ScioSense

ENS220

Application note – ENS220 Design Guidelines

ENS220 application note

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Content Guide

1 General Description

The ENS220 is an ultra-low-power, high-accuracy barometric pressure and temperature sensor. It comes in the smallest size LGA package with digital I^2C and SPI interfaces. This enables new use cases in activity tracking, indoor navigation/localization, fall- and liquid-level detection.

This document covers different aspects related to adding an ENS220 sensor into an application. It addresses the electronic circuit and printed circuit board (PCB) design, along with notes about enclosure integration.

2 Sensing Modality

2.1 Temperature Sensing

Temperature sensing is the measurement of degree or intensity of heat present in a substance or object. To obtain accurate measurement of temperature, the mode of heat transfer has to be understood. In temperature measurement, the important modes of heat transfer include conduction, convection, and radiation. For example, in conduction, a warmer body influences the temperature measurement when it comes into thermal contact with the zone of detection. In convection, warmer matter (liquid or gas) flows past the sensor influencing the measurement. In radiation, heat is transferred through the emission of electromagnetic waves from all matter with temperature above absolute zero. This may result in heating up of the sensor. Nevertheless, it is important to identify the subject to be measured.

In case of environmental temperature sensors, the ambient temperature is the most-common subject of interest, less so is the temperature of its PCB or its casing. During a change in ambient temperature, readings of the sensor take some time before they eventually show a stabilized ambient temperature. The thermal mass of the sensor and the PCB (e.g., thickness of PCB, amount of solder used) it is mounted on, affects the response time of the readings. In any case the ENS220 should have direct access to the environment for accurate temperature measurements.

2.2 Pressure Sensing

Pressure sensing is the measurement of the force that a fluid, like air, is exerting on surfaces submerged on it. This force is measured perpendicularly to the studied surface. The ENS220 is intended for measuring barometric pressure, which means measuring the pressure of air in the earth's atmosphere.

The absolute value of pressure is used mostly for weather measurements and forecast. For most applications the most interesting value is the relative pressure. This is the relative change of pressure over time, or between two different positions. This value can be used for detecting events (doors or windows being opened, falls, insertion of earplugs, etc.) or for calculating height differences. Because quick pressure changes are also known to produce headaches on certain individuals, there are also healthcare applications for tracking this value.

An important thing to note is that the pressure at a given place changes constantly. Throughout the day changes of 20 hPa are expected, while even bigger variations might appear if storms are present. Throughout the year there are also changes in the average pressure following the seasons.

When any fluid is in motion, the pressure experienced by elements contained in the flow will change depending on the fluid's speed according to Bernoulli's principle. Therefore, the designer should be aware of these changes, and plan the location of the ENS220, data acquisition, and processing to minimize these alterations.

3 Circuit Design Considerations

3.1 Supply

The operating voltage range of the ENS220 is from 1.62 V to 1.98 V. The supply noise should be minimized because it can affect the measurement noise. A decoupling capacitor near to the sensor is highly recommended. Please note that a 0.1 µF decoupling capacitor should always be present on the supply, and as close as possible to the device.

If the supply voltage is disconnected from the device, then SDA/SDI and SCL should also be disconnected. Leakage from the bus into the pins may occur, and the bus may be pulled down.

3.2 Voltage levels on the digital IOs

The SCL/SCLK and SDA/SDI pins can be operated in the range of 1.8 to 3.3 V, exceeding the supply voltage VDD of 1.8 V. The VDD and CSN pins must always be powered with 1.8 V. The INT/SDO pin will output a value of VDD when the signal is high.

On power-up, the INT pin is set as output, setting a logic LOW on that line. The designer must take care that this behavior is compatible with the rest of the circuit. This means not having other devices working as an output on that same line, or restricting the amount of current that could be sunk by the ENS220 to not more than the limits given in the datasheet.

3.3 ENS220 with a 1.8 V microcontroller

The ENS220 can be connected directly to the microcontroller and used in all its functionalities without interfacing hardware. As an example, Figure 1 shows how to connect the ENS220 to a microcontroller that also works at 1.8 V using the I²C bus and interrupts, while Figure 2 shows the connection for SPI 4 wire.

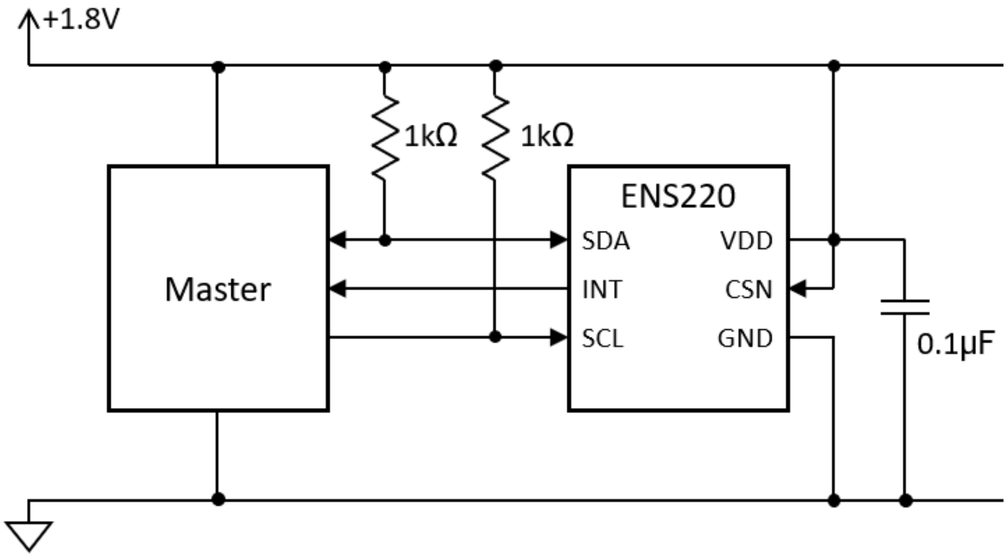

Figure 1. ENS220 connected to a 1.8 V microcontroller. Communication through I²C, interrupts available.

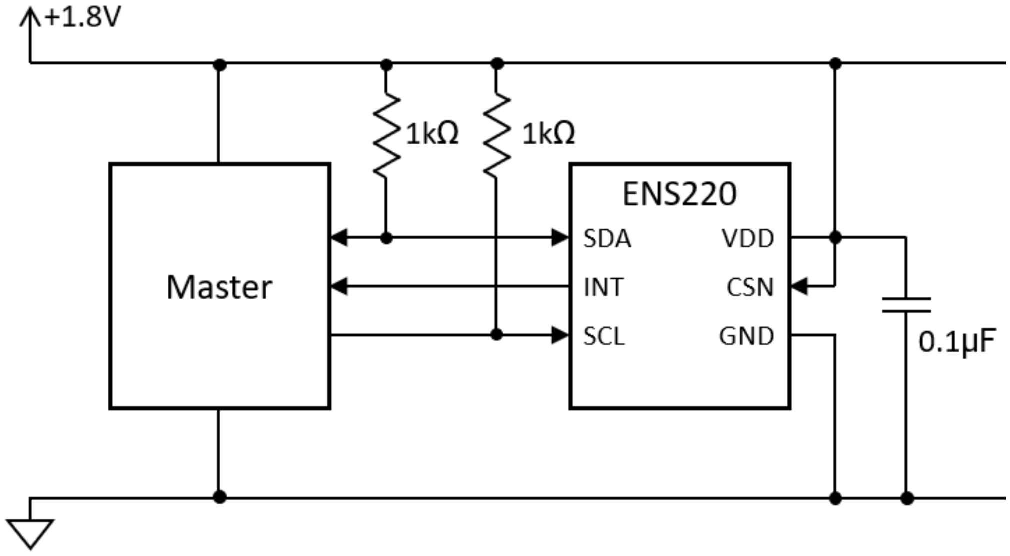

Figure 2. ENS220 connected to a 1.8 V microcontroller. Communication through SPI 4 wire.

3.4 ENS220 with a 3.3 V microcontroller, I²C

The ENS220 can be connected directly to a 3.3 V microcontroller if only the I²C communication is required. The only requirement is that the ENS220 and its CSN pin are powered with 1.8 V. Figure 3 shows how the connection diagram would look with the addition of a LDO regulator to provide 1.8 V to VDD and CSN.

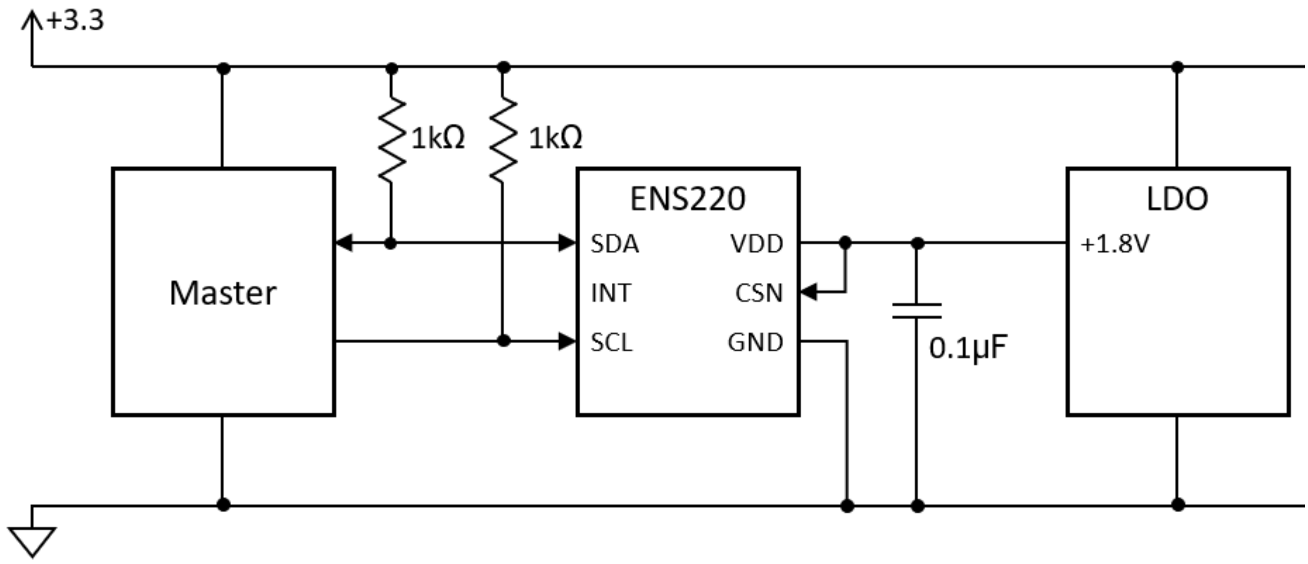

Figure 3. ENS220 connected to a 3.3 V microcontroller. Communication through I²C, interrupts not available.

3.5 ENS220 with a 3.3 V microcontroller, I²C and interrupts

To add the interrupt functionality to the ENS220 when communicating with a 3.3 V microcontroller through I²C, some extra circuitry is needed for shifting the Interrupt signal from 1.8 V to 3.3 V. Figure 4 shows the overall connection diagram, while Figure 5 shows the circuit to add with an N-Channel MOSFET and a resistor to connect the Interrupt signal.

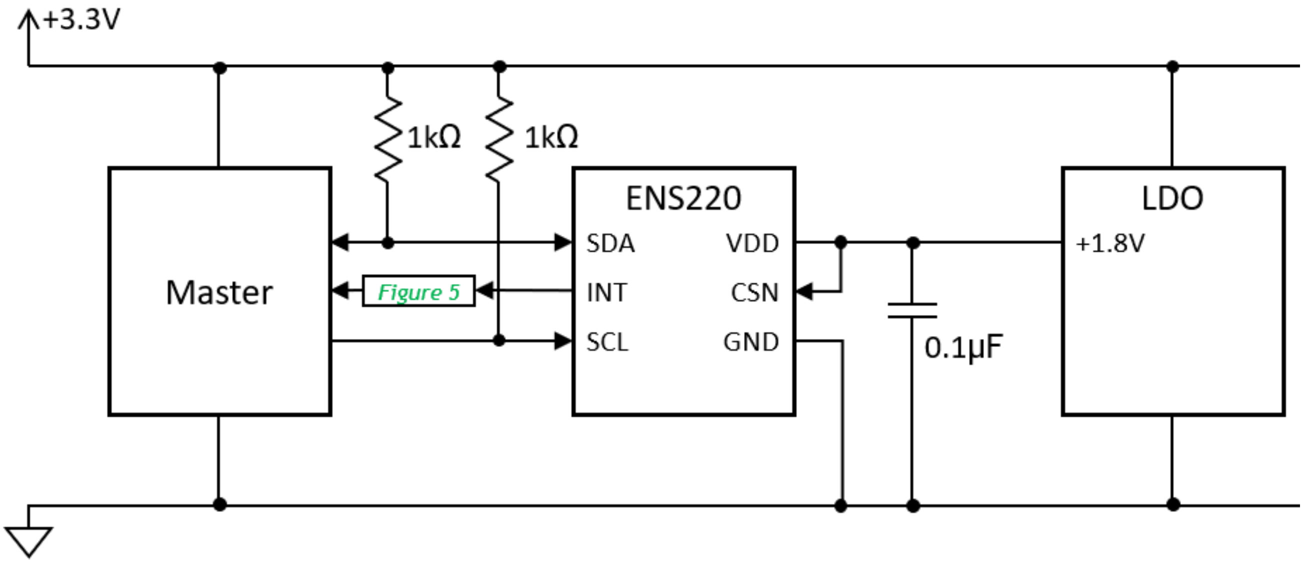

Figure 4. Connection diagram for interfacing the ENS220 to a 3.3 V microcontroller through I²C with interrupts. The circuit for connecting the interrupts can be seen in Figure 5.

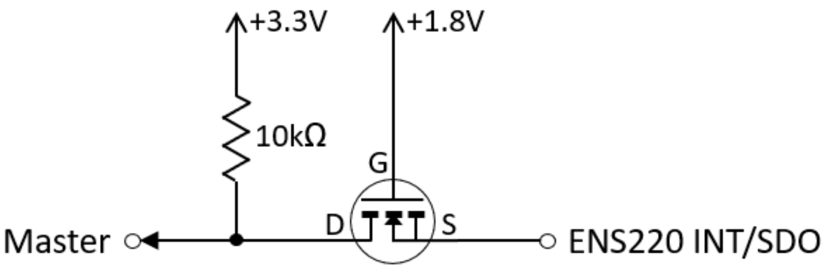

Figure 5. Level shifting of the ENS220 1.8 V signal to 3.3 V through a N-Channel MOSFET.

3.6 ENS220 with a 3.3 V microcontroller, SPI 4 wire

To interface the ENS220 sensor with a 3.3 V microcontroller through SPI 4 wire, some extra circuitry is needed for shifting the SDO and CSN signals to 3.3 V. Figure 6 shows the overall connection diagram, while Figure 5 and Figure 7 show the circuit for shifting these signals.

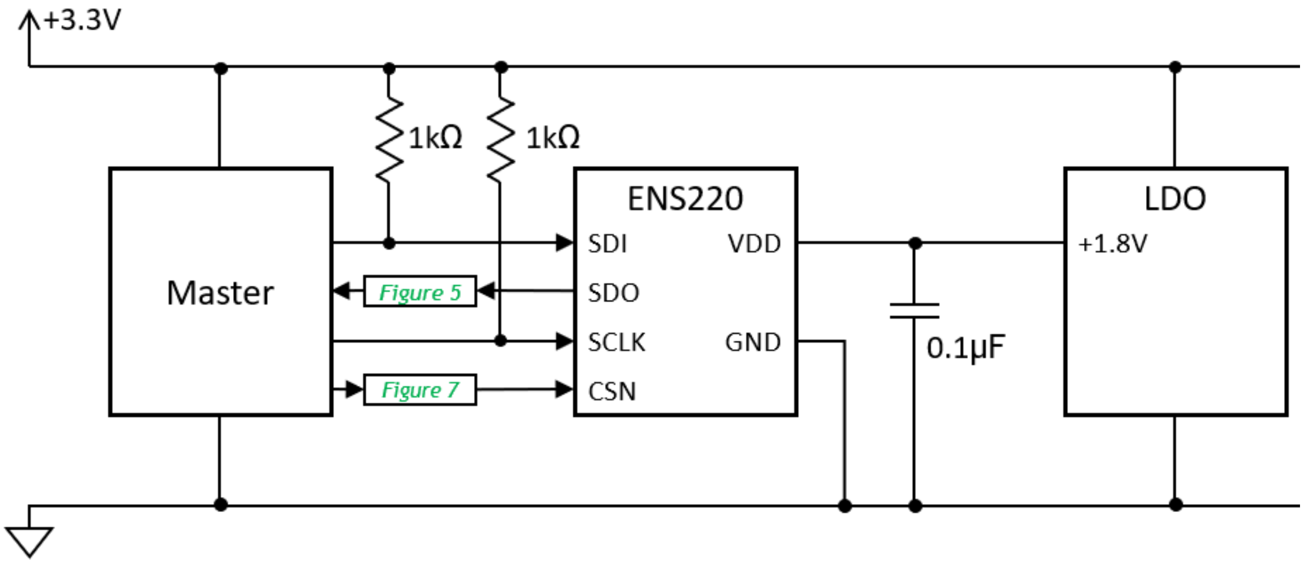

Figure 6. Connection diagram for interfacing the ENS220 to a 3.3 V microcontroller through SPI 4 wire. The circuit for connecting the SDO signal can be seen in Figure 5, while Figure 7 shows the circuit for the CSN signal.

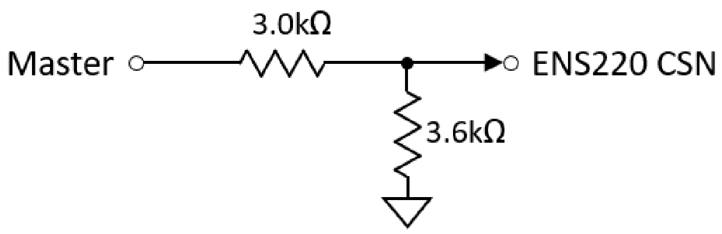

Figure 7. Circuit to use for converting 3.3 V signals from the microcontroller to 1.8 V for the ENS220.

3.7 Communication through SPI 3 wire protocol

In the SPI 3 wire protocol, pin 4 of the ENS220 becomes at the same time SDI and SDO (slave device input and slave device output). That means that the master must send and receive data through the same line. In case the master can only perform SPI 4 wire communication, some adaptation must be performed to switch the SPI 3 wire to SPI 4 wire. For this, the master must either:

- operate an open-drain MOSI pin.
- switch the MOSI pin direction to input when it is expecting data.
- have a passive component that allows the MOSI and MISO line to have separate voltages. This can be a resistor (as in Figure 8) or a Schottky diode (as in Figure 9) between MOSI and MISO.
    - The resistor should be big enough that the total current being supplied by the master and pull-up resistor sunk by the ENS220 stays below the maximum allowed. It must

also be small enough that when the master outputs a logic 0 on MOSI, the voltage at SDI is under the maximum low-level input voltage V_{IL}.

- The Schottky diode should have a forward voltage drop low enough to ensure that the voltage at SDI is under the maximum low-level input voltage V_{IL}.

Figure 8 and Figure 9 give examples of how to use passive components to interface the ENS220 in SPI 3 wire mode to a master that works in SPI 4 wire. Please take note that the master is powered with 1.8 V in these examples.

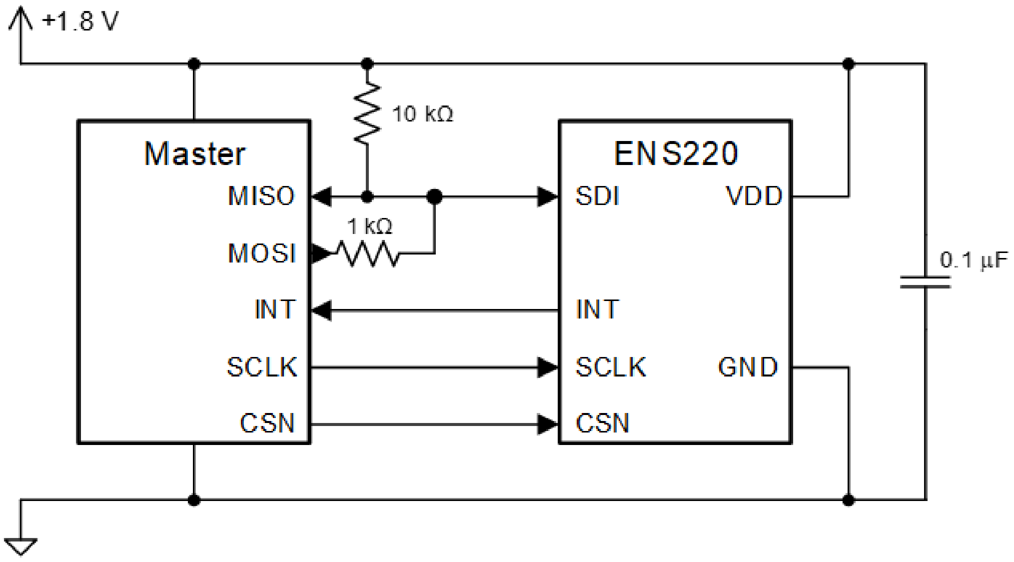

Figure 8. Use of a resistor for interfacing a SPI 4 wire microcontroller to the ENS220 in SPI 3 wire mode. The 10 kΩ pull-up resistor can be omitted if the MOSI pin is a push-pull output.

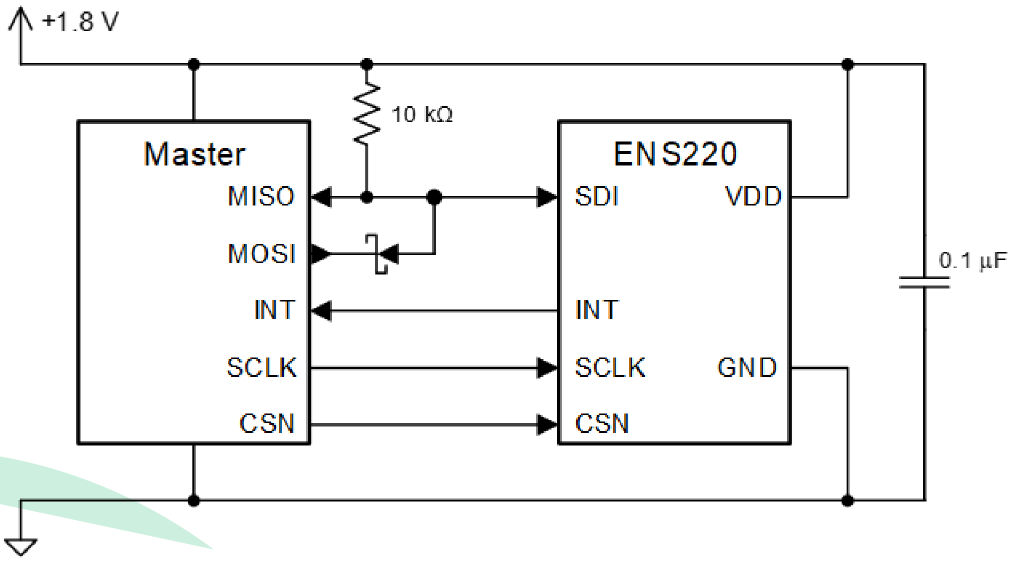

Figure 9. Use of a Schottky diode for interfacing a SPI 4 wire microcontroller to the ENS220 in SPI 3 wire mode.

The ENS220 SDI is an open-drain pin. Therefore, the line must have a pull-up resistance, implemented either on the microcontroller itself, on the line, or as a series resistance to the MOSI pin.

4 PCB Layout considerations

The recommended footprint for the sensor can be found on the datasheet, while a schematic and footprint library is available at https://www.snapeda.com/parts/ENS220S-BLGT/ScioSense/view-part/?ref=search&t=ENS220S-BLGT.

Pins 1 and 5 of the ENS220 are not connected to the sensor, so they can be left unsoldered, unconnected, or connected to any voltage that fits within the maximum ratings indicated on the datasheet.

All three GND pins (3, 8, and 9) of the ENS220 are connected internally, so it is not necessary to wire all of them.

4.1 Overall design recommendations

There are several external factors that may affect the accuracy of all capacitive pressure sensors. To ensure the best accuracy even in the most demanding applications:

- **Ensure a stable voltage supply.** Add decoupling capacitors with the shortest distance possible to the power and ground pads of the ENS220. Isolate from devices which introduce noise in the supply.
- **Decouple from heat sources.** Place the sensor far from hot components or isolate it through cutouts and copper design.
- **Decouple the sensor from mechanical stresses.** Prevent deformations of the PCB to get transmitted to the sensing element by moving it to areas not subject to deformation or by isolating it through cutouts.
- **Avoid areas with airflow.** Due to fluid dynamics, the pressure in moving air will depend on the speed at the measurement point. Due to this, the path that airflows will take in the equipment and subsequent pressure distributions must be considered when choosing a location for the sensor.
- **Shield from direct sunlight.** Prevent direct sunlight from shining directly on the sensor.
- **Maximum temperature during soldering.** The ENS220 is calibrated to achieve the maximum accuracy after soldering with an IPC/JEDEC J-STD-020E profile. Using different temperatures than indicated in the datasheet may introduce an offset after the soldering process.

4.2 Power supply noise decoupling

A good power supply decoupling is recommended to reduce the influence of supply noise on the ENS220 measurement output in very low noise applications. A value between 100 nF and 10 µF is recommended for the decoupling capacitor which needs to be placed close to the sensor. The lower value is suitable for most applications, while higher ones should be used if there are long and thin power lines to the device or if there is noise in the supply. Ultimate noise reduction is achieved with a dedicated linear regulator for the supply of the sensor.

It is important to minimize the distance between the power and ground pads of the ENS220 and the pads of the capacitor. An increase in the length of these tracks adds resistance and inductance to them, lowering the ability of the capacitor to quickly increase the current to the sensor. The ground pads of the ENS220 are all connected internally, so it is not necessary to route all of them.

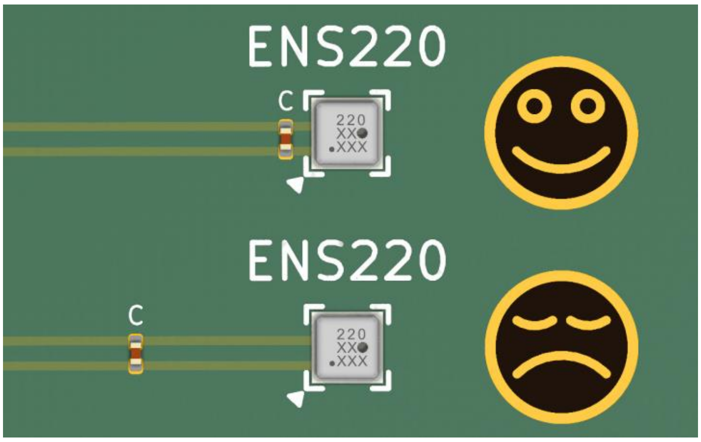

Figure 10. Minimize the distance of the decoupling capacitor to the power pads.

4.3 Thermal decoupling

Many components on a PCB generate heat, some of them substantially. This not only introduces distortions to the board, but also warms up devices which are in close thermal proximity to them. In this case the temperature measured by the ENS220 may not correspond to the actual temperature of the air. Additionally, fast thermal changes can temporarily reduce the accuracy of the measurement until the temperature of the sensor is uniform.

The ENS220 pressure output is temperature compensated with a highly accurate temperature sensor. Nonetheless, during fast temperature changes two effects appear which affect all capacitive pressure sensors:

- The temperature measured by the sensor might be different than the temperature of the sensing element which is always at the temperature of the air.
- Until there is a thermal equilibrium in the PCB, different areas will have different temperatures and expand in different magnitudes. This causes distortions on the PCB which could couple to the sensor.

The temperature effects may be compensated by placing several temperature sensors on the board. Please contact your local ScioSense representative for advice and algorithms for achieving this compensation.

Figure 11 presents an example of a cutout being used to isolate thermally a sensor from a hot device. For a cutout to be effective, the ground and power planes should not extend under the ENS220, as doing so would carry heat more effectively from the hot device to the sensor.

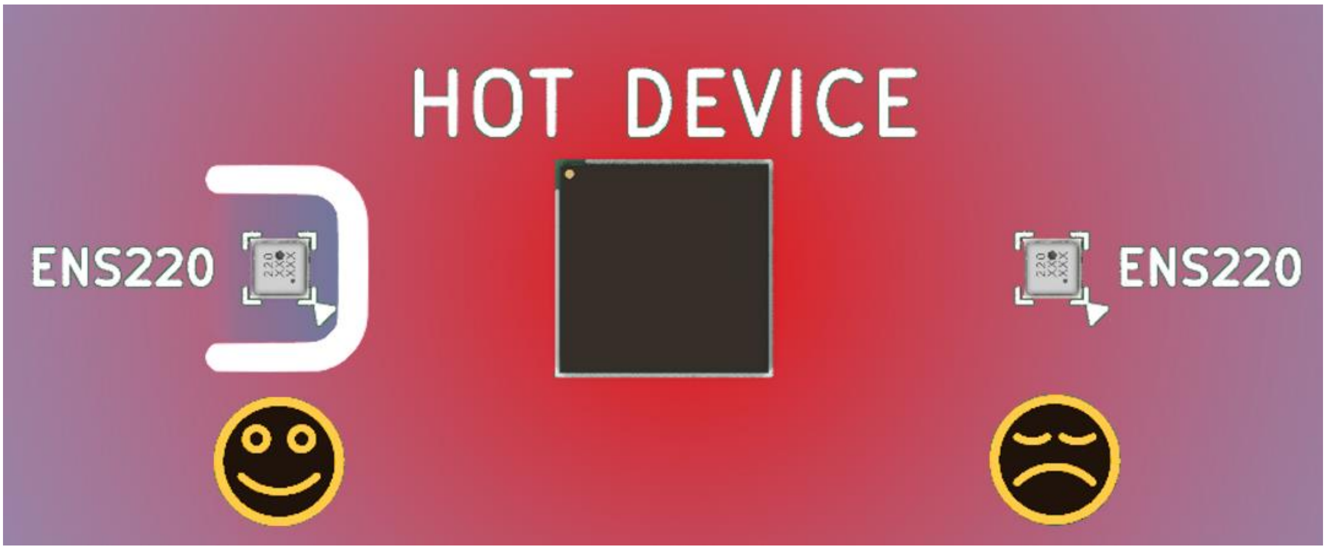

Figure 11. A cutout combined with not extending the power planes under the sensor is a good way of decoupling the sensor from heat sources when it is not possible to put it far away.

4.4 Mechanical stress decoupling

Deformations on a PCB can have many sources:

- **Mechanical fasteners.** By far the greatest factor that introduces stress to a PCB is the deformation imparted by the fasteners. Through these, the deformations of the rest of the structure will be transmitted to the PCB, and it will also limit its thermal expansion. Vibrations from the rest of the equipment also find their way into the board in this manner.
- **Thermal expansion.** The components and PCB substrate have a different expansion coefficient, and the mismatch will create forces on the component.
- **Thermal gradient.** A component that is sinking high amounts of heat into the PCB will generate a gradient of temperatures on the board. If a component is exposed to such gradients, the different temperatures it experiences might create mechanical distortions on it.
- **Direct contact with package.** In very tight-fitting devices, there might be components, heatsink pads, seals, etc. in direct contact with the package of the ENS220, thereby producing stress on the sensor.

The best solution is always to place the sensor away from all places where the PCB is subject to deformations. Nonetheless, this is often not possible in practice. Luckily, it is possible to reduce, or even eliminate, the effect of PCB deformations near the ENS220. In this regard, when there is available space, cutouts provide great improvements. The orientation of the sensor can also significantly improve the resistance to outside forces.

The ENS220 sensor does not have the same sensitivity to deformations from every direction. The direction between pins 4 and 9, the same direction as the letters on the package, is the least affected to external forces, as it is indicated on Figure 12.

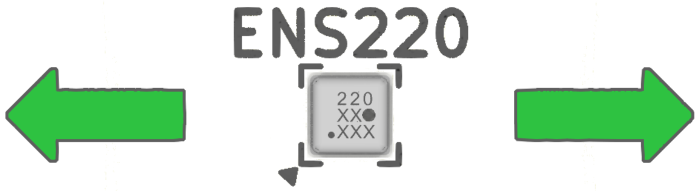

Figure 12. The device is more resistant to deformations from the direction of the green arrows (horizontal in the picture) than in other directions.

Figure 13 summarizes the comparative impact on the sensor of stresses under different directions and cutouts. To minimize the effect of distortions in one direction, the following are the actions to take from most to least effective:

- Move the sensor to an area that is not exposed to deformations (Section 4.5).
- Create a C-shaped cutout in which the belly of the cutout is pointing to the direction of the expected deformation.
- Align the axis formed by pins 4 and 9 with the direction of the expected deformation, as indicated in Figure 12.
- Place a slot perpendicular to the direction of the expected deformation.

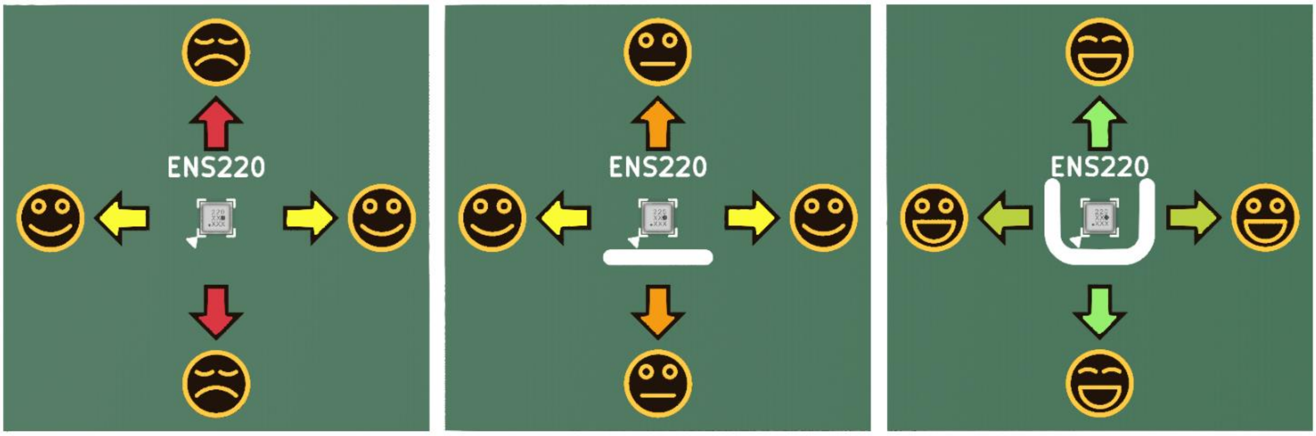

Figure 13. Effect of PCB deformations on the ENS220 measurement depending on the direction of the distortion and cutouts. The impact of the PCB deformation decreases from left to right.

4.5 Placement on PCB

A good positioning on the PCB ensures that the ENS220 will not be affected by external factors. The areas that are not ideal for the placement of the sensor are:

- Areas close to fixing points (screws, clamps, spacers, heatsinks coupled to the enclosure).
- Areas close to interaction elements (buttons, pogo pins, probing points).
- Attachment points of heavy components (electrolytic capacitors, inductor coils).
- Near components that generate lots of heat (regulators, microcontrollers, FPGAs).
- Near connectors.
- Areas where air flows are expected (active or passive cooling).

If the expected distortions in the board are known due to how the system will be stressed during use, then it is possible to calculate the best placement and orientation of the ENS220. Nevertheless, in most applications the stresses will be a product of the mismatch in thermal expansion between the PCB and the enclosure, stresses introduced during assembly into the enclosure, pressure exerted by heatsink pads, etc. These situations make it difficult to estimate the real distributions of stresses on the board.

As a rule of thumb, it is recommended to avoid placing the sensor in between the fixing points which are the closest to each other. The further away two mounting points are, the more uniform will be the distribution of deformations throughout the board, making the placement less critical.

Placing the sensor on an overhanging portion of the PCB will always be the best option for avoiding the coupling of distortions from the rest of the board. These areas are more prone to vibrations or PCB handling contamination, so a case-to-case evaluation should be done.

Even though this solution is in many cases not feasible, the use of cutouts on the board is a very effective method in every case, as described in Section 4.2. Figure 14 summarizes the previously presented information in one image.

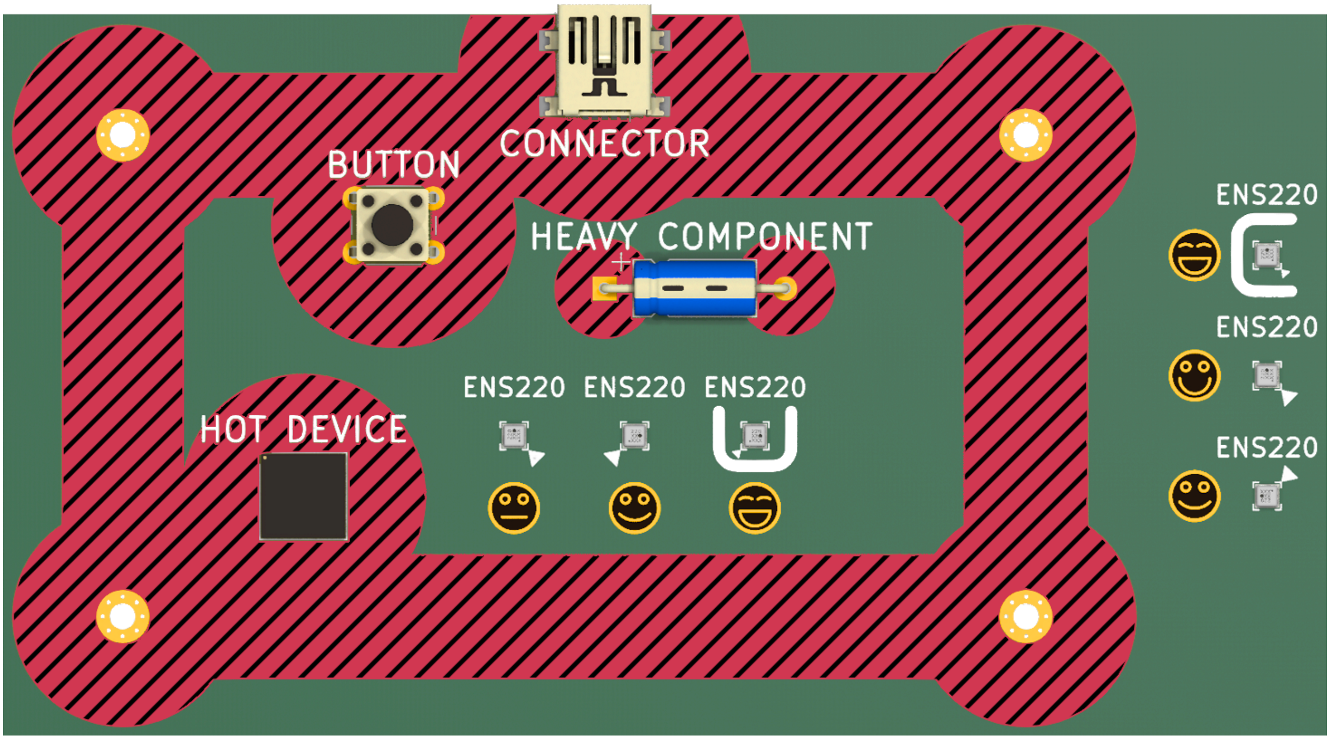

Figure 14. Layout suggestions, showing areas to avoid in red with stripes and preferred orientations. The orientation of the ENS220 is based on the long and short direction of the PCB, and whether the sensor is inside of the area enclosed by the mounting points or overhanging.

4.6 Recommendations for solder mask and silkscreen

Depending on the tolerances and capabilities of the PCB manufacturer, the solder mask expansion around the pads and the silkscreen clearance should be revised. If the manufacturer is not able to properly align the different layers two problems might arise:

- The solder mask extends over the pad.
- The silk screen ends up under the ENS220 package.

Both situations would cause the sensor to sit unevenly over the pads, and might lead to solder bridges, unsoldered pads, or mechanical stress on the package after soldering (which would affect the measurement accuracy).

When the accuracy of the manufacturer's alignment is not known, bigger solder mask expansions around the pads can be created, as well as increasing the clearance of the silkscreen to the package.

When increasing the solder mask expansion, the remaining solder mask width between pads should be taken into consideration. Each manufacturer has a minimum solder mask width they can produce. It is not recommended to remove the solder mask bridges between the pads, as doing so increases the risk of solder bridges.

5 Enclosure design considerations

The two main factors to consider when integrating a PCB with an ENS220 into an enclosure are temperature and air flow. If the objective is to measure the temperature of the outside air, which is the case in most applications, then it is best to place the ENS220 as close as possible to the air inlets to maximize the thermal contact with the exterior.

Nevertheless, the area close to the enclosure openings will also be a place where air typically flows, either forced (through a fan), or by natural convection. Because a fluid in motion changes its pressure, being close to the openings would mean measuring pressures that might deviate from the actual outside value. A balance must be achieved depending on the objectives and the design constraints between:

- Placing the sensor on the enclosure air inlets. Temperature readings are more accurate, but the pressure reading depends on the air flow.
- Placing the sensor close to the enclosure air inlets, but out of the air flow path. More consistent pressure readings, but there might be a temperature offset.

In all cases, the ENS220 should be placed always on the inlet side of the flow (to be closer to the outside temperature) and never downwind from a fan (the moving and turbulent air would create big changes in the pressure).

Figure 15 and Figure 16 evaluate the places where to put an ENS220 on an enclosure with forced convection (fan), while Figure 17 describes a vertical enclosure with natural convection cooling.

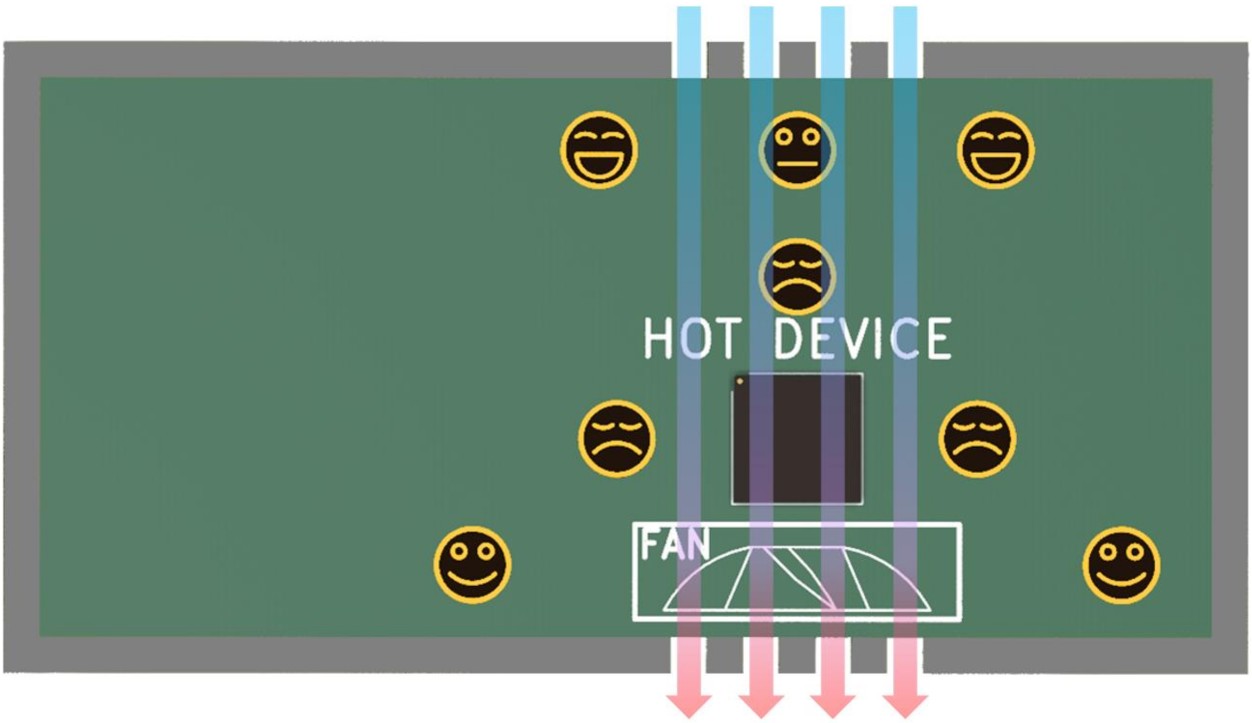

Figure 15. When a fan blows air outside the enclosure avoid the areas close to the hot device and the fan. Being directly on the air intake will improve the temperature accuracy but lower the pressure accuracy and noise.

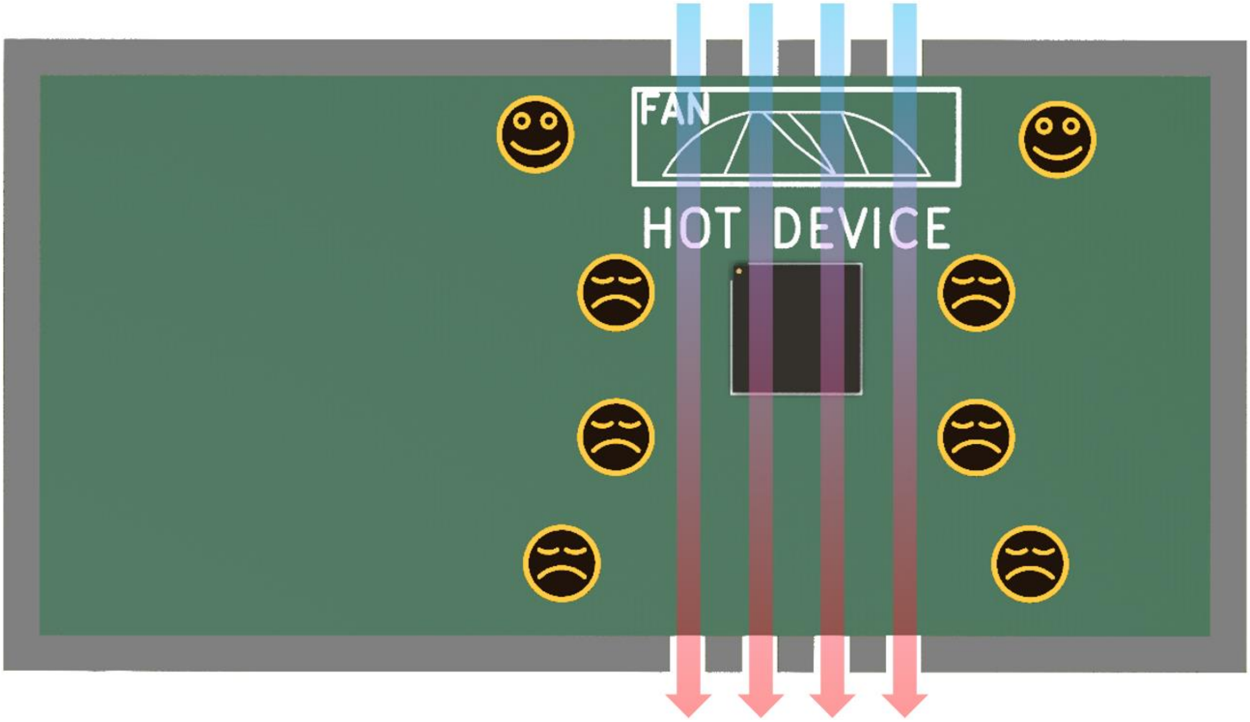

Figure 16. When a fan blows air inside the enclosure, the whole path of the air flow must be avoided, because it will affect negatively both the temperature and pressure measurements.

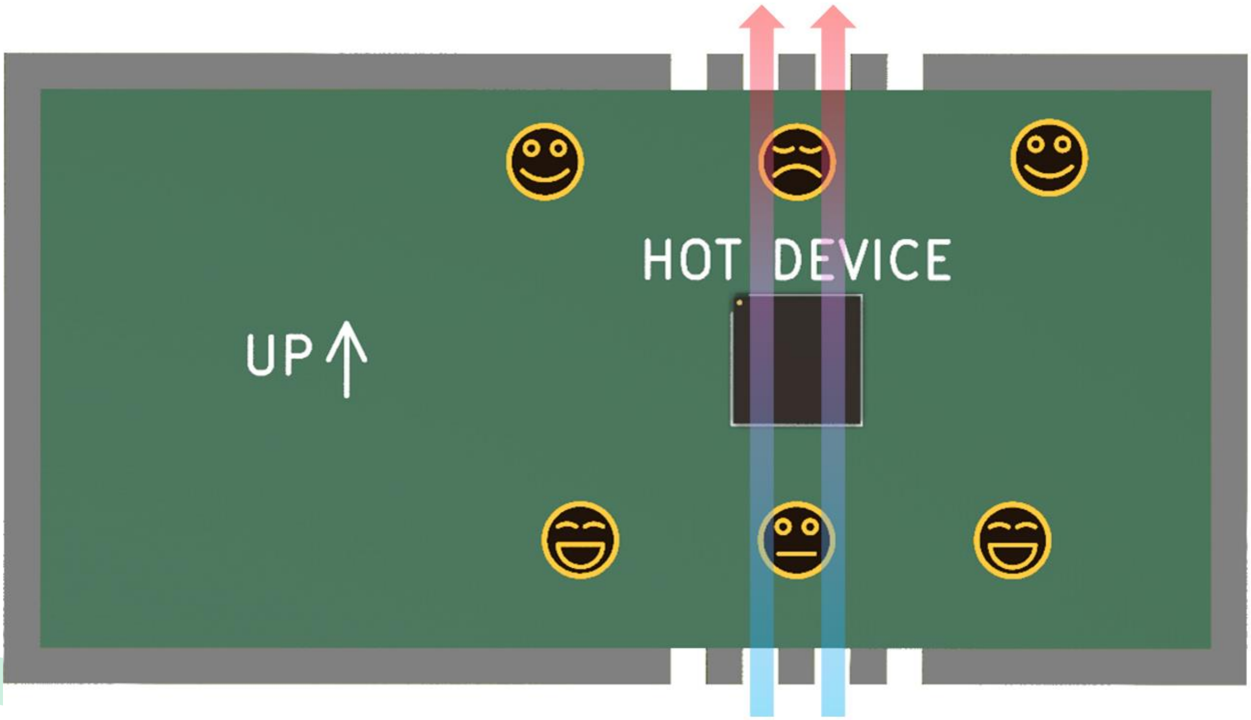

Figure 17. When an enclosure cools down by natural convection, avoid being above the heat generating elements. Being directly on the air intake will improve the temperature accuracy but slightly lower the pressure accuracy and noise.

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7 Revision information

Table 1: Revision history

Revision	Date	Comment	Page
1	15.12.2023	First edition	All

Note(s) and/or Footnote(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

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