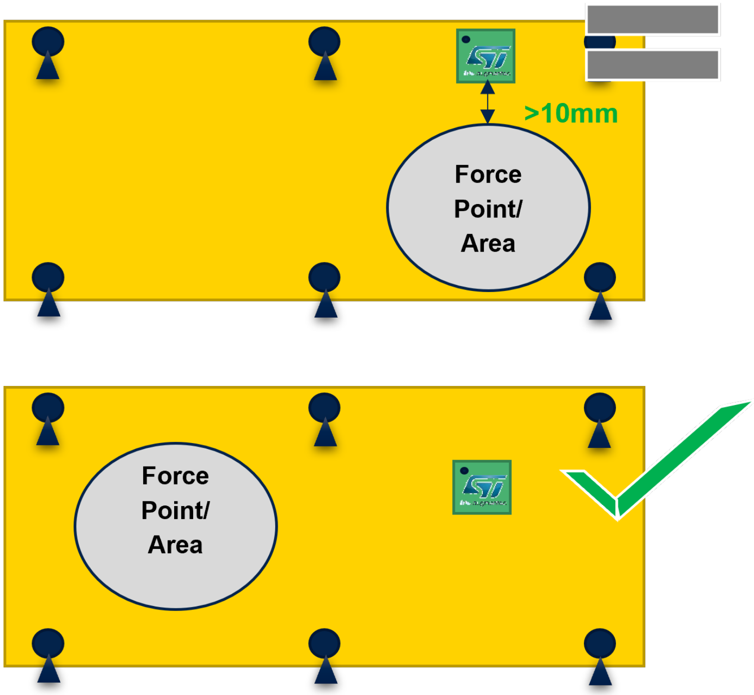


6.5 External loads/forces

Certain applications allow the possibility for external loads/forces to be exerted on the board. One example might be a series of pushbuttons or connection points that are used during normal operation.

These forces are transferred to the board and hence to the MEMS sensor. Placing the MEMS sensor away from these sources and keeping it at least 10 mm away from the source of the external force reduces the effect on the MEMS sensor.

Figure 27. **Placement of sensor far from external point of force**



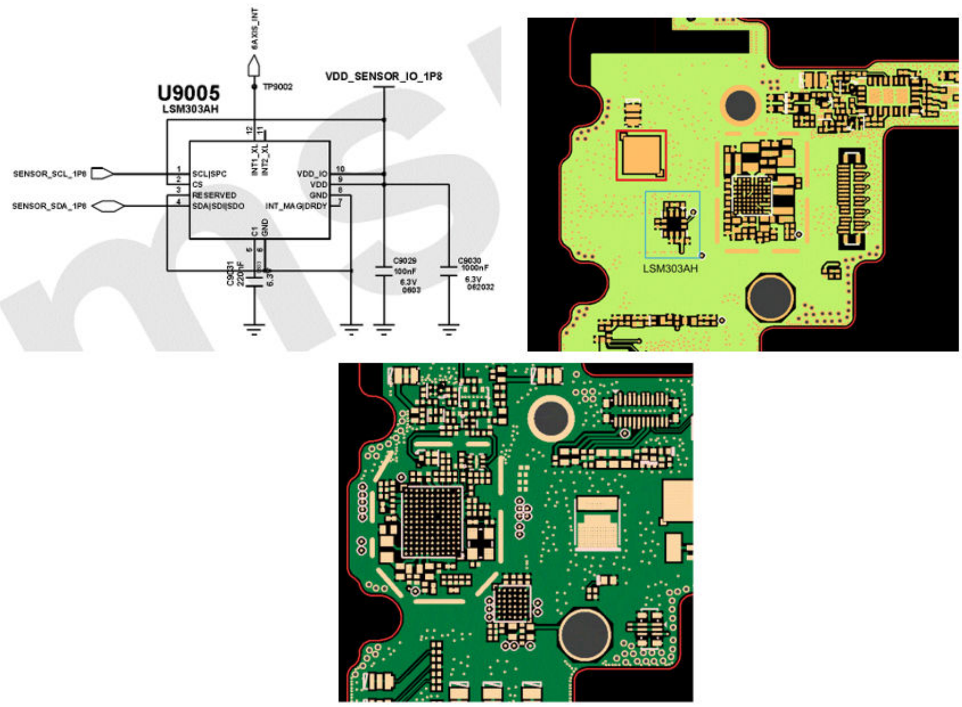
6.6 Example of shield placement

The schematic analysis of the PCB shows that it is properly designed according to ST guidelines.

On the other hand, the layout shows a metallic shield placed on the bottom side close to the MEMS component.

Based on ST's experience, this metallic shield can cause a small additional offset contribution on the device because it can cause mechanical stress.

Figure 28. Example of shield placement



6.7 Findings of shield mounting

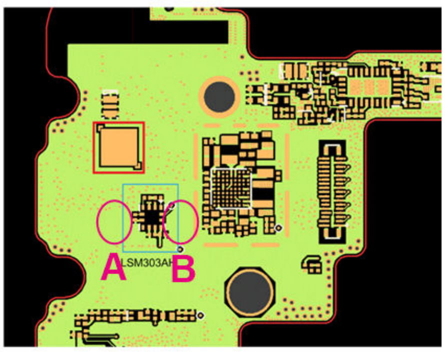
In order to estimate the effect of shield mounting, board bending has been evaluated using a profilometry analysis.

The profilometer allows measuring the radius of curvature R_c of a given surface.

If the surface is flat, $R_c \rightarrow \infty$. This means that the lower the R_c, the higher the stress applied to the PCB.

In the PCBs under test, R_c has been measured in the A and B areas (refer to the figure below) and have been found to be much smaller than that of flat PCBs.

Figure 29. Areas of measurement of radius of curvature



6.8 Solder profile according to IPC/JEDEC J-STD-020D

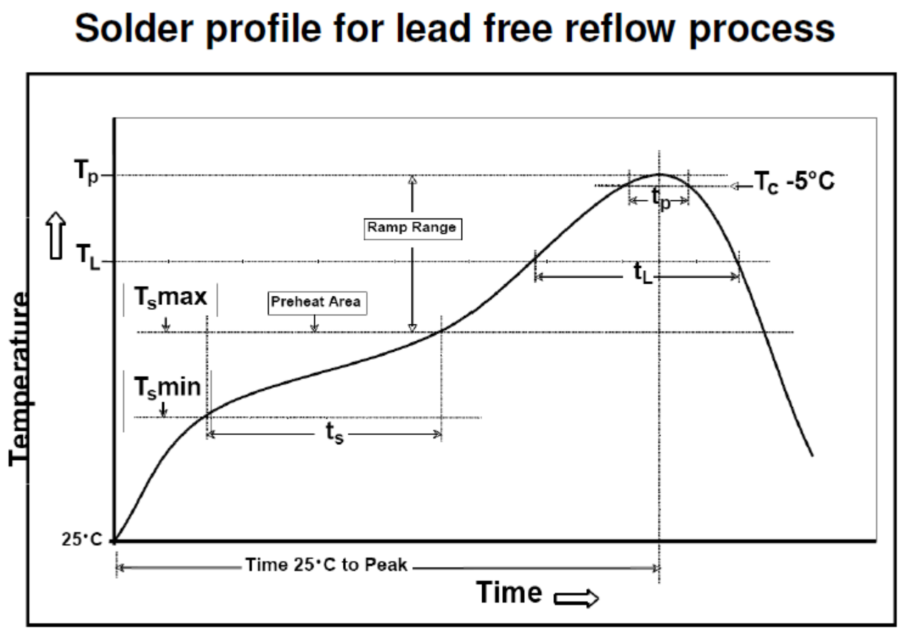


Figure 30. Classification reflow profile for SMT components

refer to IPC/JEDEC J-STD-020D

Figure 31. Classification reflow profiles and temperature

Table 1 Classification Reflow Profiles

Profile Feature	Pb-Free Assembly
Average Ramp-Up Rate (Ts_{max} to Tp)	3°C/second max.
Preheat - Temperature Min (Ts_{min}) - Temperature Max (Ts_{max}) - Time (ts_{min} to ts_{max})	 150°C 200°C 60-120 seconds
Time maintained above: - Temperature (T_L) - Time (t_L)	 217°C 60-150 seconds
Peak/Classification Temperature (Tp)	See Table 2
Time within 5°C of actual Peak Temperature (tp)	20-30 seconds (WE-GF/WE-LAN: 10 s; Tp=245°C)
Ramp-Down Rate	6°C / sec max.
Time 25°C to Peak Temperature	8 minutes max.

refer to IPC/JEDEC J-STD-020D

Table 2 Package Classification Reflow Temperature

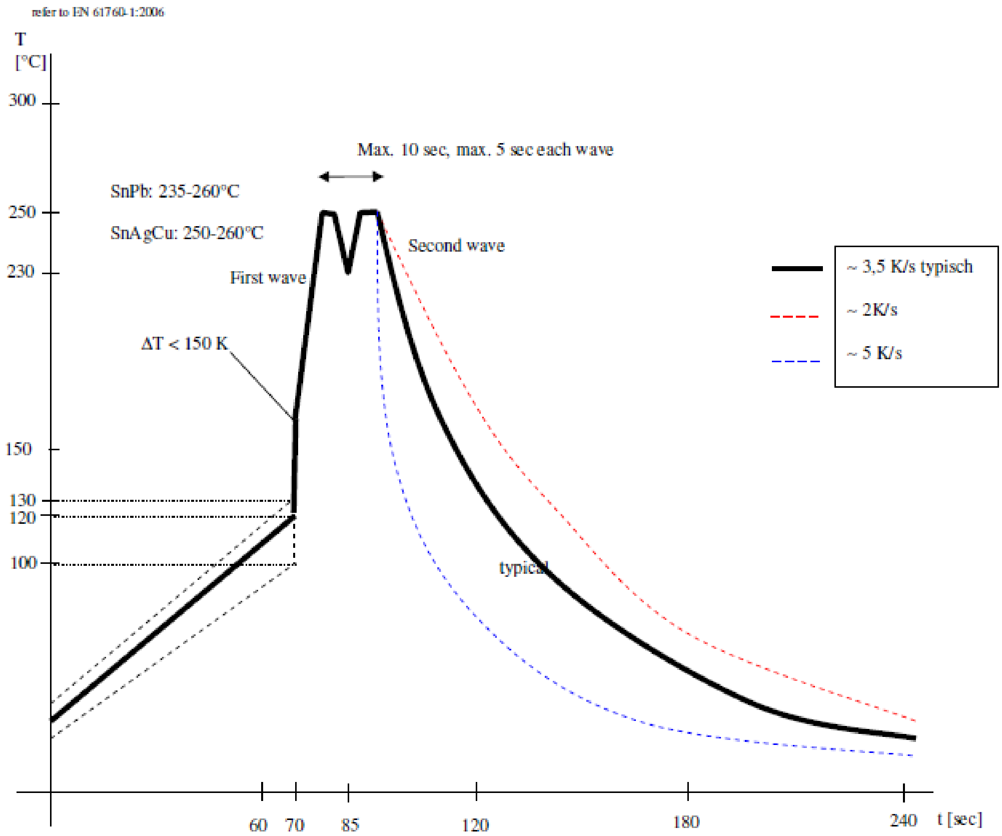
Package Thickness	Volume mm^3 <350	Volume mm^3 350 - 2000	Volume mm^3 >2000
<1.6 mm	260 °C	260 °C	260 °C
1.6 mm - 2.5 mm	260 °C	250 °C	245 °C
>2.5 mm	250 °C	245 °C	245 °C

refer to IPC/JEDEC J-STD-020D

Note: All temperatures refer to topside of the package, measured on the package body surface

Recommended for all parts which are marked with the RoHS logo
not otherwise specified in the latest revision of the product specification

Figure 32. Classification wave soldering profile for THT components

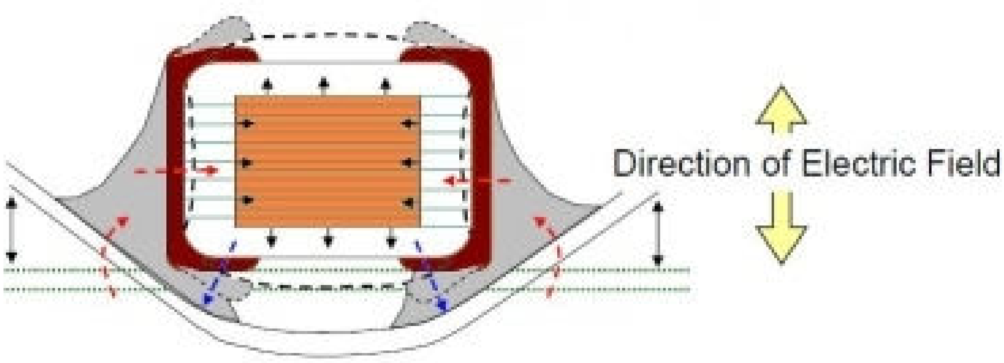


6.9 Avoiding the effect of singing capacitors on the performance of the MEMS sensor

In some applications, a vibration or low audible hum coming from certain ceramic capacitors can arise. This is sometimes described as a singing capacitor and it is actually a piezoelectric effect.

An unbalanced power circuit can generate the effect of singing capacitors that, if it is uncontrolled, can induce a vibration overlapping the gyroscope resonance frequency, thus affecting the performance of the MEMS sensor.

Figure 33. Deformation of multilayer ceramic chip capacitor affected by electric field

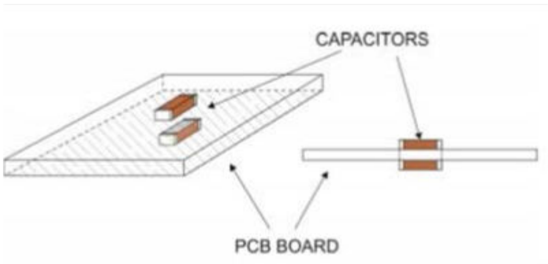


The recommendation is to reduce the effect of singing capacitors by optimizing the PCB layout. In fact, the origin of this effect is the interaction of MLCCs (multilayer ceramic chip capacitors) with the PCB, so optimizing component placement on the PCB can be effective.

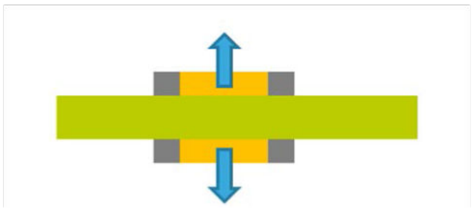
Tips:

- PCB material and thickness
  - A thicker PCB is more resistant to deformation and produces a lower sound pressure level (SPL).
- PCB layout
  - MLCCs placed at the edge of the PCB are preferred (lower SPL) with respect to a placement away from the edge of the PCB;
  - When MLCCs are placed symmetrically on each side (opposite sides) of the PCB board (as shown in the figure below), MLCCs tend to cancel out each other's vibrations.

Figure 34. Placement of MLCCs to avoid vibration



Capacitors on each side of a PCB to create vibration cancellation



If the combination of tension applied to the MLCCs is such that a destructive interference is produced, the singing capacitors effect can be avoided.

6.10 Application hints - reference designs of communication protocols and options for positioning primary and redundant sensors

Figure 35. Reference design of ASM330LHB - SPI4 communication protocol

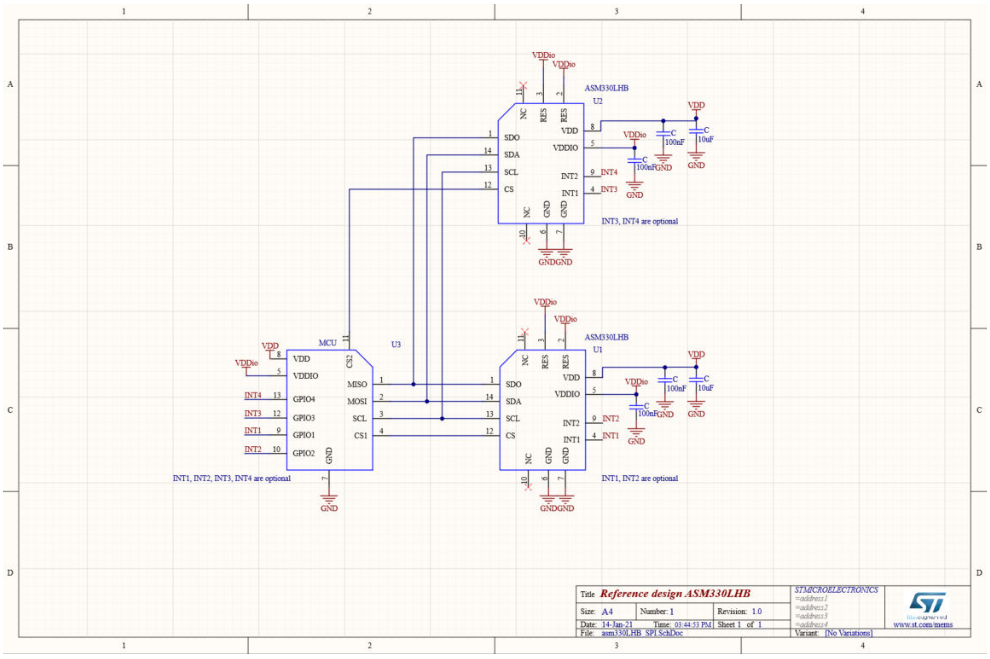
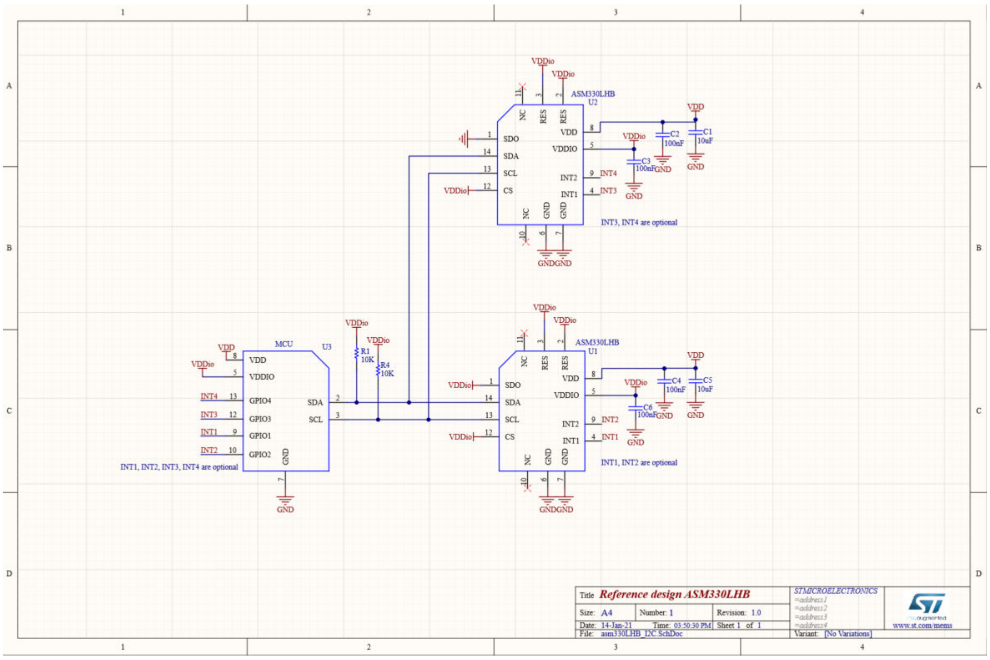


Figure 36. Reference design of ASM330LHB - I²C/I3C communication protocol



Diagrams for ASM330LHB - positioning of primary and redundant sensors

Recommended options

Figure 37. Option 1: Z-axis 90° clockwise rotation

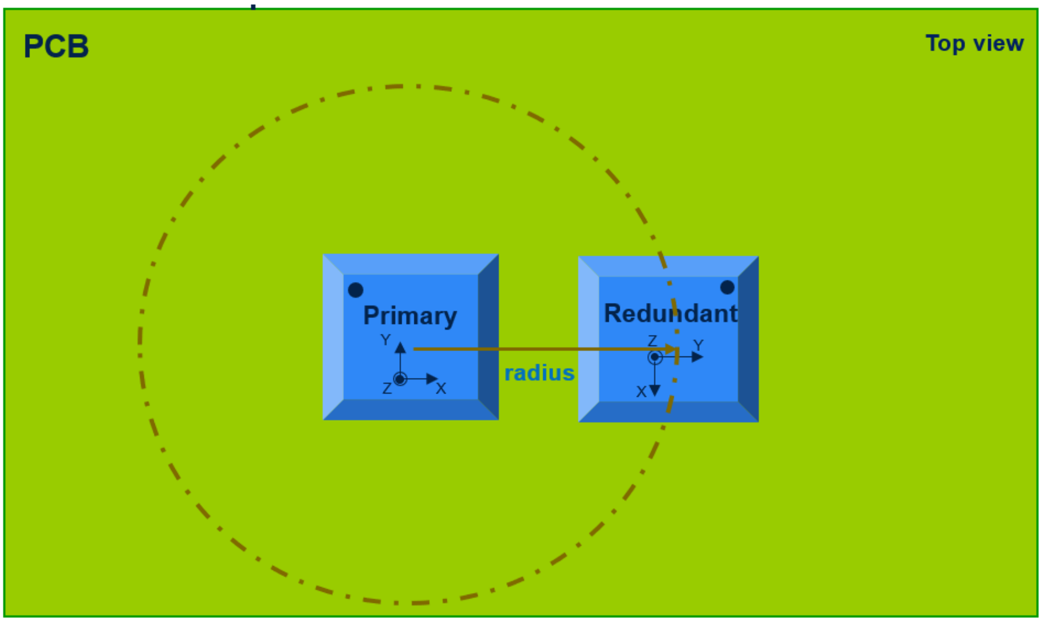


Figure 38. Option 2: Z-axis 270° clockwise rotation

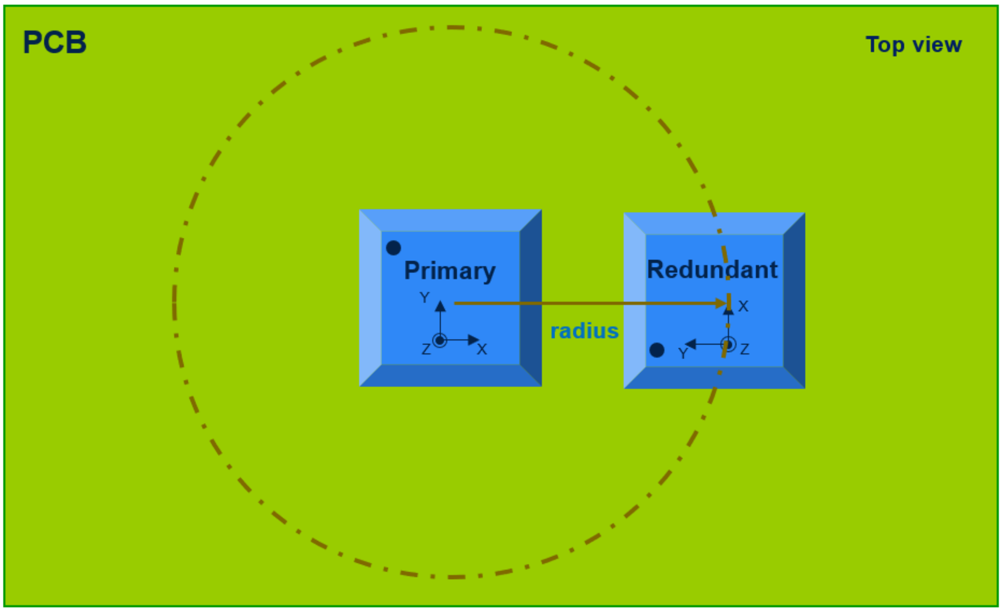
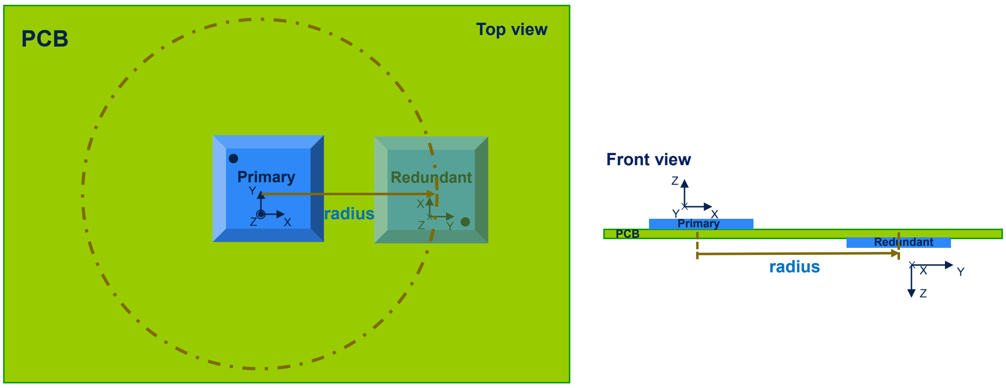


Figure 39. **Option 3: Y-axis 180° clockwise rotation and Z-axis 90° clockwise rotation**



The distance between the center of the primary sensor and the center of the redundant sensor is the radius of the shown **circumference**, in which the center is occupied by the center of the primary sensor and where the center of the redundant sensor can be placed at any point lying on this circumference. The recommended **radius** of this circumference is 2 cm.

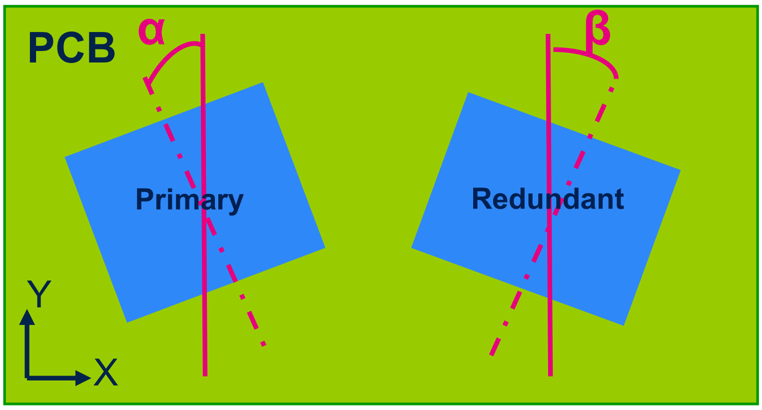
Note that the primary sensor is the one using the ENU coordinate system.

The relative distance between the primary and redundant sensors is the relevant distance, not their absolute position.

The orthogonality error between the primary and redundant sensors is expressed in terms of an angle (ϑ) that must be lower than 3° in order for the software library to work properly: $\vartheta < 3°$

The maximum ϑmax = 3° angle is obtained in the specific case, which is shown in the following figure.

Figure 40. **Orthogonality error between primary and redundant sensors**



The worst misalignment case between the primary and redundant sensors is shown in Figure 40: $\alpha + \beta = \vartheta$max

The primary and redundant sensors must be positioned so that they do not overlap.

Revision history

Table 1. **Document revision history**

Date	Version	Changes
12-Oct-2006	1	Initial release
30-Apr-2008	2	Added appendix with mechanical information
30-Jul-2013	3	Updated Section 2: PCB design guidelines Updated Section 4: Process considerations Removed Appendix A with LGA package drawings and dimensions Minor textual updates throughout technical note
31-Oct-2013	4	Textual update in Note on page 5
24-Mar-2014	5	Updated Section 2: PCB design guidelines; Section 3: Stencil design and solder paste application; and Section 4: Process considerations
20-Mar-2017	6	Updated Section 1: General guidelines for soldering surface-mount MEMS sensors
06-Jun-2023	7	Updated Section 3.1: General guidelines for soldering surface-mount MEMS sensors, Section 3.7: PCB design rules for the footprint, and Section 3.5: Solder heat resistance and environmental specifications
19-Mar-2025	8	Updated title, Introduction Added Section 1: Handling and storage of outer box, inner box, base packing (reel and tray) and subsections Added Section 3.6: PCB layout and recommended distance, Section 3.8: PCB design rules for the traces, Section 3.9: Placement rules for the top side, Section 3.10: Placement rules for the bottom side, Section 3.11: LGA package layout hints - extra tips, Section 3.12: Mounting recommendations vs. mechanical shock and thermal stress, Section 3.13: Ultrasonic baths Added Section 4: Desoldering and resoldering Added Section 5: Effects of thermomechanical stress and subsections Added Section 6: Placement considerations for inertial MEMS sensors on the PCB and subsections

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