Accelerometer and Gyroscope Design Guidelines

PURPOSE AND SCOPE

This document provides high-level placement and layout guidelines for InvenSense MotionTracking™ devices. Every sensor has specific requirements in order to ensure the highest level of performance in a finished product. For a layout assessment of your design, and placement of your components, please contact InvenSense.

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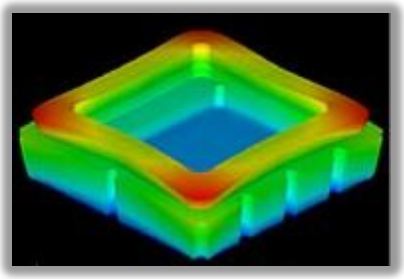
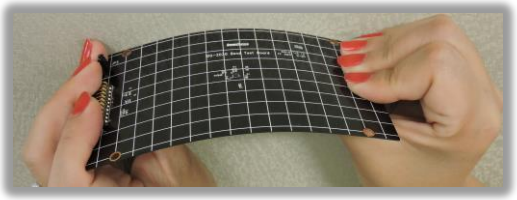
1. ACCELEROMETER AND GYROSCOPE DESIGN GUIDELINES

1.1 PACKAGE STRESS

MEMS accelerometer and gyroscope Motion Processing Units (MPUs) are mechanical devices affected by package stress. Bending of the PCB caused by mounting locations, screw holes, or misalignment, will transfer board stress to the package, and can alter the output of the MPU. In extreme cases, this stress may even damage the MEMS structure.





The MPU should be placed in a location where there will be minimal board stress. Typically, this is away from any fixed mounting location, screw hole, or large insertion components, such as buttons, shielding boxes, connectors, etc. During the design phase, the estimated misalignment, mounting method, and board geometry, may be used to determine which areas have the least internal stress.

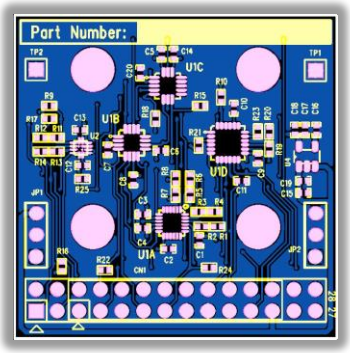
Package stress can be introduced from thermal sources during soldering or reflow processes. Uneven thermal expansion of packaging materials (e.g. sensor package) and cooling during the assembly process introduces this stress. It is recommended not to exceed the conditions in the reflow profile provided within the device's product specification document. This diagram represents maximum conditions required for component reliability testing. The profile of a typical lead-free reflow solder process ranges from +235°C and +260°C.

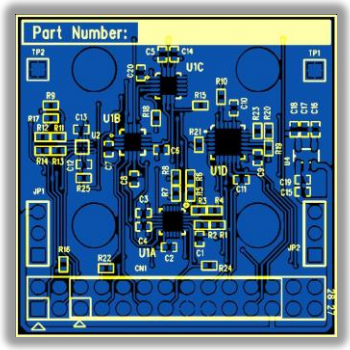
Sensor manufacturers usually recommend not to hand solder the MPU, as the uneven application of heat during soldering may not only introduce an unwanted offset bias, but also create uncontrolled thermal stress on the package. Do not place any component pads or vias within 1mm-2mm of the package land area, to ensure even cooling and minimal mechanical coupling between the MPU and adjacent components. This also helps to avoid elevation changes, orientation offsets, and non-uniform package stress.

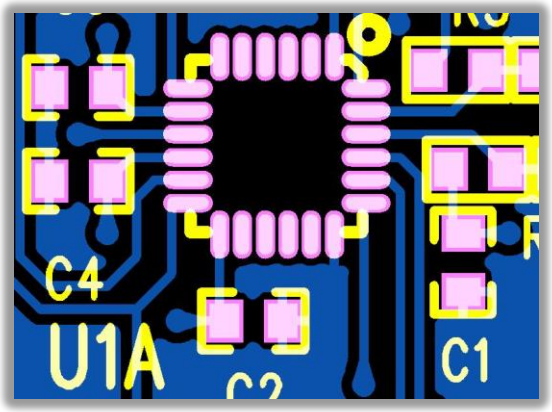
Any epoxy-sealed parts on the board should be placed at least 5 mm away from MPUs so the epoxy resin does not come in contact with the sensor package.

Also, curing epoxy or uneven thermal expansion may introduce package stress and adversely affect the sensor performance.

PCBs with four layers or more provide adequate isolation from noise. It is important to define package outlines as “keep out” areas. Set solder mask apertures for blocked areas and individually outlined pads according to your fabrication/assembly house requirements. Remember to route analog signal and power lines away from high-speed lines, such as clock and I2C/SPI interfaces; use >10 mil power traces, 0.5 oz copper planes, and a solid ground return path. Use NC pin connections to the PCB for additional stability only. Symmetrical routing improves sensor self-alignment; however, do not connect the NC pins to ground and/or power planes or islands. They are to remain unconnected as their original purpose suggests.

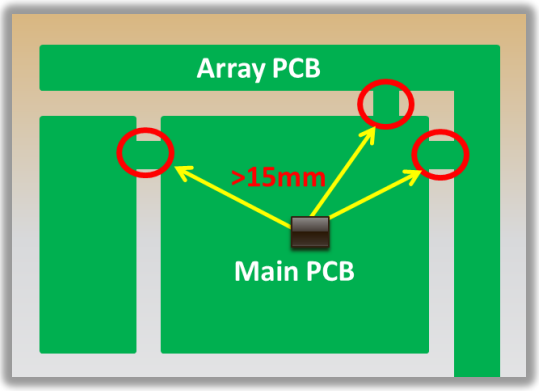






1.2 PANELIZED/ARRAY PCB

V-cut type panels will usually separate by bending the boards after assembly. This can add undesired mechanical stress to the sensor package during separation processes, in particular if the sensor is located close to the V-cuts. Unlike mouse bites, V-cuts do not leave jagged edges, but mouse bites may be laser cut by the assembly house, eliminating the mechanical stress on the package.



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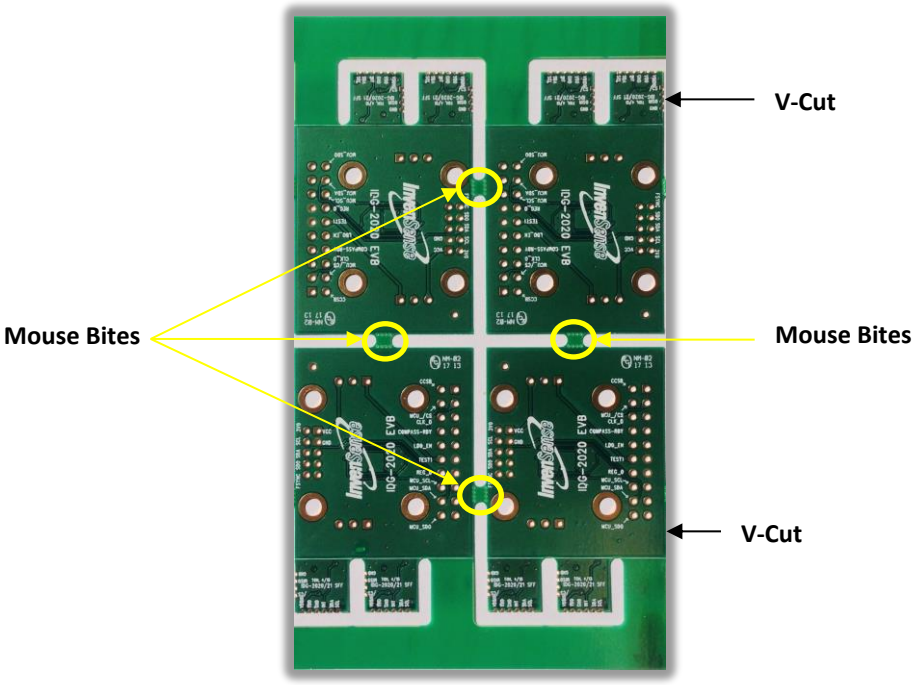
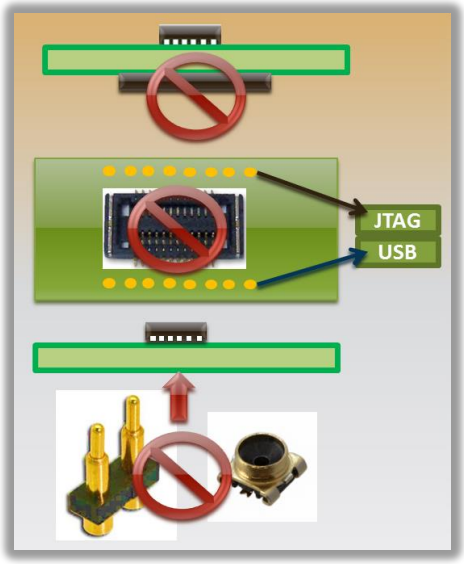


Recommended Distance from Panelized PCB Bridges

Push buttons, toggle switches, connectors (JTAG, USB, etc.), and test points for pogo pins (spring-loaded test points), should not be placed behind the sensor (backside of the PCB). This will create unwanted mechanical stress on the sensor package once activated by applying pressure to them.



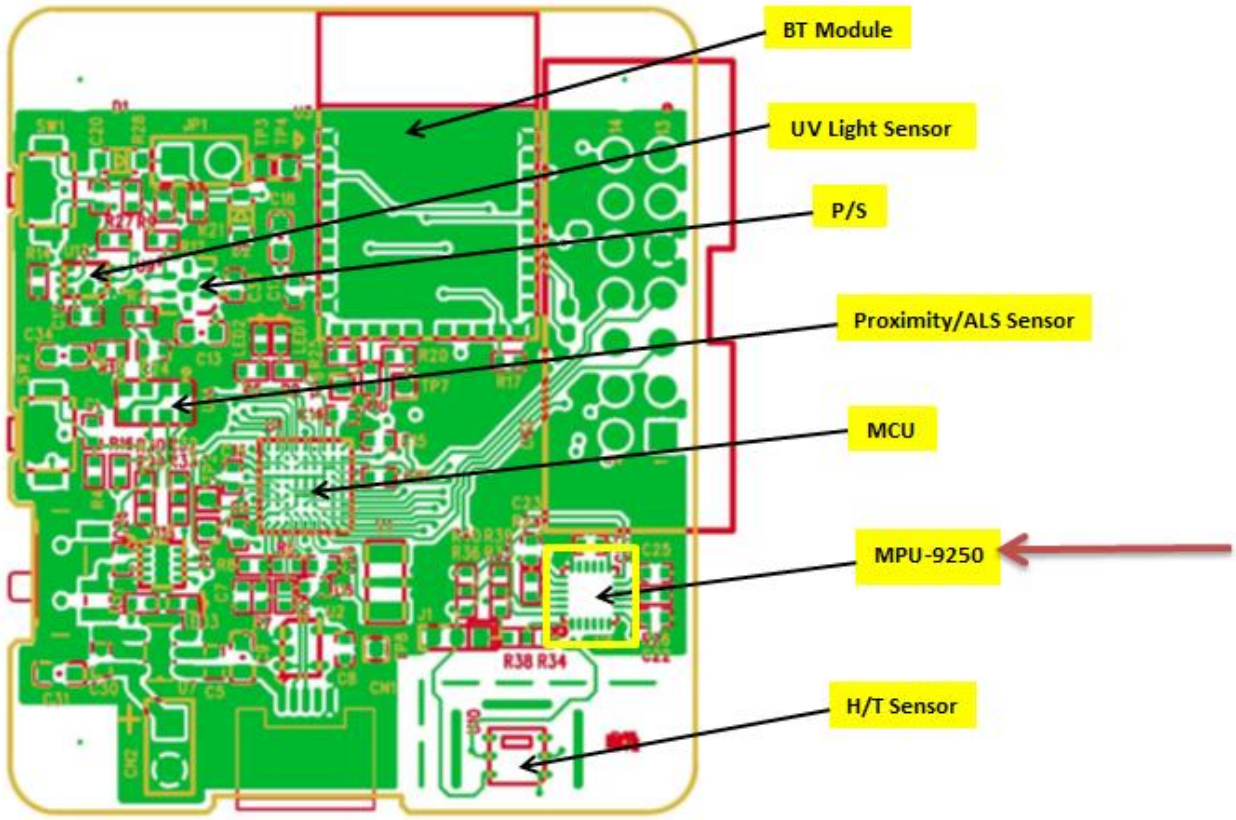
Avoid Connectors Directly Behind the Board

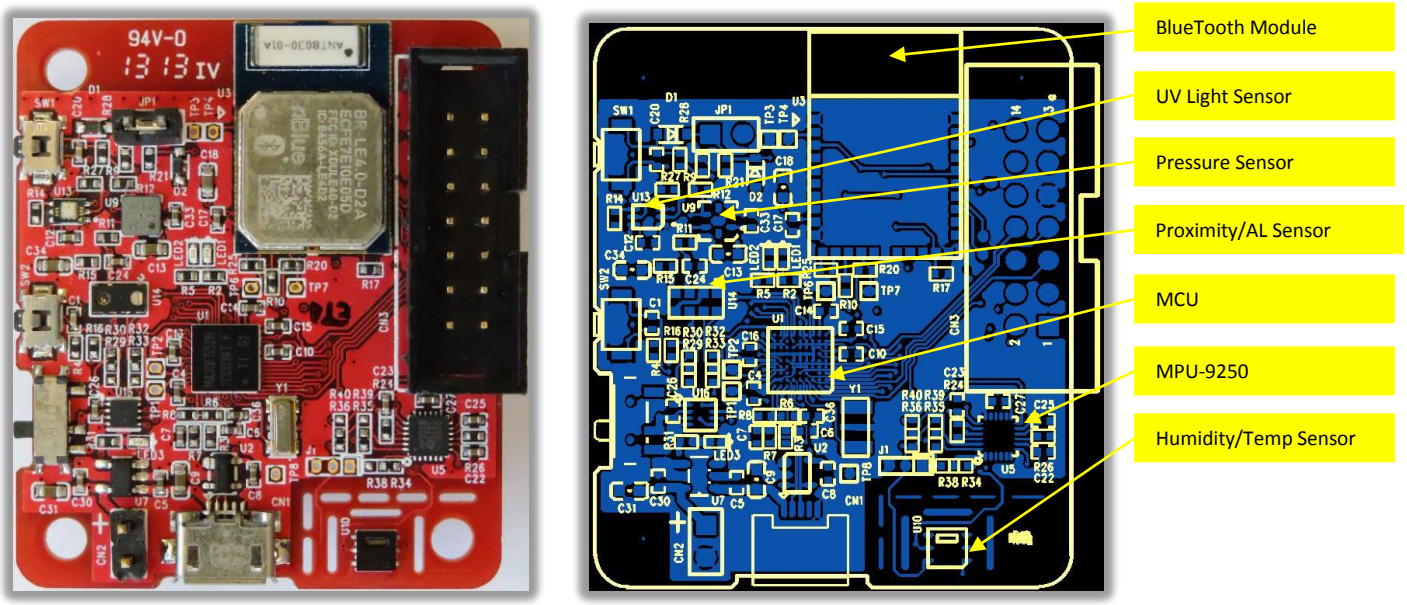
1.3 THERMAL REQUIREMENTS

For InvenSense MPU devices, software-based temperature compensation is available. However, variations in device temperature may cause changes in sensor accuracy and should be avoided. Care should be taken for placement of the MPU relative to heat sources, which may include processors, power management circuitry, or other high-current carrying devices. The temperature gradient across the board should be minimized for best results.

1.4 EXAMPLE: CA-SDK

The Contextual Awareness System Development Kit (CA-SDK) combines nine sensors in a compact, 1.71 inch x 1.46 inch space. Designing for a small space with high component density proves to be an obvious challenge, including accommodating all suggested PCB/layout recommendations for each sensor. Using the Humidity/Temperature (H/T) sensor on the lower right of the board as an example, it requires physical slots in the PCB to isolate temperature impacts from surrounding components to transfer to the PCB. Without these slots, the actual ambient temperature measurement by the H/T sensor would be falsified, as it would pick up heat from other transferring components.



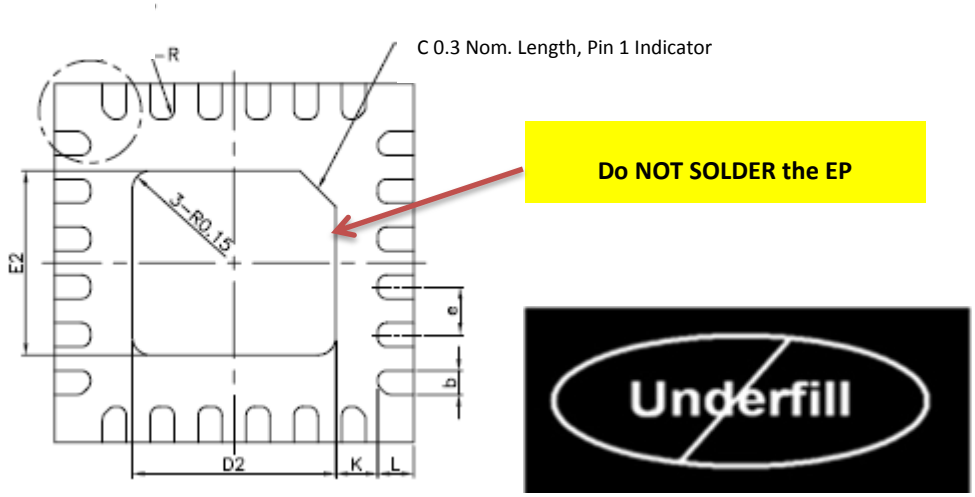


Another good example is the 9-axis motion sensor, MPU-9250, which is situated in a location where there is likely the least amount of board stress.

1.5 EXPOSED PAD REQUIREMENTS

PCB land patterns are defined within the product specification document and should be followed closely. The exposed /center pad (EP) for MPU devices is a no connect (NC) pad. To avoid package stress, do not solder the EP to the PCB. The EP is not used for thermal relief or improved noise performance, and should not be soldered to the PCB. Note that there is no electrical connection between the EP and the CMOS portion of the sensor.

It is strongly recommended to define a keep-out layer beneath the MPU, and not place any trace, fill, or via array on the top layer under the exposed pad, as described in the figure below.



SYMBOLS	DESCRPTION	DIMENSIONS IN "MM"		
		MIN	NOM	MAX
D2	Exposed Pad (EP) Width	1.65	1.70	1.75
E2	Exposed Pad (EP) Length	1.49	1.54	1.59
K	Lead/Pad to EP Space	-	0.35 REF	-
L	Lead/Pad Length	0.25	0.30	0.35
R	Lead/Pad Corner Radius	0.08	REF	-
b	Lead Finger/Pad Width	0.15	0.20	0.25
e	Lead Finger-to-Lead Finger/Pad-to-Pad Pitch	-	0.40	-

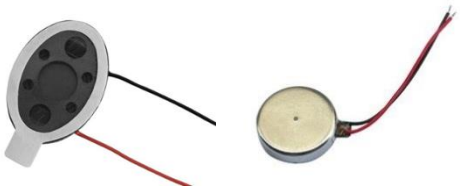
Exposed Pad (EP) Requirements

Except for the EP, a solder mask opening is required for all pin footprints. All pins should be soldered to the board to reduce uneven assembly stress, and the solder paste stencil should not have an opening for the exposed pad to prevent stress and pitch misalignment.

1.6 NOISE SOURCES

Physical noise sources can cause unnecessary vibration and contaminate the data on the sensor output. The MPU should be mounted in a rigid location with minimal external vibration.

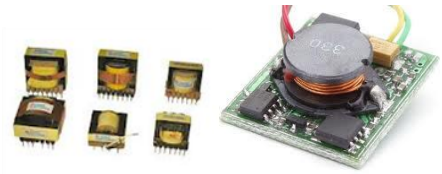
Moving parts cause vibration and are not intended to be measured through the motion sensor, such as speakers, vibration/haptic motors, buttons, etc.



Speaker and Tactile Vibrations can be Interpreted as Noise by the MPU

Active signals may harmonically couple with the gyro MEMS structure, compromising gyro responses. InvenSense MPU gyroscopic sensors operate at drive frequencies: X = 33+/-3 kHz, Y = 30+/-3 kHz, and Z = 27+/-3 kHz. To avoid harmonic coupling, do not route active signals directly below or near the package. For best performance results, design a ground plane under the EP to reduce PCB signal noise. If the MPU device is stacked under an adjacent PCB board, take measures to design a ground plane that shields the MPU from the adjacent PCB.

Electrical sources, such as a switched-mode power supply (SMPS) shown below, can cause high frequency vibration. SMPS with switching noise below 150 kHz (including Harmonics) can reduce the motion sensor's performance.



Switched-Mode Power Supply Circuitry to Avoid

OVERVIEW

As stated in the previous sections, sensor data will be affected by the location of the device and its surrounding components. InvenSense recommends to customers to contact their local InvenSense support team when the need to characterize devices using InvenSense MPUs arises.

REVISION HISTORY

REVISION DATE	REV NUMBER	DESCRIPTION
10/07/2014	1.0	Initial Release

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