Pressure Sensor PCB Design Guidelines

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1 PURPOSE AND SCOPE

This document provides high-level placement and layout guidelines for InvenSense pressure sensors. Being a MEMS device, ICP-101xx contains mechanical moving parts within the package, and as a result, proper layout is crucial for InvenSense pressure sensors to ensure the highest performance in a finished product. For a schematic and layout assessment of your design, including placement, please contact InvenSense.

2 GENERAL DESCRIPTION OF INVENSENSE PRESSURE SENSORS

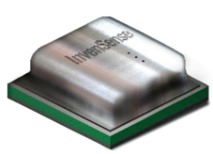
The ICP-101xx pressure sensor family is based on MEMS capacitive technology, which provides ultra-low noise at lowest power, enabling industry-leading relative accuracy, sensor throughput, and temperature stability. The pressure sensor can measure pressure differences with an accuracy of ±1 Pa, an accuracy enabling altitude measurement differentials as small as 8.5 cm, less than the height of a single stair step.

Consuming only 1.3 µA @1 Hz, the ICP-101xx is ideally suited for mobile phones, wearable fitness monitoring, drones, and battery-powered IoT. The ICP-101xx offers an industry leading temperature coefficient offset of ±0.5 Pa/°C. The combination of high accuracy, low power, temperature stability, waterproofing in a small footprint enables higher performance barometric pressure sensing for sports activity identification, mobile indoor/outdoor navigation, and altitude-hold in drones.

2.1 DEVICE INFORMATION

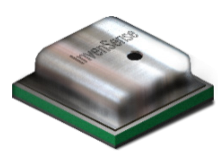
PART NUMBER	PACKAGE	LID OPENING
ICP-10100	2x2x0.72 mm LGA-10L	3-Hole, IPx8: 1.5m Waterproof
ICP-10101 / ICP-10114	2x2x0.72 mm LGA-10L	1-Hole
ICP-10110	2x2.5x0.92 mm LGA-8L	3-Hole, IPx8: 1.5m Waterproof
ICP-10111 / ICP-10113	2x2.5x0.92 mm LGA-8L	1-Hole
ICP-10125	3.55x3.55x1.45 mm HTCC-10L	Gel filled HTCC package with machined lid; IPx8 waterproofing to 10 ATM

Table 1. Device information



3-Hole IPx8 Lid Opening

ICP-10100/ICP-10110/ICP-10114



1-Hole Lid Opening

ICP-10101/ICP-10111/ICP-10113

Gel filled HTCC package with machined lid

ICP-10125

Figure 1. Device information

3 PRESSURE SENSOR DESIGN GUIDELINES

3.1 SENSOR PLACEMENT AND PACKAGE STRESS

InvenSense MEMS pressure sensors are mechanical devices and are affected by package stress. Bending in the PCB caused by mounting locations, screw holes, or misalignment will transfer board stress to the package and can alter the output of the pressure sensor, or in extreme cases, may even damage the MEMS structure.

The pressure sensor should be placed in a location where there will be minimal board stress. Typically, this is away from any fixed mounting locations, screw holes, 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 the areas which have the least internal stress, through static or finite element analysis.

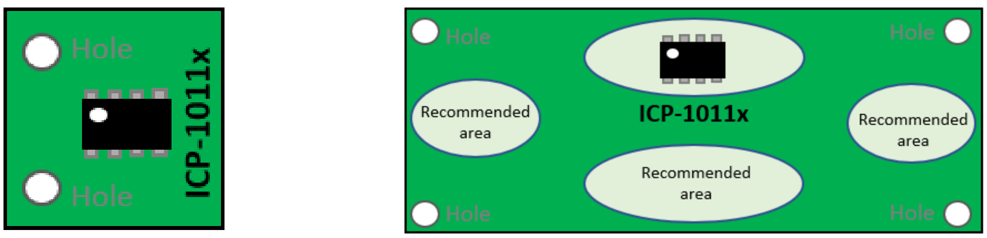


Figure 2. Improper (left) and proper (right) placement of pressure sensor relative to mounting holes

Package stress can also be introduced from thermal sources during soldering or reflow processes. Uneven thermal expansion and cooling during the assembly process introduces this stress. It is recommended not to exceed the conditions in the reflow diagram provided within the device's Product Specification document. This diagram represents maximum conditions required for component reliability testing. Typical lead-free reflow solder processing is conducted between 235°C and 260°C.

Hand soldering the pressure sensor is not recommended, as the uneven application of heat during soldering may introduce an undesired bias offset in the part. Do not place any component pads or vias within 2 mm of the package land area to ensure even cooling and minimal mechanical coupling between the pressure sensor and adjacent devices.

A standard PCB thickness of ~63 mils or 1.57 mm is fine for InvenSense pressure sensors, but thinner boards (<1 mm thick) are recommended to reduce PCB stress. Use FR4 PCBs with TG above the application/process temperature. Flex PCBs can also be used if the sensor placement is on the flat surface of the PCB or with a stiffener added underneath the sensor.

Any epoxy-sealed parts on the board should be placed away from the pressure sensor such that the epoxy resin does not come in contact with the package. Curing shrinkage or uneven thermal expansion may introduce package stress and adversely affect the sensor output.

Do not place connectors or test points for Pogo pins on the PCB surface below the pressure sensor location, as in Figure 2. Deflection and shock from snapping the connectors and pressure from the Pogo pin during functional test on a production line may damage the MEMS part. Avoid PCB bending during enclosure mounting.

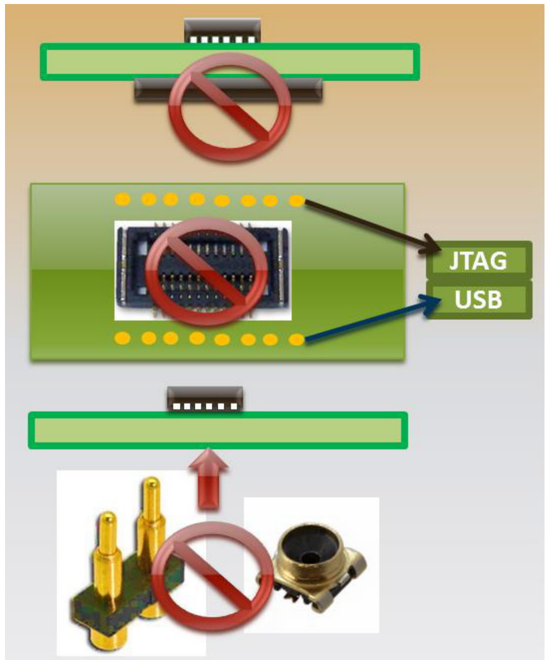


Figure 3. Avoid connectors on the opposite side of the board directly behind the pressure sensor

Additional considerations to avoid pressure sensor damage in component placement:

- Avoid any source of external point load directly below or above the pressure sensor as this can cause MEMS breakage
- Avoid shock or impact in manufacturing flow or system assembly process

3.2 THERMAL REQUIREMENTS

The internal measurement of the pressure sensor is dependent on temperature. For InvenSense pressure sensors, temperature compensation is performed in the factory. However, avoid variations in device temperature because they may cause changes in sensor accuracy. Take care in the placement of the pressure sensor relative to heat sources, which may include processors, power management circuitry, video ICs, MOSFETS, or other high current devices. Placement of these devices should be avoided in close proximity to the pressure sensor, or insulation techniques must be adapted as shown Figure 3. Minimize the temperature gradient across the pressure sensor for best results. InvenSense recommends using separate ground planes for pressure sensor and heat generating circuits. Physical slots may be applied in the PCB around the pressure sensor to reduce PCB heat conduction to the sensor itself.

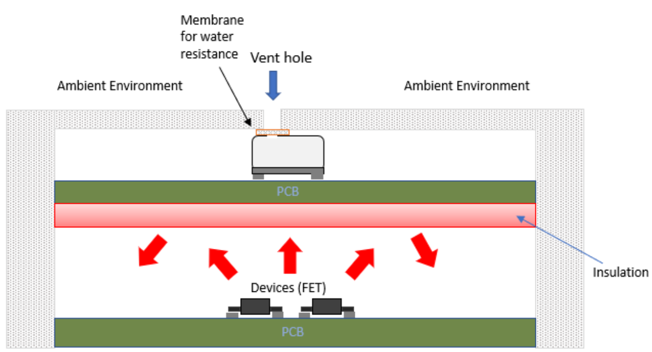


Figure 4. Thermal Isolation

Placing heat generating devices far away from the pressure sensor and adding a thermal insulator on the PCB is recommended to avoid thermal gradients from reaching the pressure sensor.

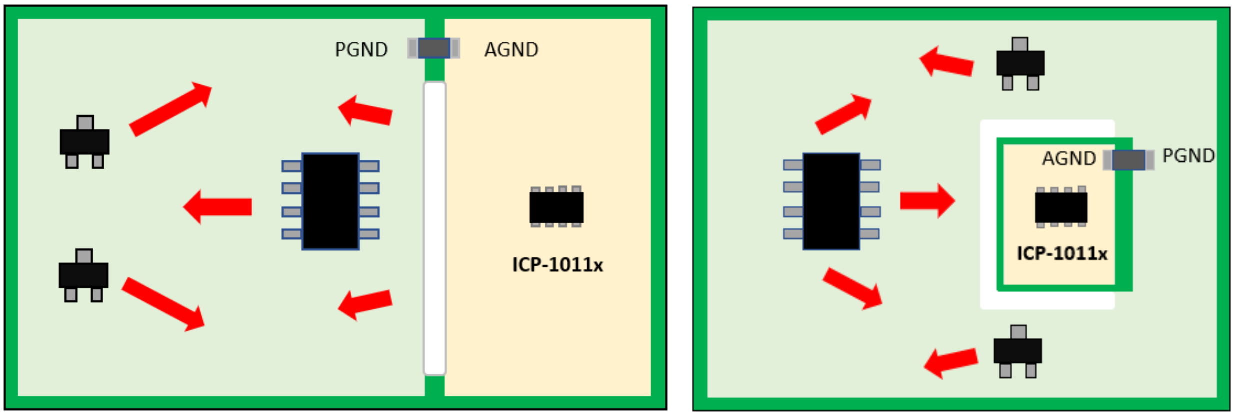


Figure 5. PCB Slot and GND Plane Isolation examples

3.3 SMT PROCESS EFFECTS

Pressure sensor die and adhesive materials tend to relax inside the package after going through solder reflow process due to high temperature exposure. Therefore, allowing sensors to relax for 5 days after reflow process if sensor absolute accuracy post SMT is important to the application is recommended.

All system-level calibration should be done after relaxation period, if required for the application.

3.4 PCB TRACE LAYOUT

Do not route any traces underneath the pressure sensor on the layer that it is placed on. Traces connected to pads should be as symmetrical as possible. Symmetry and balance for pad traces will improve component self-alignment and lead to better control of solder paste reduction after the reflow process. For high speed I^2C interfaces, all clock and data traces should be routed with the same length and away from the serial bus or other highspeed traces. Power traces should also be routed away from high speed signals and kept 10 mil or thicker for a 0.5 oz copper PCB. Provide a solid ground return path with traces 10 mil or thicker for a 0.5 oz copper PCB.

Place vias outside of the solder area and near the pad. Do not place vias within the pad outline as vias and their related plating materials can contribute to non-uniform mechanical package stress.

Removing the solder mask from under the pressure sensor is recommended. Solder flux and/or debris can get trapped under the pressure sensor, and this may cause stress on the ceramic package and impact performance of the pressure sensor. To reduce the risk of solder flux/debris impact on the output of the pressure sensor, remove the solder mask from under the pressure sensor to increase the distance between the bottom of the pressure sensor and the top of the board. Maintain a minimum clearance of 50 µm between component and PCB to avoid physical contact between the two. Solder mask opening should be larger than the PCB land pattern. Also, solder height uniformity should be maintained within 20%.

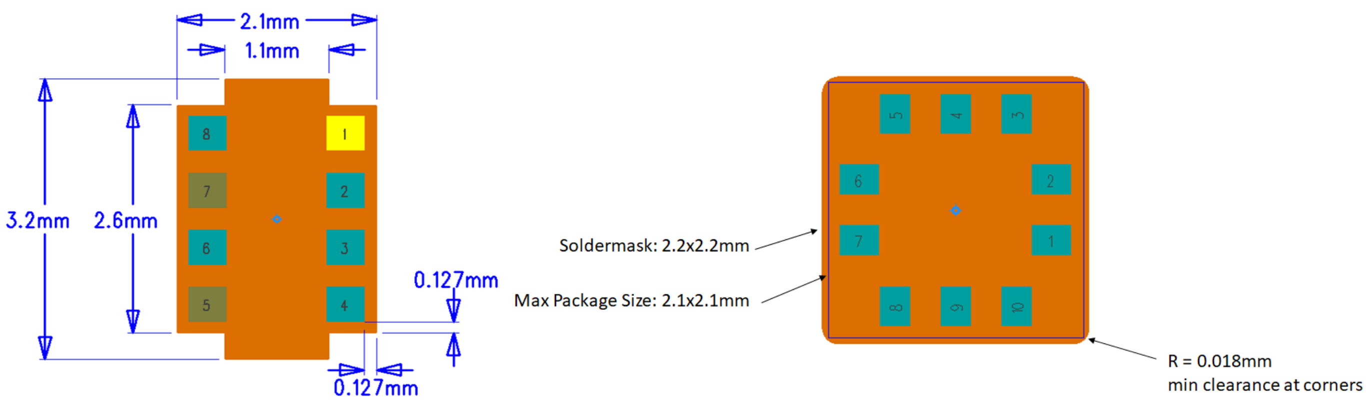


Figure 6. Recommended Solder Mask Keep-Out Area for ICP-1011x (left) and ICP-1010x (right)

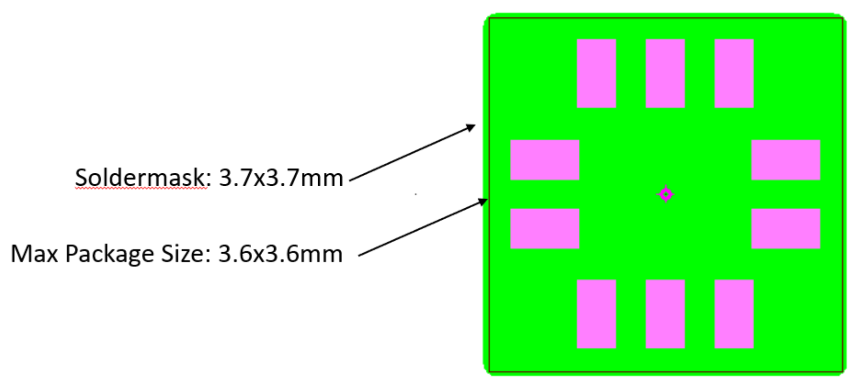
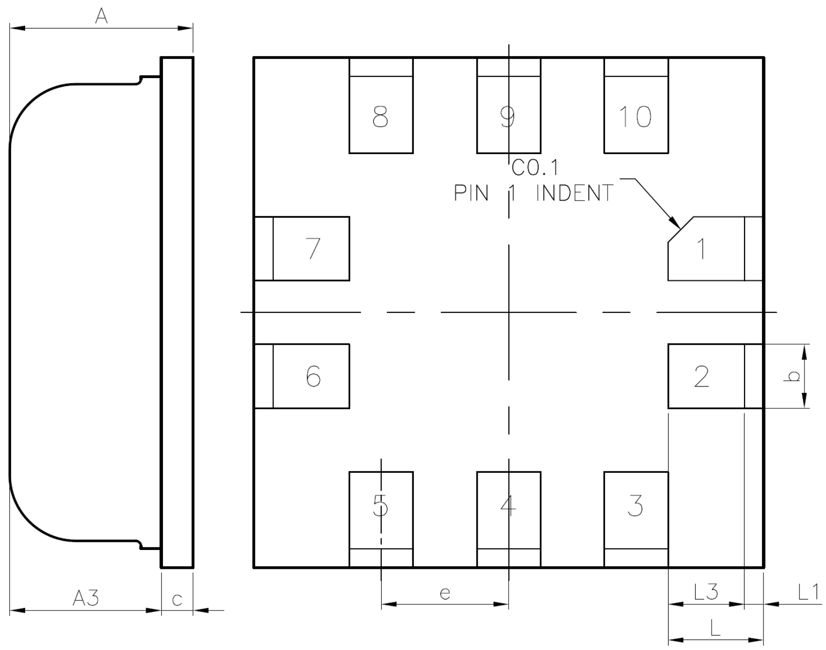


Figure 7. Recommended Solder Mask Keep-Out Area for ICP-10125

The PCB Layout Diagram and recommended pad size is provided within the pressure sensor device datasheet documents. Figure 7 below provides a package outline drawing and an example of a PCB footprint from ICP-101xx datasheet. Please use the most recent revision of the datasheet for the device that you are working with.

3.5 PKG DRAWING/RECOMMENDED FOOTPRINT

Package dimensions for the ICP-10100, ICP-10101 and ICP-10114:



Bottom View: ICP-10100/ICP-10101/ICP-10114

Figure 8. ICP-10100/ICP-10101/ICP-10114 package diagrams

SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN.	NOM.	MAX.
A	0.64	0.72	0.800
A3	---	0.595 REF.	---
b	---	0.25	---
c	---	0.125 REF.	---
D	1.90	2.00	2.10
D1	---	1.85	---
E	1.90	2.00	2.10
E1	---	1.85	---
e	---	0.50	---
L	0.275	0.375	0.400
L1	0.025	0.075	0.100
L3	0.250	0.300	0.325

Table 2. ICP-10100/ICP-10101/ICP-10114 package dimensions

Recommended PCB land pattern for the ICP-10100, ICP-10101 and ICP-10114:

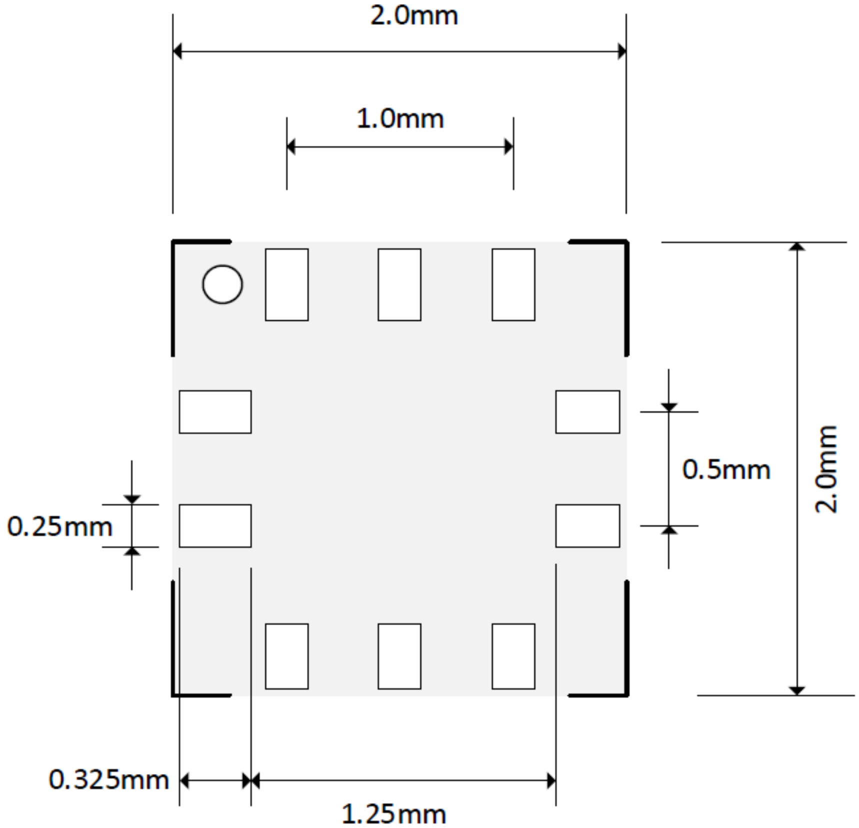
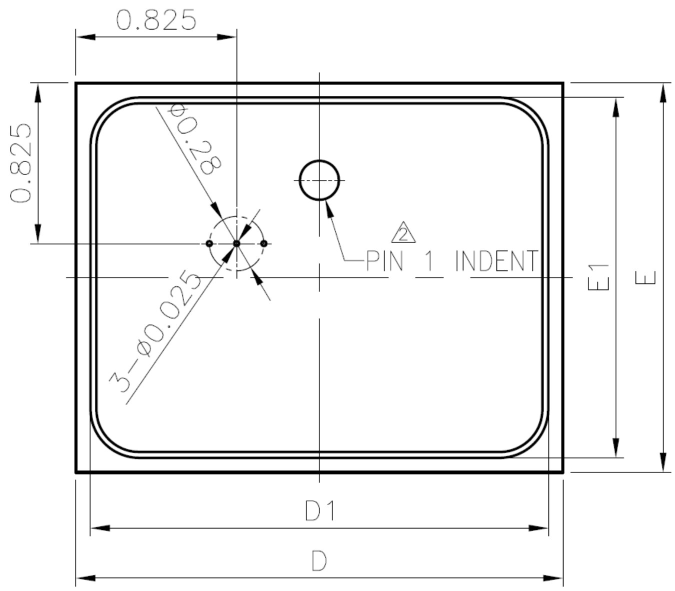
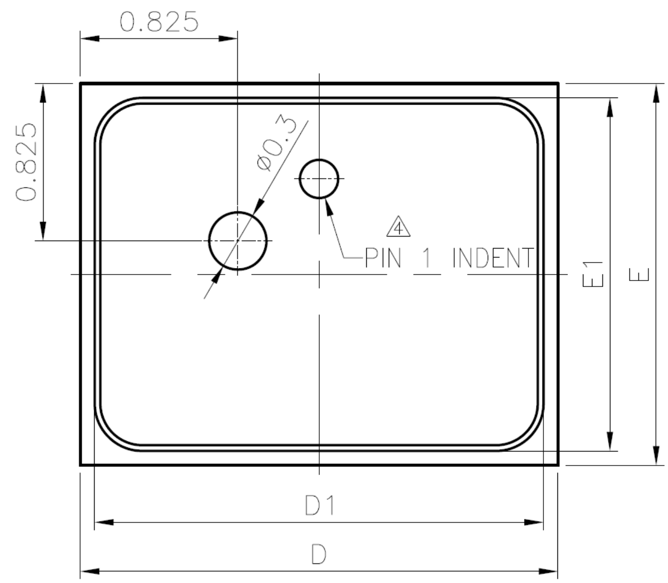


Figure 9. ICP-10100, ICP-10101 & ICP-10114 recommended PCB land pattern

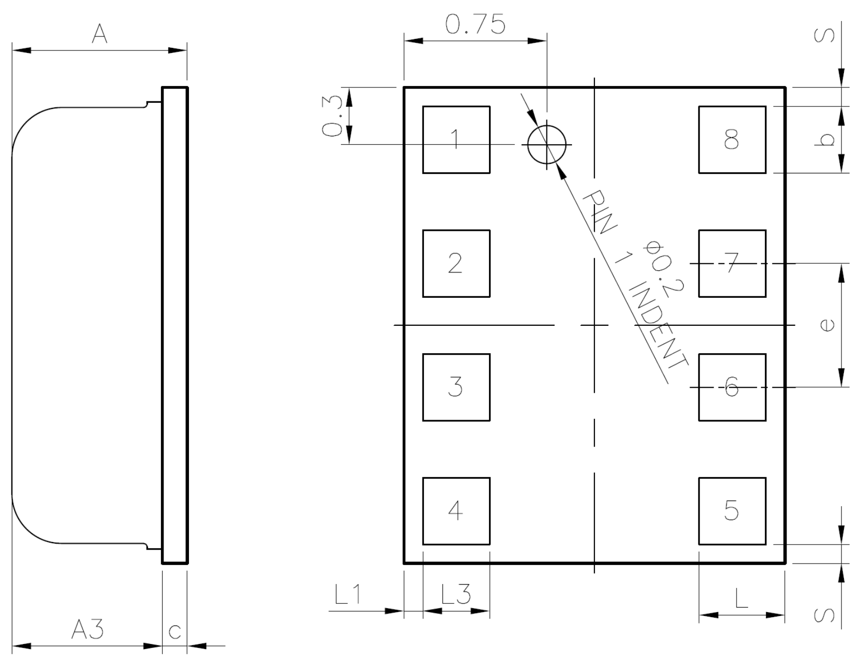
Package dimensions for the ICP-10110, ICP-10111 and ICP-10113:



Top View: ICP-10110



Top View: ICP-10111



Bottom View: ICP-10110/ICP-10111/ICP-10113

Figure 10. ICP-10110/ICP-10111/ICP-10113 package diagrams

SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN.	NOM.	MAX.
A	0.84	0.92	1.00
A3	---	0.79 REF.	---
b	---	0.35	---
c	---	0.13 REF.	---
E	1.90	2.00	2.10
E1	---	1.85	---
D	2.40	2.50	2.60
D1	---	2.35	---
e	---	0.65	---
L	0.35	0.45	0.55
L1	0.05	0.10	0.15
L3	0.30	0.35	0.40
S	---	0.10	---

Table 3. ICP-10110/ICP-10111/ICP-10113 package dimensions

Recommended PCB land pattern for the ICP-10110, ICP-10111, and ICP-10113:

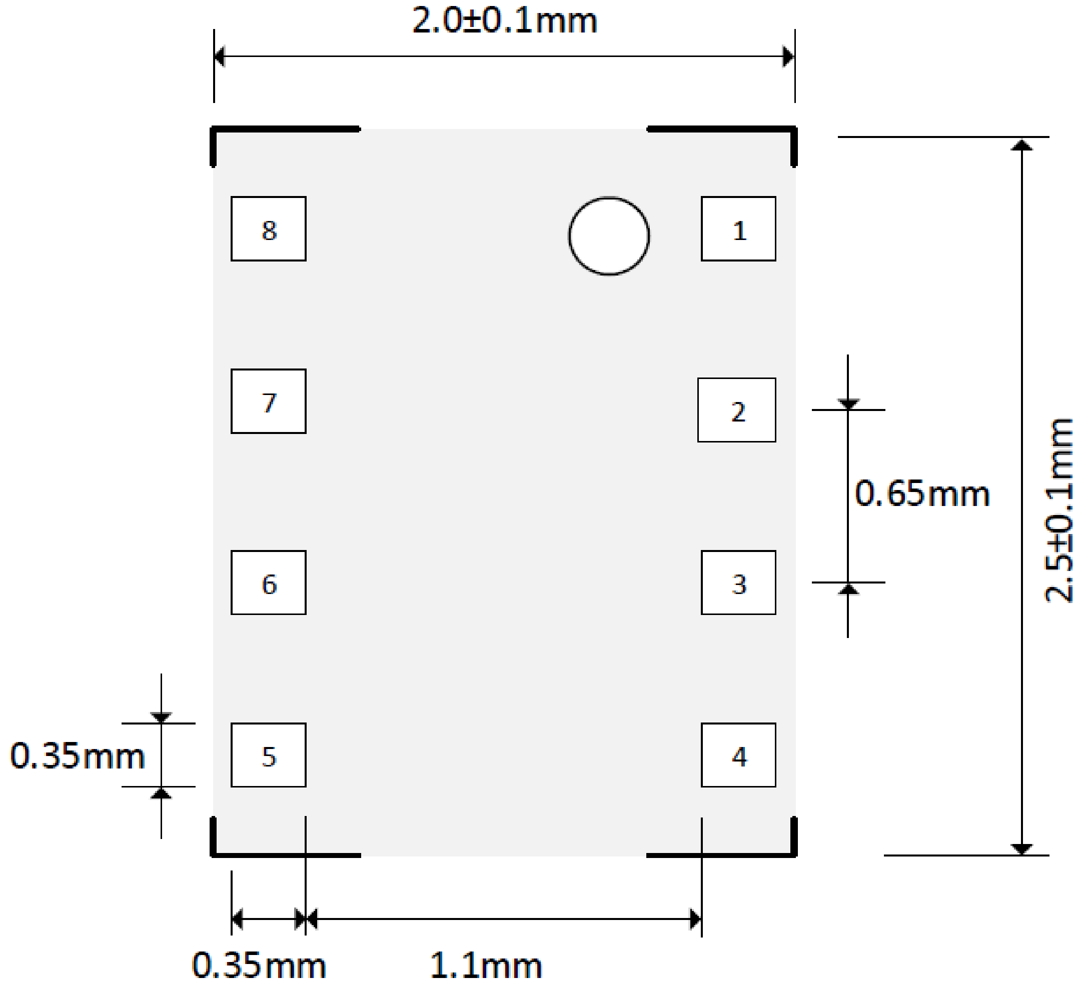
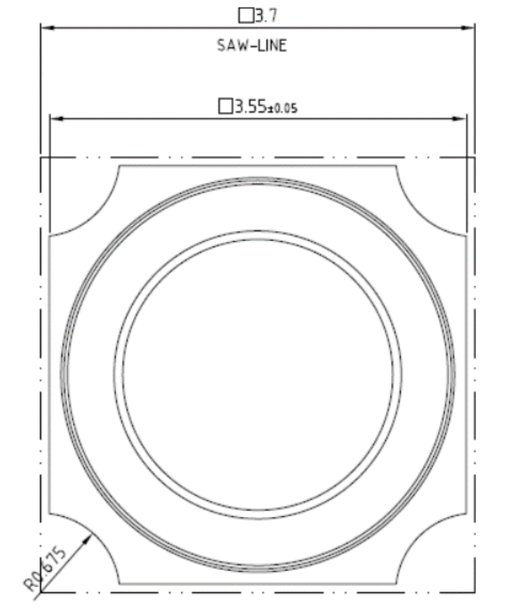
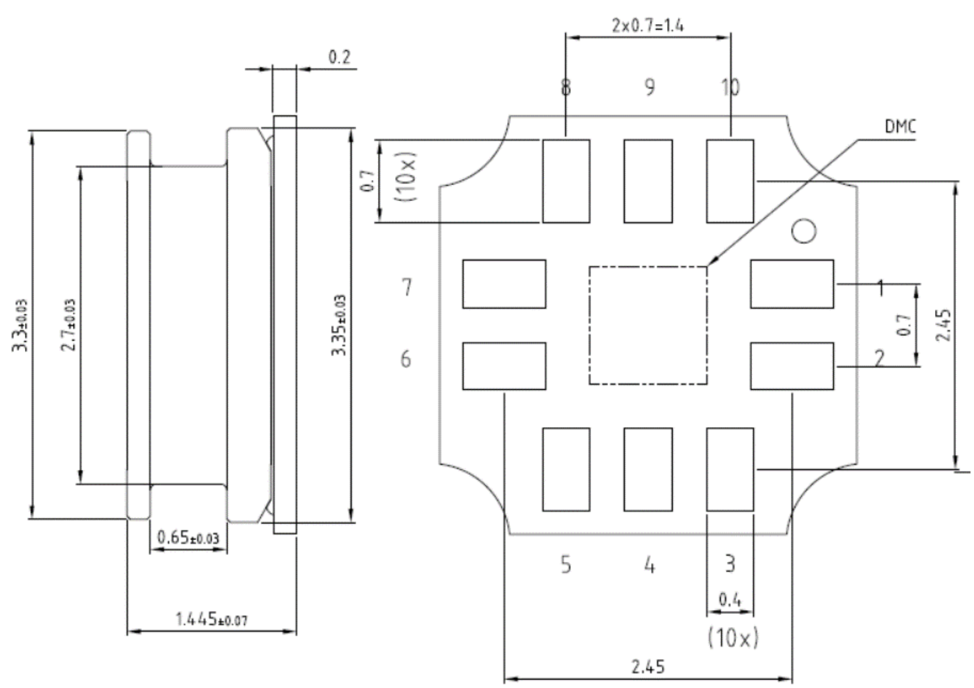


Figure 11. ICP-10110/ICP-10111/ICP-10113 recommended PCB land pattern

Package dimensions for the ICP-10125:



Top View



Side & Bottom View

Figure 12. ICP-10125 package diagram

Recommended PCB land pattern for the ICP-10125:

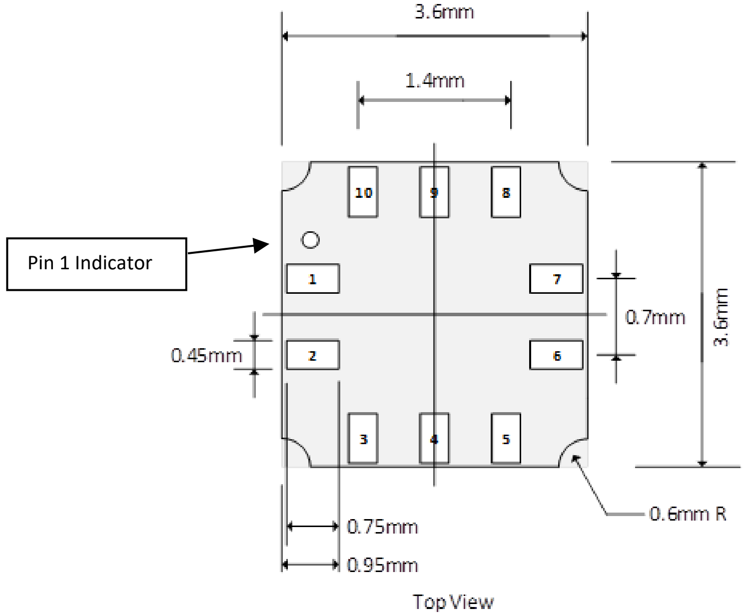


Figure 13. ICP-10125 recommended PCB land pattern

3.6 NOISE SOURCES

Physical noise sources can cause unnecessary vibration and contaminate the desired measurement. The pressure sensor should be mounted in a rigid location, which will have minimal external vibration. Moving parts which cause vibration and are not intended to be measured, such as speakers, vibration/haptic motors, buttons, etc. (Figure 10), should be mechanically isolated from the pressure sensor. InvenSense recommends placing any vibration sources as far away as possible from the pressure sensor. However, if there is limited board space and placement options are limited, the recommended distance is ≥5 mm away from the MEMS device. If placement is uncertain, consult with the local the FAE to provide a more detailed analysis.

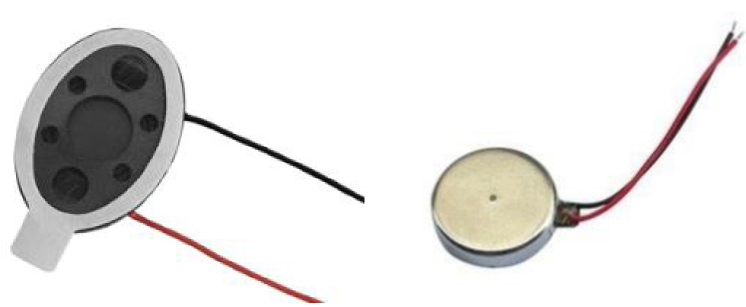


Figure 14. Speaker and tactile vibrations can be interpreted as noise by the pressure sensor

4 ANALYZING SENSOR DATA ISSUES DUE TO SENSOR PLACEMENT

4.1 OVERVIEW

As stated in the previous sections, sensor data will be affected by the location of the device and its surrounding components. This section describes the tools that can be used to analyze the sensor data and to characterize and correct issues of package stress, noise, and thermal conditions. InvenSense recommends our customers contact their local InvenSense support team when the need to characterize devices using InvenSense pressure sensors arises.

4.2 ANALYZING SENSOR DATA

InvenSense Sensor Test Tools

InvenSense software releases are packaged with test tools that provide the capability to collect sensor data at run-time. Using the test tools provided by InvenSense to first verify if the sensor is responding correctly and the sensor data is within spec is recommended. Analyzing run-time sensor data will help in detecting problems with sensor performance.

Sensor Data Collection

InvenSense software has the capability to log sensor data to a file during device operation. The software provides the capability to collect raw data. This gives us the option to replay the sensor data later and detect any errors due to placement issues. Sensor data collected in this fashion can be post-processed using mathematical analysis software to detect the effects of package stress, noise, and thermal conditions, and assist in mitigation of those effects.

5 QUICK REFERENCE

This section is added a brief listing of PCB design guidelines which may be used in review when defining device placement. This list is not complete and does not reflects all information provided within this document.

DESCRIPTION	ISSUE	CORRECTIVE ACTION
Package Stress	Increased sensor offsets	Place part in a location of minimal PCB stress
Thermal Stress	Temperature variation of data	Avoid a thermal gradient across the part

Table 4. Quick reference

6 REVISION HISTORY

REVISION DATE	REVISION	DESCRIPTION
02/06/2018	1.0	Initial Draft
03/04/2020	1.1	Added ICP-10113 and ICP-10125. Updated PCB Layout Guidelines.
05/01/2020	1.2	Updated placement figures for thermal isolation and routing guidelines
06/12/2020	1.3	Updated PCB Landing Footprints for 2x2 mm and 2x2.5 mm packages (Figure 9 and Figure 11)
12/16/2020	1.4	Updated section 3.3

Compliance Declaration Disclaimer

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