

TDK IMU Devices PCB Design Guidelines For ICM-42607x and ICM-42670x Products

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1 INTRODUCTION

This document provides high-level placement and layout guidelines for TDK IMU devices, which may incorporate a combination of gyroscope and accelerometer. Each sensor has specific requirements to ensure the highest performance in a finished product. For a layout assessment of your design, including placement and estimated temperature disturbances, please contact TDK.

TDK IMU Devices discussed in this document, such as the ICM-42607x and ICM-42670x products, consist of 3-axis MEMS gyroscopes and 3-axis MEMS accelerometers.

Please refer to MEMS Handling Application Note (AN-IVS-0002A-00) for additional PCB design guidelines.

2 ACCELEROMETER AND GYROSCOPE DESIGN GUIDELINES

2.1. PACKAGE STRESS

MEMS accelerometer and gyroscope motion processors are mechanical devices and are affected by package stress. Bending the PCB due to mounting locations, screw holes, or PCB overheating will transfer board stress to the package and can alter the output of the IMU, or in extreme cases, may even damage the MEMS structure.

The IMU 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 the areas that have the least internal stress, through static or finite element analysis.

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. Exceeding the conditions in the reflow diagram provided in the MEMS Handling Application Note (AN-IVS-0002A-00) is not recommended.

Hand soldering the IMU is not recommended, as the uneven application of heat during soldering may introduce an undesired bias offset in the part. Uneven solder on each pin, may also lead to package stress that may affect the data output. Do not place any component pads or vias close to the package land area, to ensure even cooling and minimal mechanical coupling between the IMU and adjacent devices.

Epoxy-seal can bring mechanical stress to IMU. It is prohibited. Any epoxy-sealed parts on the board should be placed away from the IMU such that the epoxy resin does not contact with the package. Curing shrinkage or uneven thermal expansion may introduce package stress and adversely affect the sensor output.

Keep the IMU away from the edge of the PCB or bridges for PCB separation by router (Figure 1). Deflection from a routing drill or saw can damage the MEMS device. Similarly, dull router bits and saw blades can cause excessive mechanical vibration, which should be avoided. Do not snap apart panelized boards, since snapping apart the PCB boards may introduce severe bending forces and mechanical shock, which may damage the IMU.

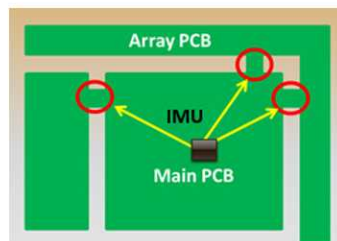


Figure 1. Panelized PCB Bridges

Do not place connectors or test points for Pogo pins on the PCB surface below the IMU 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.



Figure 2. Avoid connectors directly behind the board

2.2. SHOCK AND VIBRATION

The MEMS device can be damaged when shock level is over datasheet specification. Shock or impact should be avoided in manufacturing flow or device assembly process.

When powered on, the ICM-42607x and ICM-42670x can withstand up to 4,500g shock.

During the design phase the IMU should be placed in the location where it will receive the least amount of shock possible. Various measurements can be taken to reduce shock transfer, such as location of the IMU, shock absorbing washers/gaskets for screw points, and shock absorbing foam pads. From a systems level, the placement of other PCBs/Modules/Sub-systems should be placed away from the top/bottom of where the IMU is located, to prevent possible contact.

If there are concerns regarding a system level design, the systems should be tested with the IMU as a whole system or tested beforehand and double checked to ensure there is no damage to the IMU.

MEMS gyro and accel have multiple internal resonance points. System level designs should avoid vibrations with the same frequency of IMU resonances. Please consult TDK technical support for each device's resonant frequency.

The ICM-42607x and ICM-42670x gyroscope sensors operate at drive frequencies of 25 kHz ~ 29 kHz. Any vibration within these frequency ranges will cause extra gyro noise or even damage the gyro.

The most common PCB board level vibration source is from power circuits such as a wireless charger, and buck and boost power regulation circuits. Powered devices that may generate acceleration or vibration to the MEMS structures can cause damage to MEMS devices. Examples of such components are inductors, capacitors, PMIC, haptic motors, speakers, etc.

The shock experienced from a PCB level versus device level may and will be different. In order to attain the most accurate data reading, the measurements should be taken from a PCB level as close to the IMU as possible. If there is a source of acceleration or vibration in the vicinity of the MEMS device, we recommend testing on the PCB with a vibrometer to confirm that the MEMS device is not being excited by any resonance frequency.

2.3. THERMAL REQUIREMENTS

The internal measurement of the MEMS sensor is dependent on temperature. For TDK IMU devices, temperature compensation is available. However, variations in device temperature may cause changes in sensor accuracy and should be avoided. Consideration should be taken for placement of the IMU relative to heat sources, which may

include processors, power management circuitry, or high current devices. The temperature gradient across the IMU should be minimized for best results.

Any uneven temperature between the top and bottom of the IMU can create out of spec sensor offset. Any heat shock (sudden temperature change) can generate unwanted big sensor output. Avoid placing a big heat variation part on the bottom side of the IMU. For example, a wifi chip, AP processor, and so on.

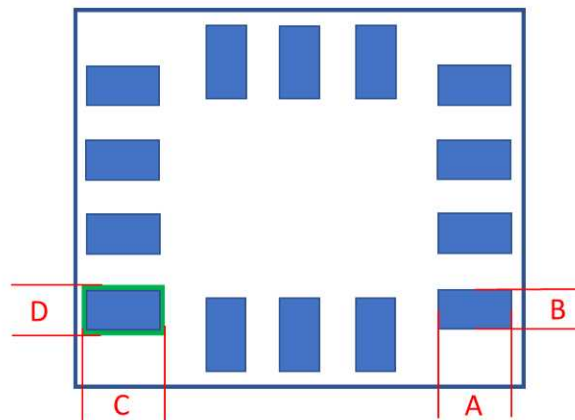
2.4. PCB TRACE LAYOUT

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 interfaces, such as I²C, I3C and SPI, all clock and data traces should be routed with the same length, and away from other high-speed traces. Power traces should also be routed away from high speed signals.

We recommend 6mil or thicker traces for a 0.5 oz copper PCB. Provide a solid ground return path, with traces 10mil or thicker for a 0.5oz copper PCB. Do not use small vias for power and GND traces.

The PCB Layout Diagram and recommended pad size is provided within the IMU device datasheets. Figure 3 below provides an example of a PCB Layout Diagram for ICM-42607x and ICM-42670x products. Please use the most recent revision of the datasheet for the device that you are working with. Dummy traces can be added on unused pins.



- A = PCB land length = LGA solder pin length
- B = PCB land width = LGA solder pin width
- C = Solder mask opening length = PCB land length + 0.1 mm
- D = Solder mask opening width = PCB land width + 0.1 mm

Figure 3. Recommended PCB Layout footprint for the ICM-42607x and ICM-42670x products

Trace, via, and filled copper are not allowed under the IMU chip directly, as they can cause elevation changes.

Do not place vias within the pad outline because vias and their related plating materials can contribute to an orientation offset and non-uniform mechanical package stress.

NC (No Connect) pins should be soldered to the board for mechanical stability, but those pads on the board should not be connected electrically.

2.5. FLEX PCB

Flex PCB should be avoided for MEMS sensor part. If flex PCB must be used, a stiffner must be provided on the

opposite side of the flex PCB. The thickness of the stiffner depends on its material. The goal is to prevent the flex PCB bending, which will generate mechanical stress to MEMS.

2.6. NOISE SOURCES

Physical noise sources can cause unnecessary vibration and contaminate the desired measurement. The IMU should be mounted in a rigid location, which will have minimal external vibration.

Moving parts that cause vibration and are not intended to be measured, such as speakers, vibration/haptic motors, buttons, etc. (Figure 4), should be mechanically isolated from the IMU.

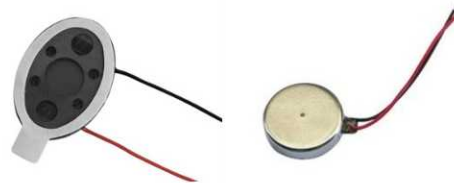


Figure 4. Speaker and Tactile Vibrations can be interpreted as Noise by the IMU

Active signals may harmonically couple with the gyro MEMS devices, compromising gyro response. TDK IMU gyroscopic sensors operate at drive frequencies: 25 kHz ~ 29 kHz. To avoid harmonic coupling don't route active signals directly below or near the package. If the IMU device is stacked under an adjacent PCB board, design a ground plane to shield the IMU from the adjacent PCB.

Electrical sources, such as a switched-mode power supply (SMPS) shown in Figure 5, can cause high frequency vibration. SMPS (switched mode power supply) with switching noise below 150 kHz (including Harmonics) can reduce device performance.

As mentioned in section 2.2, in addition to unwanted IMU vibration output, the mechanic vibration can damage MEMS if the vibration frequency matches the MEMS resonant frequency.

The recommendation is to place any acceleration or vibration sources as far away as possible from MEMS devices. If placement is uncertain, consult the local FAE to provide a more detailed analysis.



Figure 5. Switched-Mode Power Supply Circuitry should be avoided

3 BOARD DESIGN AND ASSEMBLY PRECAUTIONS

3.1. MEMS HANDLING AND ASSEMBLY GUIDE

Do not clean MEMS devices in an ultrasonic bath. Ultrasonic baths can induce MEMS damage if the bath energy causes excessive drive motion through resonant frequency coupling.

Please refer to MEMS Handling Application Note (AN-IVS-0002A-00) for additional information.

3.2. GYROSCOPE SURFACE MOUNT GUIDELINES

TDK MEMS gyroscopes sense rate of rotation and mechanical stress coming from the PCB board. This board stress can be minimized by adhering to certain design rules:

When using MEMS gyroscope components in plastic package devices, PCB mounting and assembly can cause package stress. This package stress in turn can affect the output offset and its value over a wide range of temperatures. This stress is caused by the mismatch between the Coefficient of Linear Thermal Expansion (CTE) of the package material and the PCB. Care must be taken to avoid package stress due to mounting.

Traces connected to pads should be as symmetrical as possible. Maximizing symmetry and balance for pad connection will help component self-alignment and will lead to better control of solder paste reduction after reflowing.

Any material used in the surface mount assembly process of the MEMS gyroscope should be free of restricted RoHS elements or compounds. Pb-free solders should be used for assembly.

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 magnetic distortion, package stress, noise, and thermal conditions. TDK recommends contacting the local TDK support team when the need to characterize devices using TDK IMUs arises.

4.2. ANALYZING SENSOR DATA

When possible, the orientation of the device should be analyzed simultaneously, in order to characterize sensor angular accuracy.

4.2.1.1. TDK sensor test tools

TDK software releases are packaged with test tools that provide the capability to collect sensor data at run-time. Using the test tools provided by TDK 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 detect problems with sensor performance.

4.2.1.2. Third party sensor tools

Third party tools such as Microsoft's Sensor Diagnostic Tool or Traceview can be also used to collect run-time sensor data to detect problems with sensor performance. These tools provide capabilities to save the individual accelerometer and gyroscope to a comma separated (CSV) file. The CSV data can be analyzed, and sensor data can be graphed to detect placement-related problems.

4.2.1.3. Sensor data collection

TDK software has the capability to log sensor data to a file during device operation. The software provides the capability to collect raw as well as calibrated sensor 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 magnetic distortion, package stress, noise, and thermal conditions, and assist in mitigation of those effects.

5 REVISION HISTORY

REVISION DATE	REVISION	DESCRIPTION
03/01/2021	1.0	Initial release

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