Guidelines for PCB Design and Assembly with mCube Sensors

The following document is a general guideline for the PCB layout, device handling, soldering and assembly of mCube's sensors. The purpose is to minimize the stress on the package by using optimized practices and to minimize magnetic interference in the eCompass use case. Stress on the package often leads to sensor offset errors. The guidelines provided here are based on design experiments for the packages shown. They do not represent exact conditions present at real customer implementations. The information recommended here should be used as guidelines while developing an application specific solution.

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1. Device Handling

1.1 Mechanical Shock

mCube's mechanical sensor are designed to handle high-g shock events, but direct mechanical shock to the package will generate high g forces and should be avoided. SMT assembly houses should use automated assembly equipment with either plastic nozzles or nozzles with compliant (soft i.e. rubber or silicone) tips.

<u>Recommendations:</u>

- Do not use metal or ceramic nozzle tips during assembly.
  - These cause excessive g forces and therefore are NOT recommended.
- Place the sensor with minimal direct force during assembly.
  - This is achieved by optimizing the placement force control in the g-sensor library for chip shooters or IC placers.
- Place the sensor with minimum pick and place assembly speeds.
  - This is achieved by optimizing the speed settings control in the g-sensor library for chip shooters or IC placers.
- Discard mishandled sensors.
  - If the sensor is dropped from a height of 50mm or greater it should be discarded and not used.
  - Direct impact to a hard surface can also generate high g forces. The best practice is to discard any part that has been dropped.
- Handle partially finished PCB assemblies carefully.
  - Transport assemblies in shock-absorbent carriers.
  - Do not expose partial assemblies to bending, flexing or excessive shocks during product assembly.

1.2 Moisture Sensitivity Level Control (MSL)

The typical factory floor life of mCube sensors is 168 hours (1 week) at ambient conditions ≤30°C/60%RH (MSL3) with special case of WLCSP package having unlimited floor life at ambient conditions of ≤30°C/85%RH (MSL1)

Refer to **IPC/JEDEC J-STD-020D.1 "Joint Industry Standard: Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices**" and **IPC/JEDEC J-STD-033A "Joint Industry Standard: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices.**"

Recommendations:

- Store the carrier tape and reel in the dry pack unopened until required on the assembly floor.
- If the product reel has been removed from the dry pack, reseal the product reel inside the dry pack with a black protective belt to avoid crushing the carrier tape from the reel or store openly it in a controlled humidity condition.
- Store the pizza box in the vertical position.

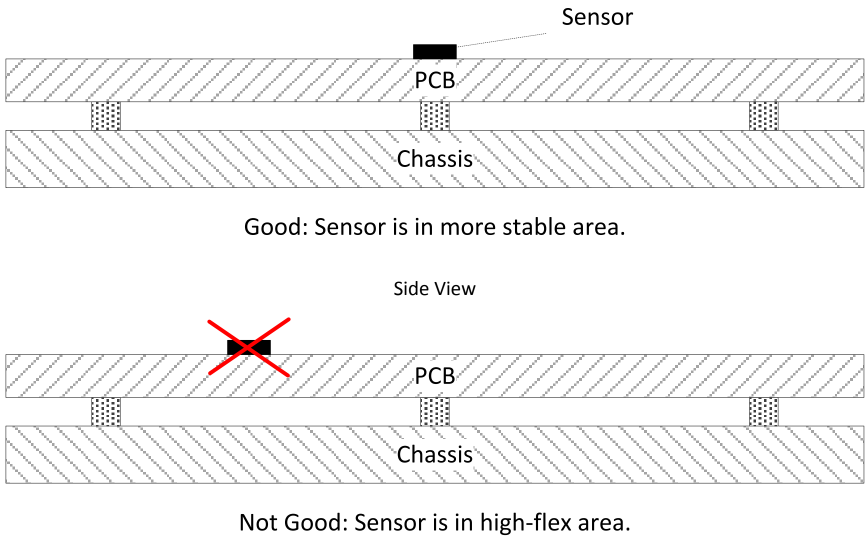
1.3 Electrostatic Discharge (ESD)

- Refer to the JEDEC standard JESD625-A "Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices" for the correct handling techniques.

2. PCB Design and Accelerometer Sensor Placement

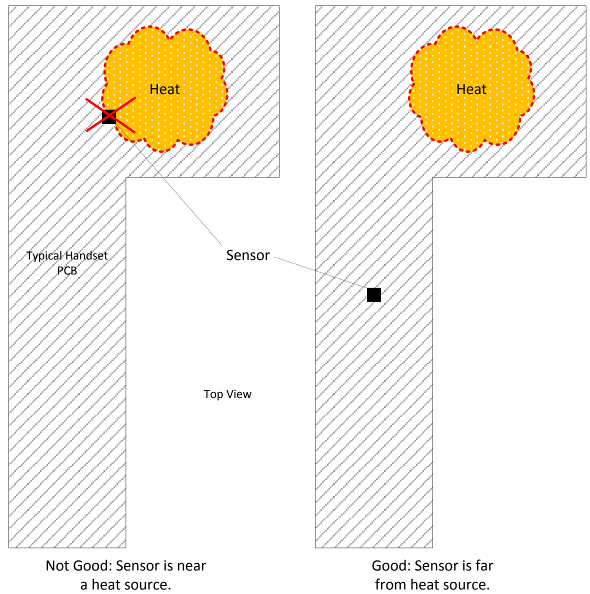
Recommendations (see Figure 1 through Figure 5):

- Use a rigid PCB material, as thick as possible.
    - A PCB thickness of 0.6mm or more is recommended.
    - Use materials with a low coefficient of thermal expansion.
- Place the sensor in a part of the PCB which is mechanically stable as depicted in Figure 1.
    - It should not be exposed to any flexing or twisting during device operation.



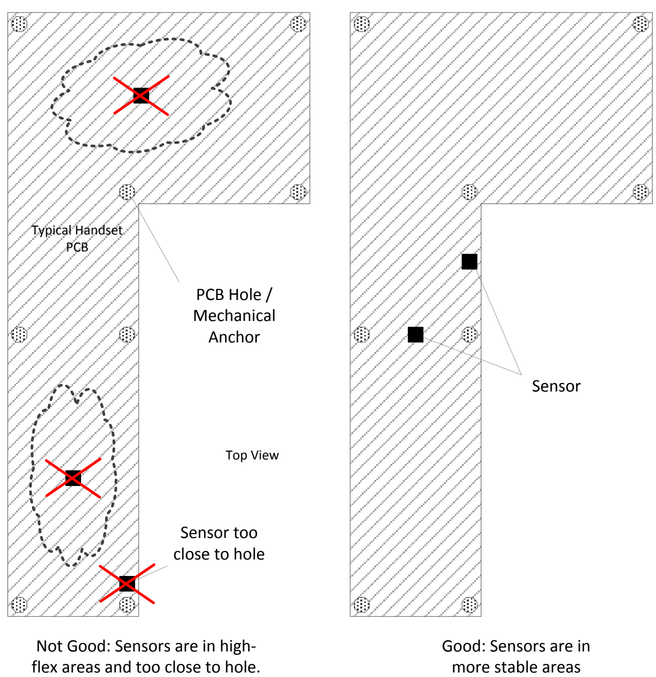
- **Figure 1 - Place Sensor in a Mechanically Stable Area of PCB**

- Do not place the sensor near a heat source (battery, power amplifier, microprocessor, backlighting circuitry, etc…) as depicted in Figure 2.
  - Heat can cause the PCB to flex, causing PCB stress which leads to offset errors.



- **Figure 2 - Do Not Place Sensor Near Heat Source**

- Do not place the sensor too close to PCB screw holes and anchor points.
  - The screw can flex the PCB and stress the sensor package.



- **Figure 3 - Be Careful of Mechanical Anchor Points of Chassis**

- Keep at a minimum of 3 mm from the edge of the PCB.

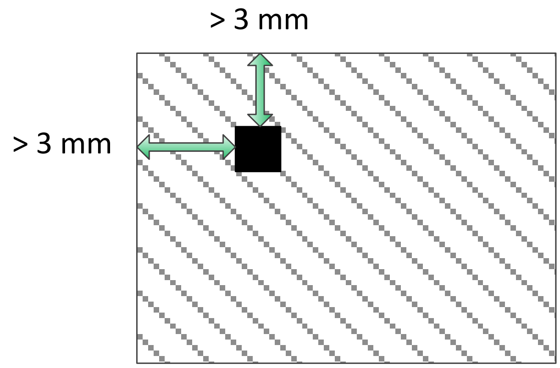


Figure 4 – Minimum of 3 mm from PCB edge

- Place the sensor away from mechanical connectors as depicted in Figure 5.
  - These produce a mechanical ‘snap’ force when the connector is used. This can cause the sensor to see excessive g-forces and is not recommended.
  - Do not place the sensor in places where using the connector will bend the PCB underneath the sensor.

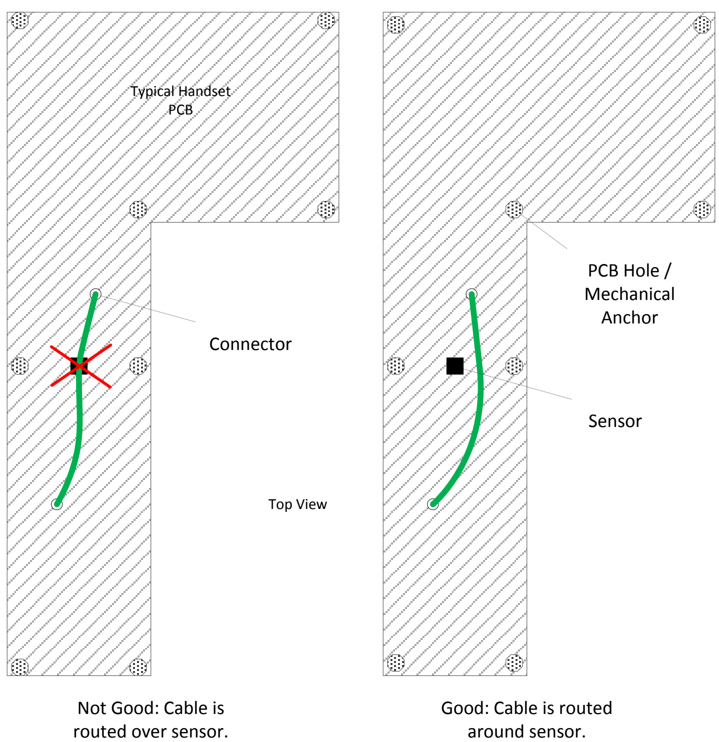
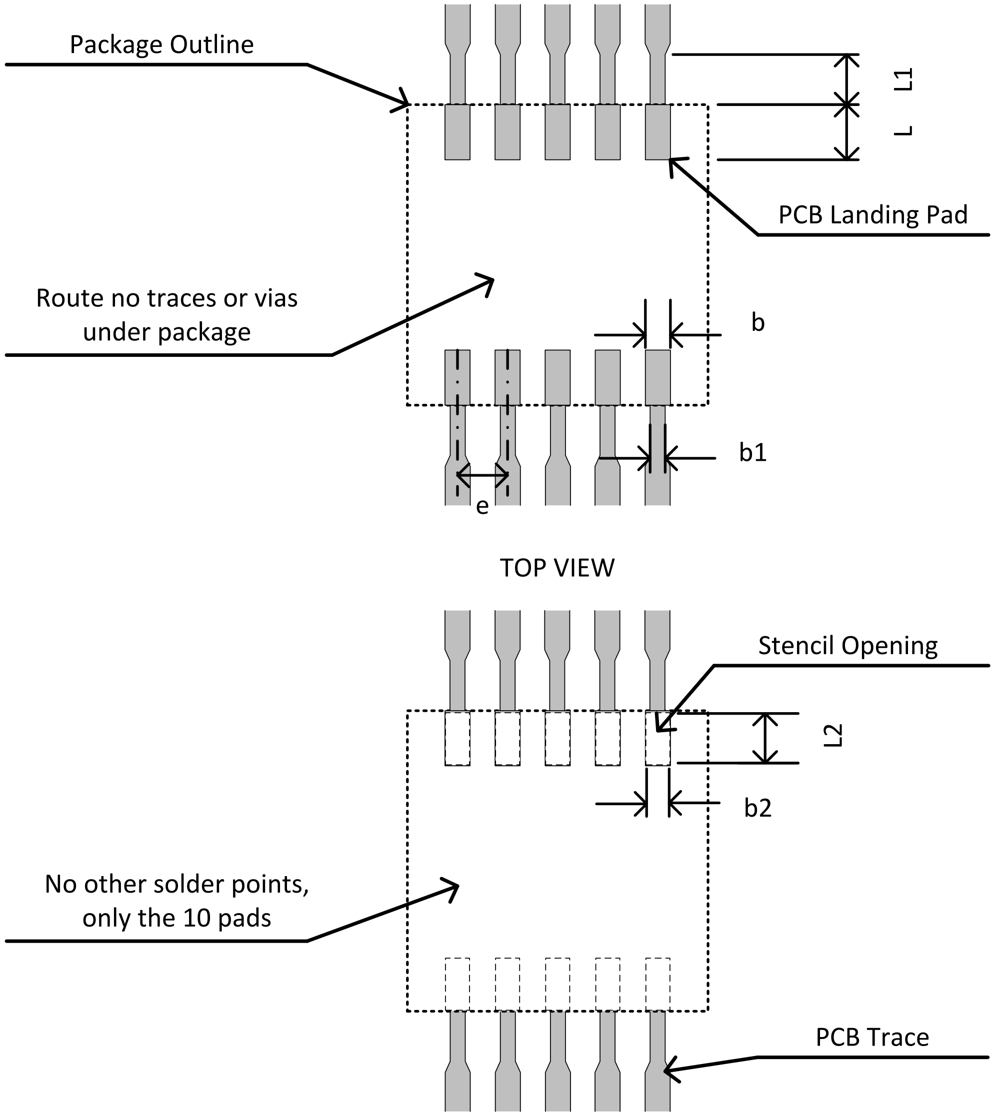


Figure 5 - Be Careful of Cable Routing

3. PCB Landing Pattern Design

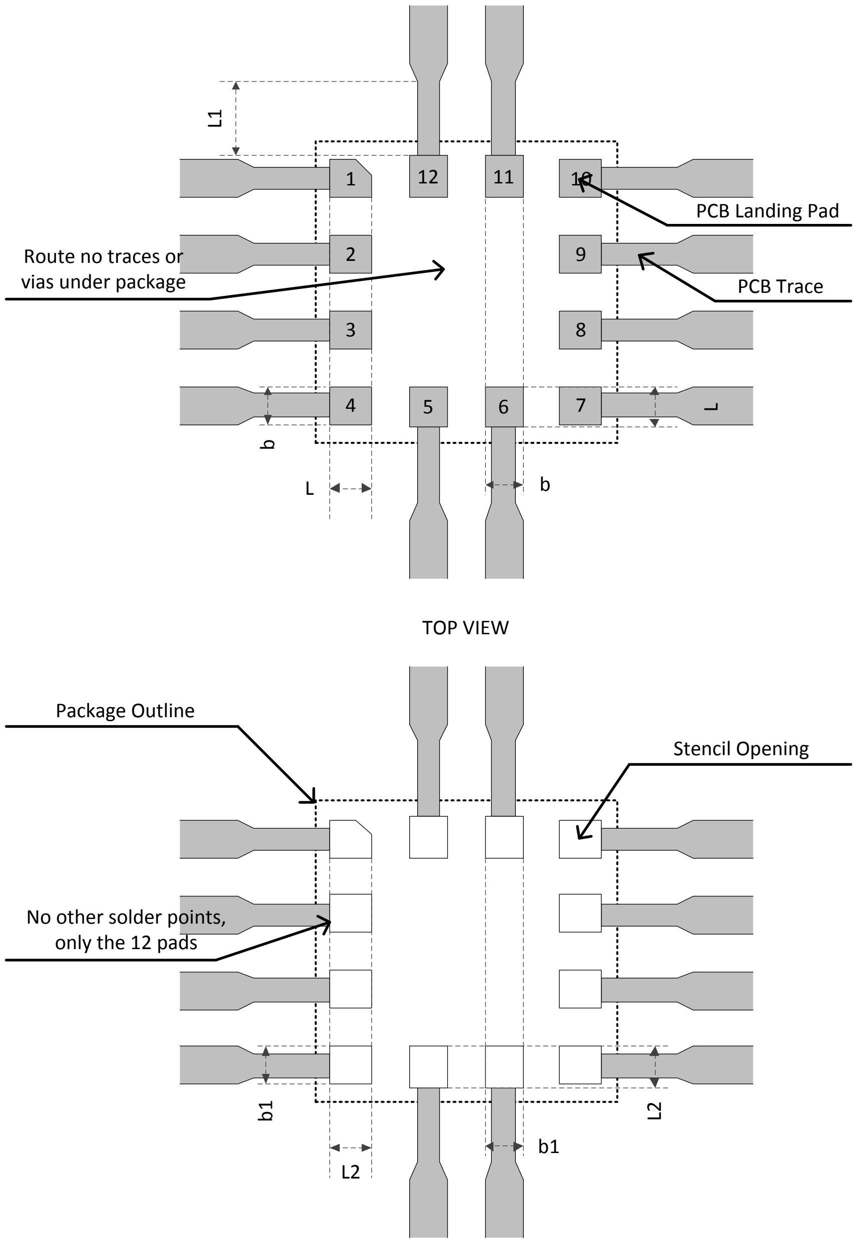
With the use of proper PCB footprint design, the package will undergo minimal stress and will self-align. Refer to Figure 6, Figure 7, Figure 8 and Figure 9.

- Make the PCB landing pads the same size as the package pads.
- Make signal traces near sensor with smaller sizes.
  - Signal traces near the package should have minimal width as design allows and drawn straight away from the package.
  - Wider traces can be used after 0.5mm from the package.
- Do not place vias or traces under the package.
  - These can cause uneven assembly during reflow.
  - These can cause the PCB to bend and flex unevenly with temperature changes.



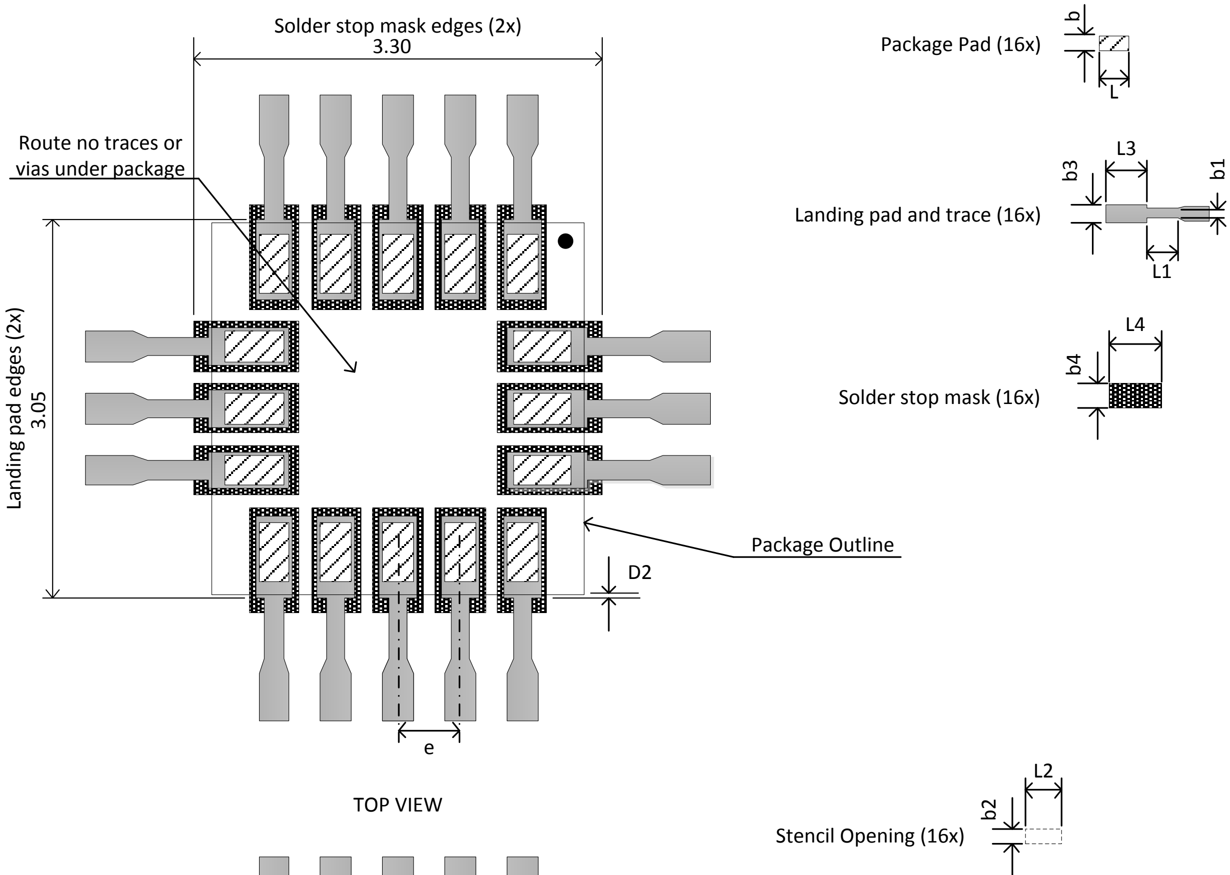
Symbol	Description	Dimensions (mm)		
		Min.	Nom.	Max.
L	pad length	0.50	0.55	0.60
b	pad width	0.20	0.25	0.30
e	pad pitch	0.50 BSC		
L1	trace length		0.50	
b1	trace width		0.15	
L2	stencil length		0.52	
b2	stencil width		0.24	

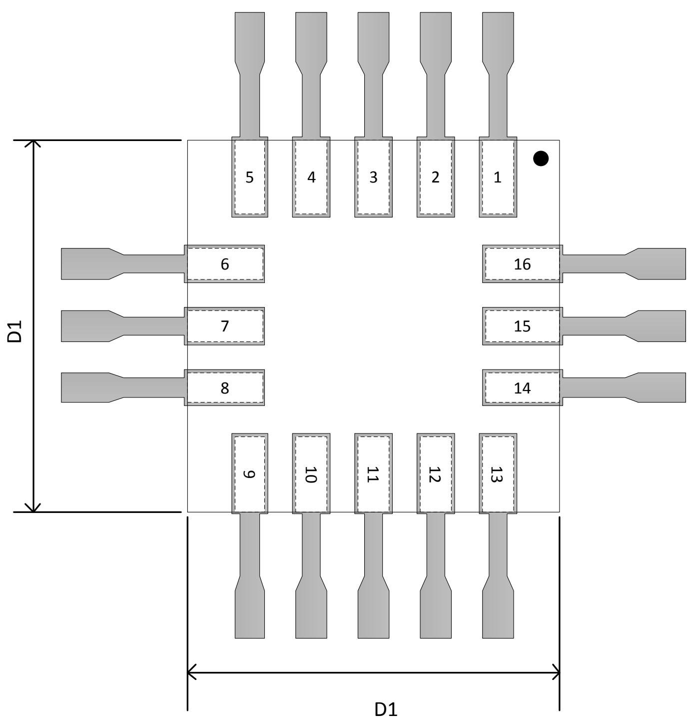
Figure 6 - PCB and Stencil Design Recommendations (10-pin 3x3mm Package)



Symbol	Description	Dimensions (mm)		
		Min.	Nom.	Max.
L	pad length	0.225	0.275	0.325
b	pad width	0.20	0.25	0.30
L1	trace length		0.50	
L2	stencil length		0.275	
b1	stencil width		0.25	

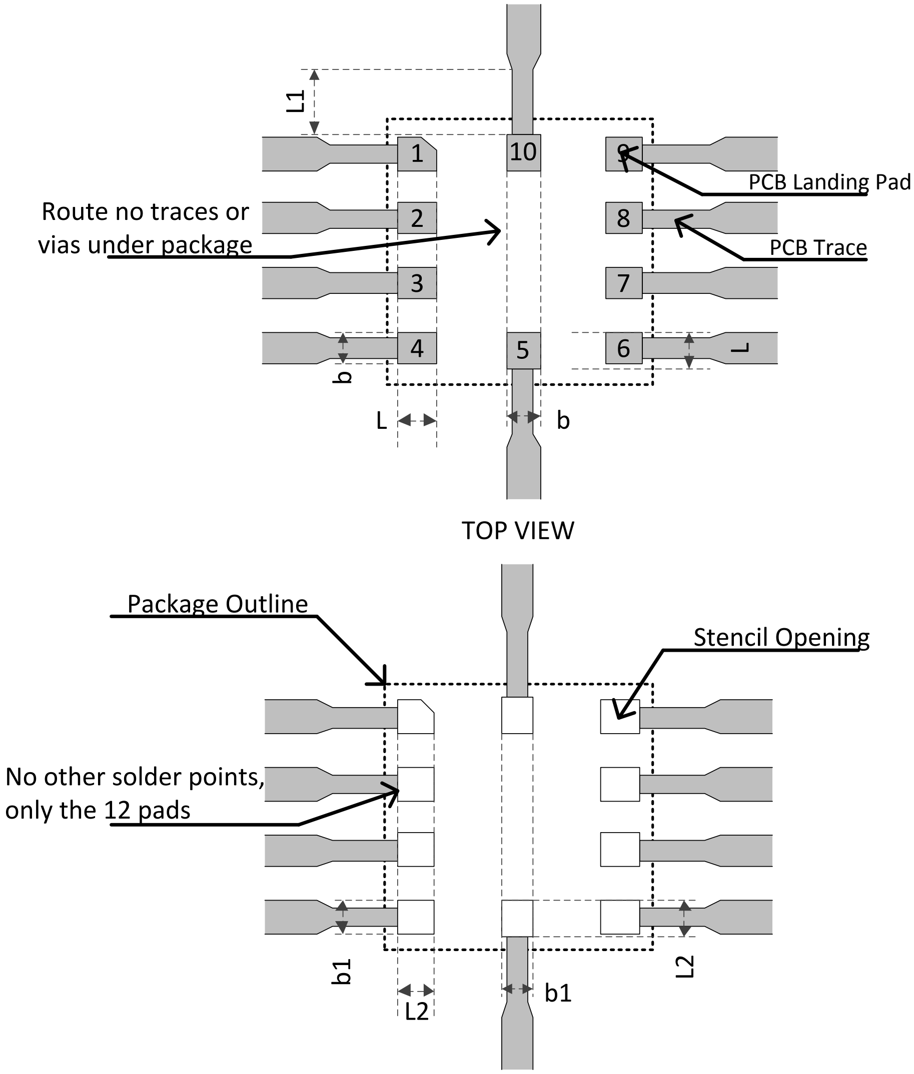
Figure 7 - PCB and Stencil Design Recommendations (12-pin 2x2mm Package)





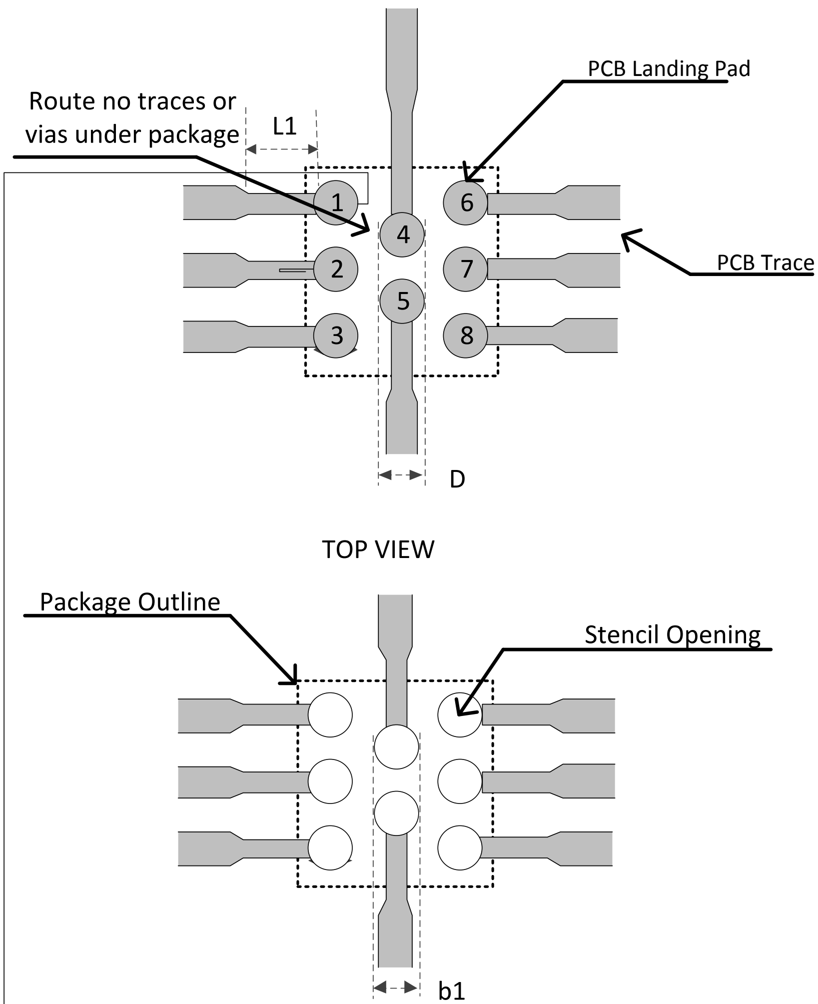
Symbol	Description	Dimensions (mm)		
		Min.	Nom.	Max.
L	Package pad length	0.445	0.475	0.505
b	Package pad width	0.22	0.25	0.28
e	Package pad pitch	0.47	0.50	0.53
L1	Trace length	0.50		
b1	Trace width		0.15	
L2	Stencil length		0.60	
b2	Stencil width		0.25	
L3	Landing pad length		0.65	
b3	Landing pad width		0.30	
L4	Stop mask length		0.85	
b4	Stop mask width		0.40	
D1	Stencil outline		3.00	
D2	Land pad to edge		0.025	

Figure 8 - PCB and Stencil Design Recommendations (16-pin 3x3mm Package)



Symbol	Description	Dimensions (mm)		
		Min.	Nom.	Max.
L	pad length	0.25	0.30	0.35
b	pad width	0.15	0.20	0.25
L1	trace length		0.40	
L2	stencil length		0.30	
b1	stencil width		0.20	

Figure 9 - PCB and Stencil Design Recommendations (10-pin 1.6x1.6mm Package)



Symbol	Description	Dimensions (mm)		
		Min.	Nom.	Max.
D	pad diameter	0.25	0.30	0.35
L1	trace length		0.40	
b1	stencil opening diameter		0.30	

Figure 10 - PCB and Stencil Design Recommendations (8-pin 1.29x1.09mm Package)

4. Stencil Design and Solder Paste

A proper stencil design and use of proper solder paste will reduce package stresses. Refer to Figure 6, Figure 7, Figure 8, Figure 9 and Figure 10.

Recommendations:

- Use a laser-machined stainless steel stencil with trapezoidal walls.
- The stencil thickness should be as follows:
  - For 10-pin 3x3mm packages, the stencil thickness can be 0.127mm (5 mil).
  - For 12-pin 2x2mm packages, the stencil thickness can be 0.102mm (4 mil).
  - For 10-pin 1.6x1.6mm packages, the stencil thickness can be 0.102mm (4 mil).
  - For 8-pin 1.29x1.09mm packages (WLCSP), the stencil thickness can be 0.102mm (4 mil).
  - Stencil thickness and size can be optimized at the production line for best solder release and yield.
- The openings of the stencil should be as follows:
  - For 10-pin 3x3mm packages, the openings should be 90% of the PCB landing pad area.
  - For 10-pin 1.6x1.6mm packages and 12-pin 2x2mm packages, the stencil width openings should be the same width as the pad size, but longer **in the direction away from the package** by 0.025mm.
  - For 16-pin 3x3mm packages see Figure 8.
  - For 8-pin 1.29x1.09 packages (WLCSP), the stencil opening should be 0.3mm.
- Accurately align the stencil and PCB using automated equipment prior to application of the solder paste.
  - With proper PCB trace and pad layout, the package should self-align.
- Use solder paste appropriate for the pad size
  - i.e. Use finer paste for smaller pad sizes or stencil holes.

5. Soldering Guidelines

Recommend to have nitrogen supply during SMT reflow process; recommend to have auto stencil cleaning every shift at SMT process.

5.1 Soldering Profile

Figure 11, Table 1 and Table 2 are provided as a recommended soldering profile based on JEDEC J-STD-020D.1 Standard.

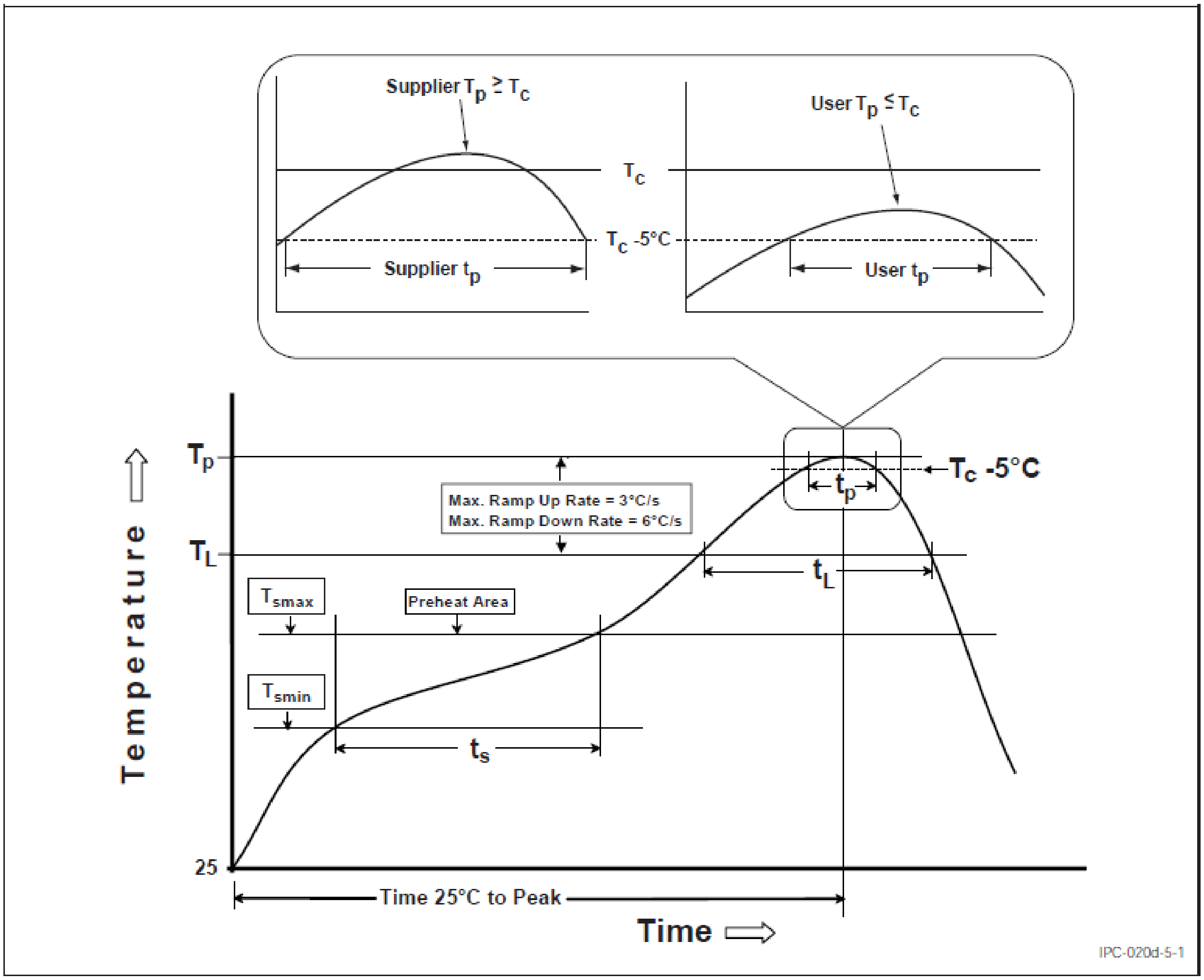


Figure 11 - Classification Profile (Not to scale)

Profile Feature	Pb-Free Assembly
Preheat/Soak Temperature Min (T_{smin}) Temperature Max (T_{smax}) Time (t_s) from (T_{smin} to T_{smax})	150 ºC 200 ºC 60 – 120 seconds
Ramp-up rate (T_L to T_p)	3 ºC/second max.
Liquidous temperature (T_L) Time (t_L) maintained above T_L	217 ºC 60 – 150 seconds
Peak package body temperature (T_p)	For users T_p must not exceed the Classification temperature listed in Pb-Free Process Table in Table 2 For suppliers T_p must equal or exceed the Classification temperature listed in Pb-Free Process Table in Table 2
Time (t_p)* within 5ºC of the specified classification temperature (T_c), see Figure 10	30* seconds
Ramp-down rate (T_p to T_L)	6ºC/second max.
Time 25ºC to peak temperature	8 minutes max.
*Tolerance for peak profile temperature (T_p) is defined as a supplier minimum and a user maximum	

Table 1 - Classification Reflow Profiles

Pb-Free Process - Classification Temperatures (T_c)

Package Thickness	Volume mm³ <350	Volume mm³ 350 - 2000	Volume mm³ >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

Table 2 – Pb-Free Process – Classification Temperatures (T_c)

Solder Assembly Process Recommendations

1. Expose the sensor to only one single reflow.
    - So, if the sensor is mounted to a two-sided printed circuit board, incorporate the sensor in the second pass.
2. Use a self-cleaning solder paste.
    - If a self-cleaning solder paste is not used, clean the flux from the board after soldering to eliminate the possibility of leakage between PCB pads.
3. Do not define a specific solder profile for the sensor only.
    - Define the PCB soldering profile based on the thermal mass of the entire assembly board.
    - Use a time and temperature profile that is based on the PCB design and manufacturing process.
4. Do not use hand-soldering processes.

6. Magnetic Sensor Placement

This section describes additional guidelines beyond the ones previously mentioned, focused on optimizing the placement of devices containing magnetic sensors for best magnetic performance. For eCompass products containing both an accelerometer and a magnetic sensor, the target application will dictate if the guidelines for the accelerometer or the magnetometer would be more important. Every design will require some tradeoffs.

The performance of the magnetic sensor can depend heavily on component placement on the PCB and within a product. Careful attention should be paid to other magnetic components and materials, and also to high-current carrying PCB traces and wires. Placing the magnetic sensor far from these items will reduce magnetic-field distortions and magnetic noise and allow for better overall magnetic sensor performance.

6.1 Magnetic placement guidelines for specific PCB components

Care must be taken to not place the magnetic sensor too close to other magnetic components or materials, because these parts will create a magnetic offset and distort the magnetic field to be measured. Software can be used to compensate for some of these effects. However, for best performance (e.g. lowest error on heading-direction calculation), place the sensor as far from these types of components as possible.

General recommendation:

The recommended distance is where the offset magnetic-field strength becomes about 0.2mT or less as illustrated in Figure 12. Software calibration can typically cancel the magnetic offset sufficiently for most applications if the whole magnetic offset is less than the measurement range of geomagnetic sensor (i.e. if the sensor is not saturated during normal operation).

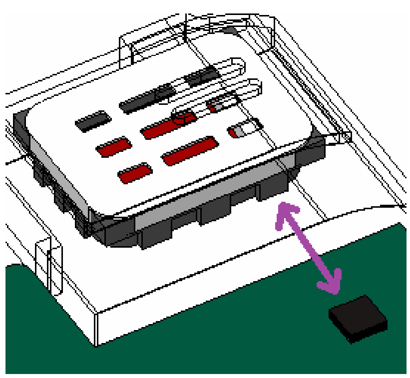


Figure 12 – Recommended distance from magnetic components

The types of magnetic components are categorized here into 5 types, listed in order of severity, meaning that Type (1) is more important than Type (5):

Type (1): PCB traces, battery and power supply cables can create magnetic fields

Reason: A large, supply current (e.g. battery or power amplifier) will create a static magnetic field. Also, the magnetic field will change with changing current.

Type (2): PCB components that can create a static magnetic-field offset

- Speaker
- Vibrator / motor
- Camera module
- Similar devices

Reason: These parts typically include a hard magnet which generates its own field, causing distortion in the field to be measured.

Type (3): Magnetized USB, HDMI and other cables

Reason: Magnetized cables can create large, magnetic offsets when the cable connects and disconnects.

Type (4): PCB components that can create dynamic magnetic fields

- Connector for micro-SD
- Connector for USB
- Connector for LCD panel (SUS stainless steel plating)

Reason: These parts will become magnetized by external magnetic fields. Once magnetized, such a component will generate its own field, causing distortion in the field to be measured. Also, battery-charging circuitry (e.g. USB) can create a magnetic field which varies over time, causing magnetic distortions.

Type (5): Metal structures and soft-magnetic materials

- Steel
- Spring steel
- Nickel
- Magnetic sheets, for example, those used for Near Field Communication (NFC) and similar sheet-type communication components (e.g. antenna)

Reason: These materials can distort temporary magnetic fields. They can also become magnetized, and hold a magnetic field and causing ongoing distortions.

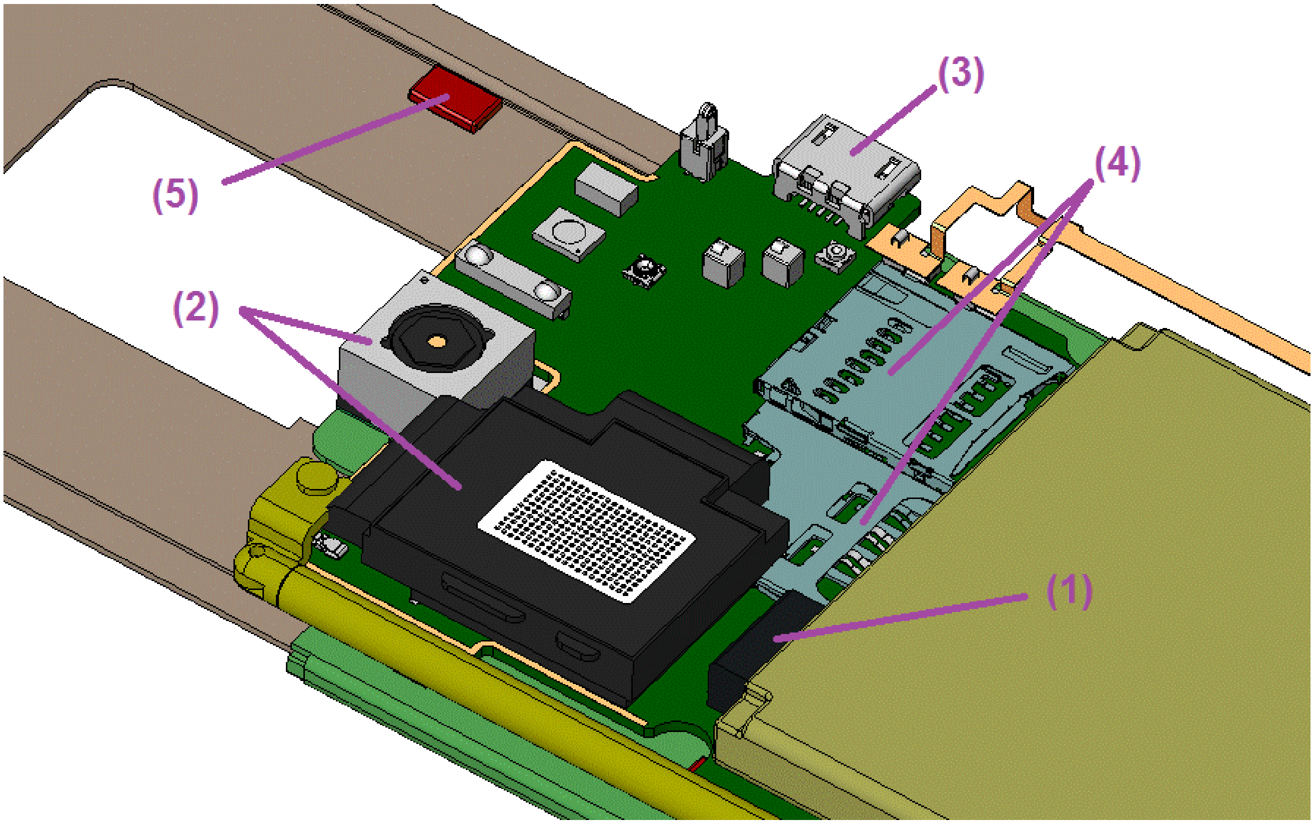


Figure 13 - Example Types of Magnetic Components

6.2 Distance Recommendations – Type (1); Battery Connector

Several situations should be kept in mind when placing the magnetic sensor near a battery or battery connector.

- The battery and battery connector can carry large currents, which then cause large, magnetic fields while the battery is charging.
- The current into the battery typically changes slowly, as the battery is charging (the current typically reduce slowly over time) and so then will the magnetic field change.
- When connecting and disconnecting for charging, the current into the battery may change abruptly, which will then cause an abrupt change in the magnetic field.

It is therefore recommended that the magnetic calibration software be run to compensate for these changing magnetic fields in these situations.

Because of the varying nature of noise on the supply signals, software compensation algorithms can have difficulty in compensating for magnetic interference caused by placing the sensor too close to these PCB traces. The best practice is to place the magnetic sensor as far away as possible.

The recommended distance between the magnetic sensor and the battery and battery connector is > 30mm.

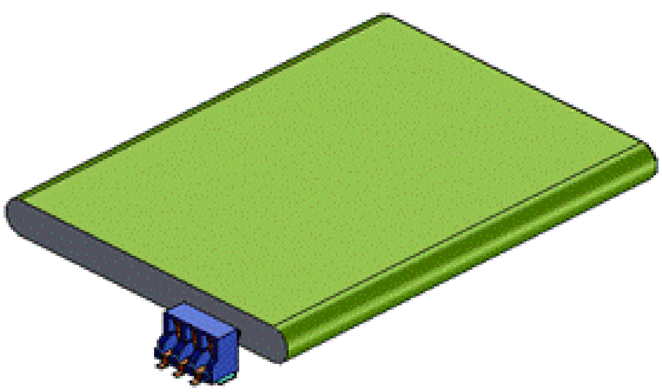


Figure 14 - Example Battery With Terminals

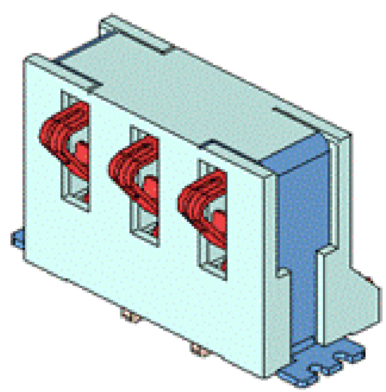


Figure 15 - Example Battery Connector

6.3 Distance Recommendations – Type (1); PCB Power Supply Traces

PCB traces and power supply cables and wires can create magnetic fields. Recommendations on placement distance away from the magnetic sensor are shown below.

Because of the varying nature of noise on the supply signals, software compensation algorithms can have difficulty in compensating for magnetic interference caused by placing the sensor too close to these PCB traces. The best practice is to place the magnetic sensor as far away as possible.

The recommended distance between the magnetic sensor and the VBAT and VBUS traces is shown in Table 33.

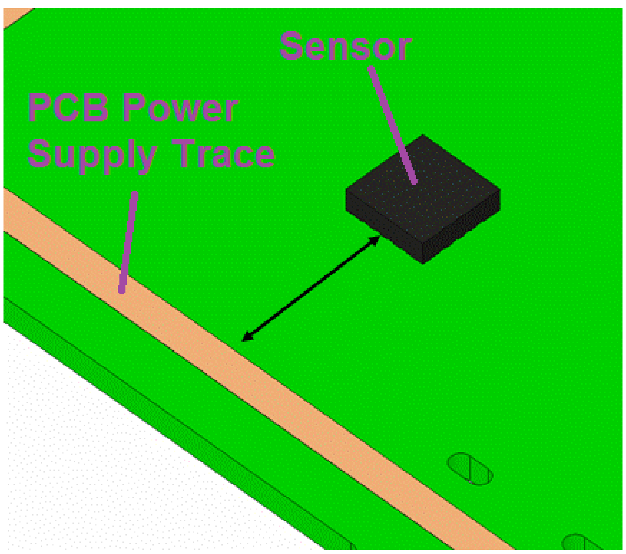


Figure 16 - Sensor Placement Near PCB Power Supply Traces

Current (mA)	Minimum Recommended Distance	
	Ripple +/- 10% [1]	**On/Off [1]**
1000	>20mm	>100mm
700	>15mm	>80mm
500	>10mm	>65mm
300	>8mm	>45mm
150	>5mm	>20mm
100	>3mm	>10mm
50	>2mm	>6mm
20	>1mm	>4mm
10	>1mm	>1mm

Table 3 - Recommended Distances from PCB Traces

[1] The recommendation should produce less than 2 degrees of error.

6.4 Distance Recommendations – Type (1); VBAT and VBUS PCB Traces

The traces which carry current from the battery and main power supply circuitry on the PCB (typically known as VBAT and/or VBUS traces) may carry large currents. These traces then cause large, magnetic fields and changing, magnetic fields, if the current changes or has ripple or other noise on it.

Because of the varying nature of noise on the supply signals, software compensation algorithms can have difficulty in compensating for magnetic interference caused by placing the sensor too close to these PCB traces. The best practice is to place the magnetic sensor as far away as possible.

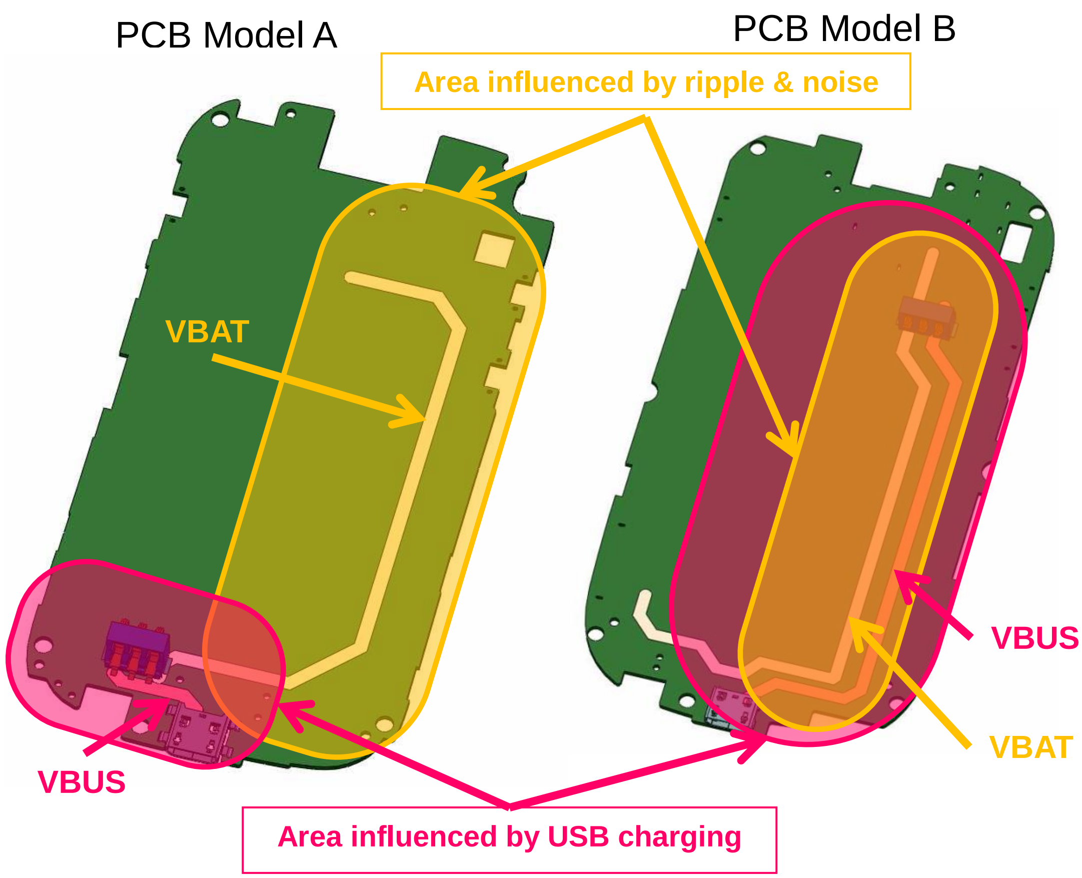


Figure 17 - Example PCB Layouts for VBUS and VBAT

6.5 Distance Recommendations – Type (2); Speakers, Motors, Magnets

Type (2) components create a static, magnetic-field offset. Attention should be paid to the change in magnetic field when the distance to the sensor is changed by opening or closing a clamshell structure, or by sliding a display component (e.g. LCD or OLED). Recommendations on placement distance away from the magnetic sensor are shown below.

Component	Minimum Recommended Distance
Speaker	>15mm
Receiver	>10mm
Vibration Motor	>8mm
AF Camera	>18mm
Non-AF Camera	>5mm
Magnet (e.g. 4x3x2mm)	>21mm

Table 4 - Recommended Distances from components

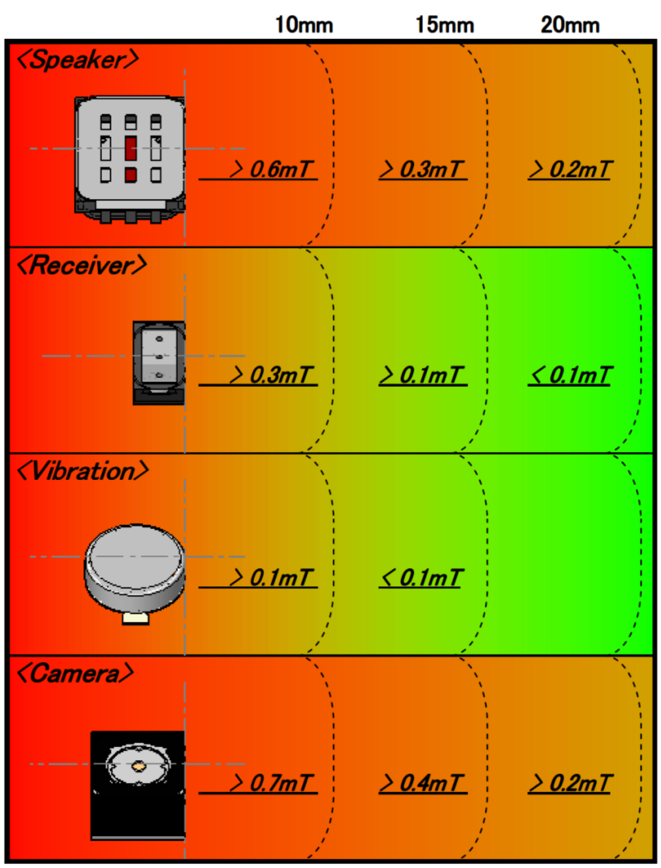


Figure 18 - Recommended Placement Distance - Type (2)

The recommended distance is where the offset, magnetic-field strength becomes 0.2mT or less.

6.6 Distance Recommendations – Type (3); USB

Magnetized cables can create large, magnetic offsets when the cable connects and disconnects. USB cables and connectors can become magnetized and create a magnetic offset. Magnetic calibration is recommended after the USB cable is connected to the PCB.

The recommended distance between the magnetic sensor and a Mini-USB cable or USB connector is > 15mm.

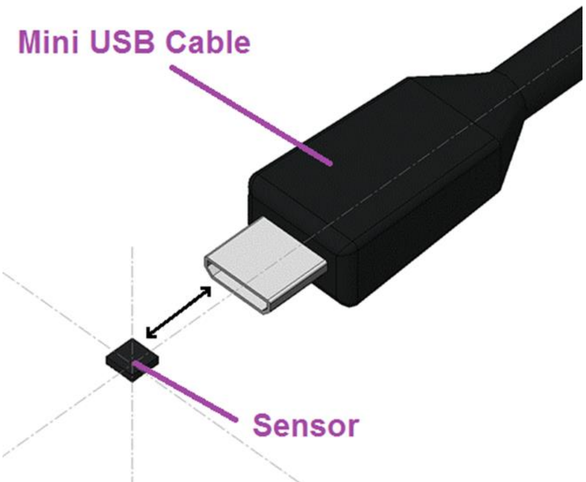


Figure 59 – USB Cable to Sensor distance

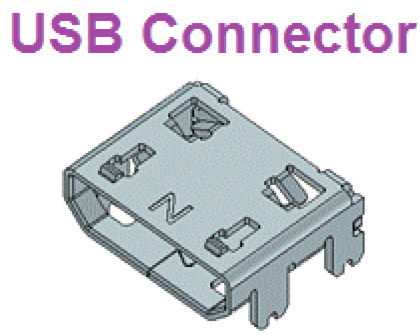


Figure 20 – USB Connector

6.7 Distance Recommendations – Type (3); HDMI

Magnetized cables can create large, magnetic offsets when the cable connects and disconnects. HDMI cables and connectors can become magnetized and create a magnetic offset. Magnetic calibration is recommended after the HDMI cable is connected to the PCB.

The recommended distance between the magnetic sensor and a HDMI connector is >39mm.

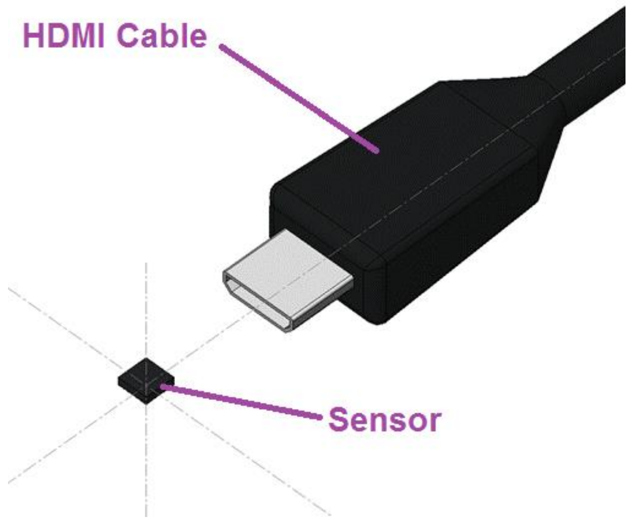


Figure 21 – HDMI cable to sensor distance

6.8 Distance Recommendations – Type (4); Mechanicals

Type (4) components can create dynamic magnetic fields. These components can become magnetized by external fields. Recommendations on placement distance away from the magnetic sensor are shown below.

Example Component	Minimum Recommended Distance
T-Flash Connector	>8mm
Micro-SD Connector	>3mm
SD Socket	>3mm
SIM Connector	>4mm
HDMI Connector	>4mm
Metal Dome	>5mm
Side Switch	>3mm
IrDA Module	>4mm
Screw (such as steel)	>4mm
Battery Electrode	>7mm
DCDC Converter	>10mm
MIC	>2mm
Spring Contact	>2mm

Table 5 - Recommended Distances from connectors

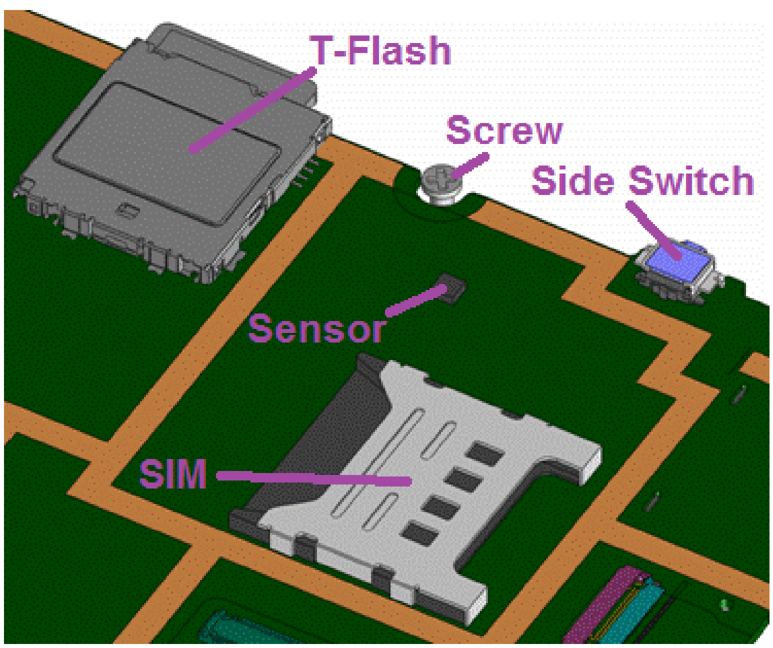


Figure 22 - Recommended Placement Distances - Type (4)

The recommended distance is where the offset, magnetic-field strength becomes 0.2mT or less.

6.9 Distance Recommendations – Type (5); Above / Below

Type (5) components are metal structures and soft-magnetic materials. These can be magnetized by external fields. They can also distort fields near the bends in the metal. Recommendations on placement distance away from the magnetic sensor are shown below.

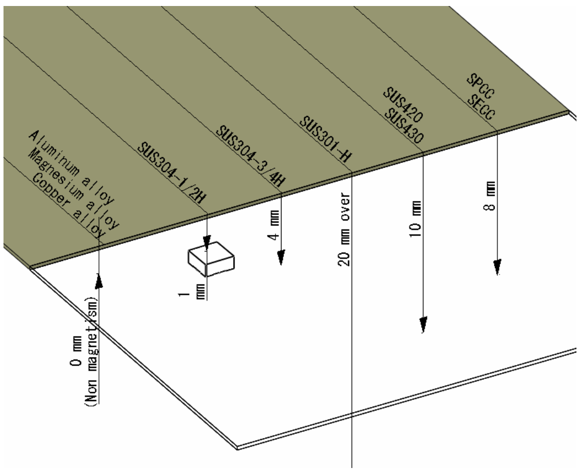


Figure 6 - Sensor Placement Near Flat Sheet Metal Above / Below

Material	Minimum Recommended Distance
Aluminum	0mm
Magnesium	0mm
Copper	0mm
STS304-1/2H	>1mm
STS304-3/4H	>4mm
STS304-H	>20mm
STS301-H	>25mm
SUS420	>10mm
SUS430	>10mm
SPCC	>8mm
SECC	>8mm

Table 6 – Recommended Distances from flat sheet metal above/below

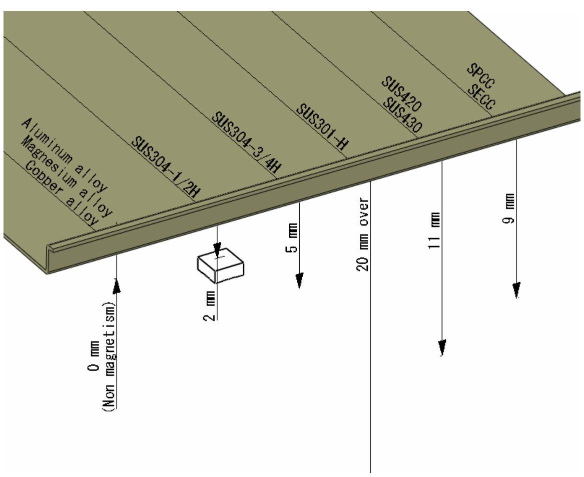


Figure 24 – Sensor Placement Near Bent Sheet Metal Above / Below

Material	Minimum Recommended Distance
Aluminum	0mm
Magnesium	0mm
Copper	0mm
STS304-1/2H	>2mm
STS304-3/4H	>5mm
STS304-H	>20mm
STS301-H	>25mm
SUS420	>11mm
SUS430	>11mm
SPCC	>9mm
SECC	>9mm

Table 7 - Recommended Distances from bent sheet metal above/below

The recommended distance is where the offset, magnetic-field strength becomes 0.2mT or less.

6.10 Distance Recommendations – Type (5); Left / Right

Type (5) components are metal structures and soft-magnetic materials. These can be magnetized by external fields. They can also distort fields near the bends in the metal. Recommendations on placement distance away from the magnetic sensor are shown below.

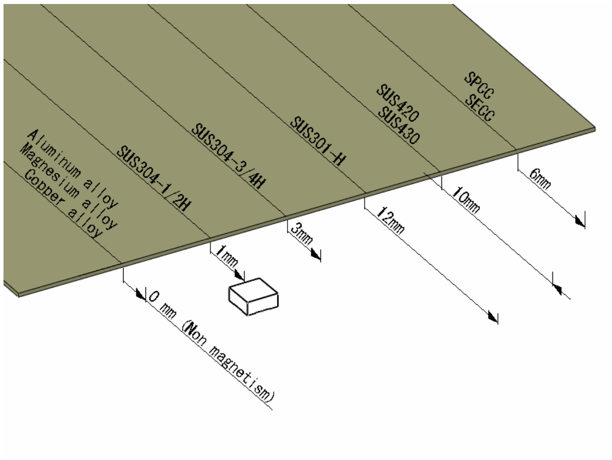


Figure 25 - Sensor Placement Near Flat Sheet Metal Left / Right

Material	Minimum Recommended Distance
Aluminum	0mm
Magnesium	0mm
Copper	0mm
STS304-1/2H	>1mm
STS304-3/4H	>3mm
STS304-H	>8mm
STS301-H	>12mm
SUS420	>10mm
SUS430	>10mm
SPCC	>6mm
SECC	>6mm

Table 8 – Recommended Distances from flat sheet metal left/right

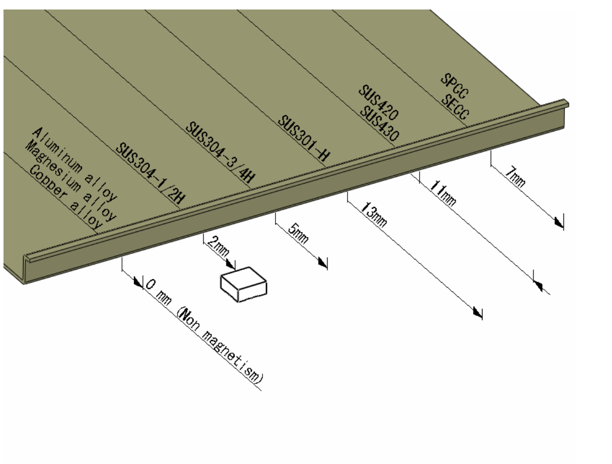


Figure 26 – Sensor Placement Near Bent Sheet Metal Left / Right

Material	Minimum Recommended Distance
Aluminum	0mm
Magnesium	0mm
Copper	0mm
STS304-1/2H	>2mm
STS304-3/4H	>5mm
STS304-H	>9mm
STS301-H	>13mm
SUS420	>11mm
SUS430	>11mm
SPCC	>7mm
SECC	>7mm

Table 9 – Recommended Distances from bent sheet metal left/right

The recommended distance is where the offset, magnetic-field strength becomes 0.2mT or less.

6.11 Distance Recommendations – Type (5); Metal Shields

Type (5) components are metal structures and soft-magnetic materials. These can be magnetized by external fields. They can also distort fields near the bends in the metal. Recommendations on placement distance away from the magnetic sensor are shown below.

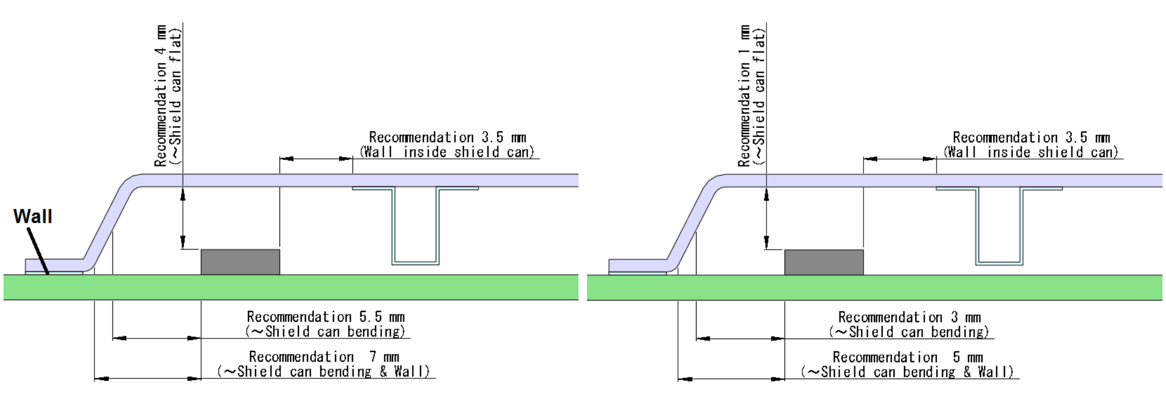


Figure 27 – Distance from metal shields

Shield Can Material	Type	Minimum Recommended Distance
STS304-3/4H (thickness : 0.4mm)	Flat	>4mm
	Bend	>5.5mm
	Wall	>3.5mm
	Bend & Wall	>7mm
STS304-1/2H (thickness : 0.3mm)	Flat	>1mm
	Bend	>3mm
	Wall	>3.5mm
	Bend & Wall	>5mm

Table 10 – Recommended Distances from metal shield

NOTE: The carved or stamped portions of metal shields may be strongly magnetized. Do not place the sensor under this portion of the metal shield.

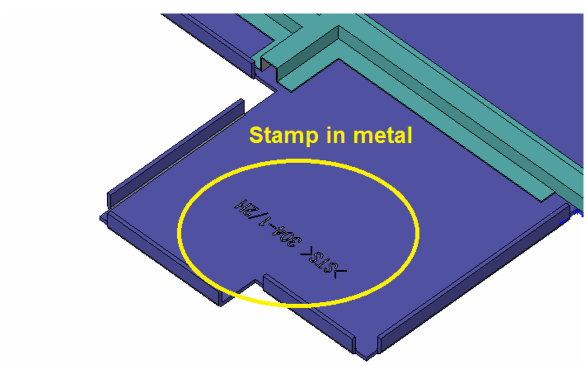


Figure 28 - Metal Stamped Area

The recommended distance is where the offset, magnetic-field strength becomes 0.2mT or less.

6.12 Distance Recommendations – Type (5); Magnetic Sheets

Type (5) components are metal structures and soft-magnetic materials. These can distort temporary, magnetic fields. Recommendations on placement distance away from the magnetic sensor are shown below.

The magnetic properties of sensor sheets and magnetic sheets can vary greatly from design to design. For a thin sheet (e.g. 0.1mm) the minimum distance from the sensor to the sheet should be >15mm. For a thicker sheet (e.g. 0.2mm) the minimum distance should be >20mm.

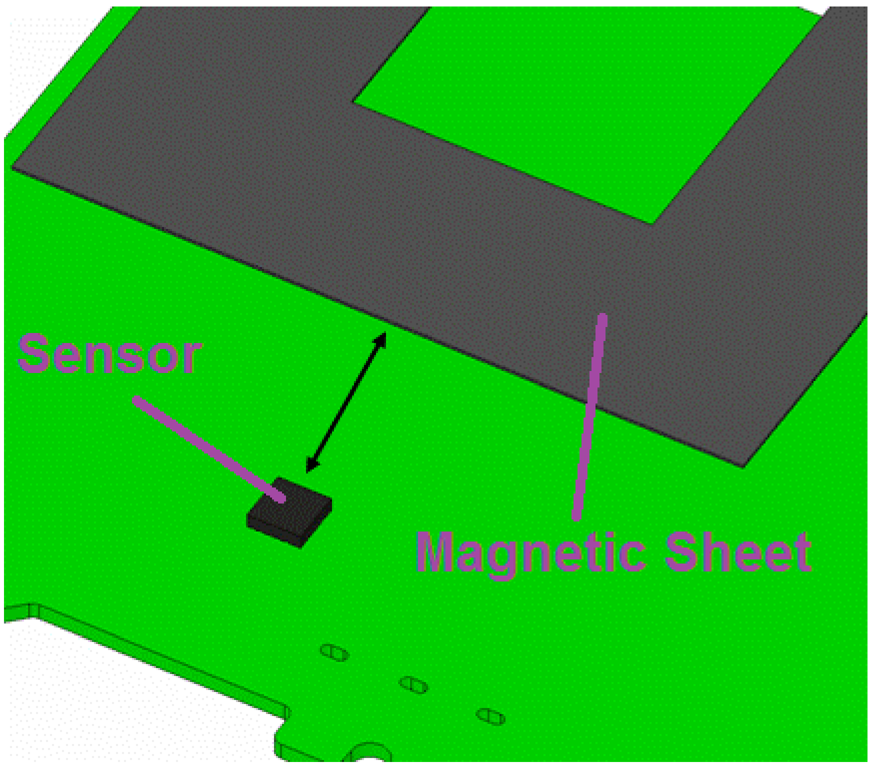


Figure 29 - Sensor Placement Near Magnetic Sheets