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## LPS22DF digital pressure sensor: hardware guidelines for system integration

### Introduction

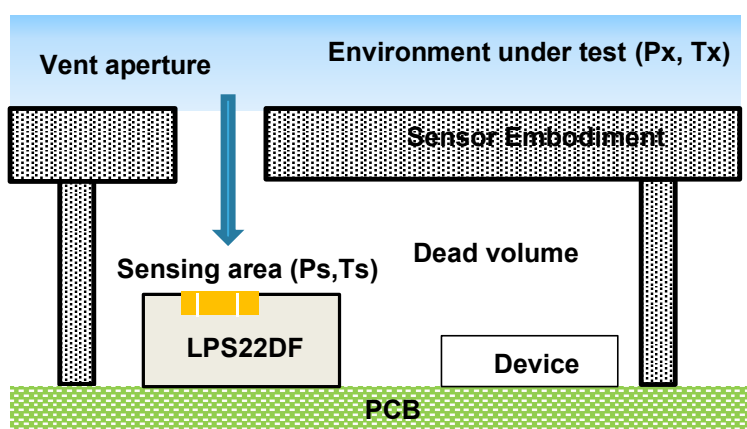
The purpose of this application note is to introduce guidelines for the hardware integration of the **LPS22DF** pressure sensor in the final application.

## 1 System integration

The integration of the LPS22DF pressure sensor as well as a temperature sensor in application systems such as portable devices like smartphones, wearable devices, weather stations, or industrial equipment shall be implemented without compromising the performance of the sensor. System integration can be done by looking at the main mechanical and geometrical parameters and the factors that influence sensor performance and thus optimizing those aspects.

A typical integration of the sensor is depicted in the following figure where the embodiment of the sensor has to be designed in order to get as much exposure as possible between the pressure ( $P_x$ ) and temperature ( $T_x$ ) conditions of the environment under test, and ( $P_s$ ,  $T_s$ ) that represent the conditions around the sensing area of the sensor, near the air vent aperture.

**Figure 1. Pressure sensor system integration**



Therefore, in order to get reliable and consistent measurements, all the parameters involved in the mechanical design must be dimensioned to get the maximum exposure of the sensor to the external environment and to get a faster response time, in terms of pressure and temperature, compatible with the required design specifications.

Every change in the "Environment under test" conditions must be reflected in the measurements reported by the sensor, also in the case of fast pressure and temperature variations. Therefore, the integration design must guarantee that the environmental conditions match the sensing area conditions not only in "steady-state" (static conditions) but also in dynamic conditions.

Deviations between the conditions under test and the conditions around the sensing area are also influenced by sources of heat coming from other devices close to the sensing area or the self-heating of the sensor. Changes in temperature are critical as not only the temperature is influenced, but changes in temperature also determine pressure deviations and, as a consequence, a slower response of the system.

Based on the previous considerations, the design optimization consists of determining the following main topics:

1. The appropriate placement of the sensor in the system
2. The embodiment and housing of the sensor
3. The protection of the sensor from dust, water, or chemical solvents using a sensor chamber in the presence of a harsh environment

These elements are further described in the following section of this document.

## 2 Mechanical design rules

For the mechanical design, the main constraints and features to be considered are described in the following sections and provide a set of basic rules such as good design practices for a successful integration of the sensor in the final application.

### 2.1 Sensor placement

The placement of the sensor, in terms of exposure to the environment, thermal propagation, and mechanical stress, has a direct impact on its performance.

#### 2.1.1 Exposure to the environment

To maximize the exposure to the environment of where to measure pressure and temperature, the sensor has to be placed in static and dynamic operating conditions.

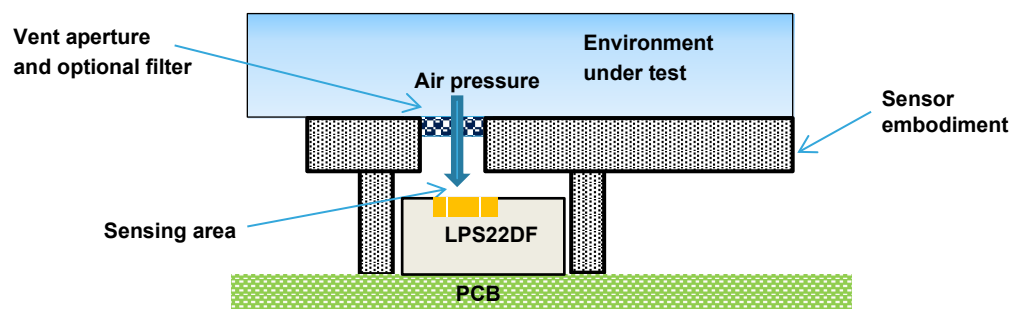
In **static conditions**, or steady-state, after a change in the pressure and the temperature environment and their stabilization, the sensing conditions must be the same as the conditions under test, or very close to the target value, depending on the application tolerance and specifications.

In **dynamic conditions**, in the presence of fast changes of the conditions under test, the sensor must be able to provide a reliable measurement output able to follow the dynamic of the environment. At the end of the design of the sensor integration, the overall response time will be modified, and the final performance shall match the target specifications. In general, the target is to avoid a design with a response time slower than the product specifications. In order to maximize sensor performance in static and dynamic conditions after system integration, depending on the design specifications the following guidelines are recommended, with reference to [Figure 2](#):

1. Position the sensor to get the best exposure to the environment under test, as close as possible to the vent aperture.
2. A large dead volume increases the response time, with a bigger contribution to the pressure response time; therefore it is recommended to minimize the volume, trying to tailor the housing to the geometry of the sensor.
3. The vent aperture should be as large as possible.
4. The depth of the vent aperture must be minimized.

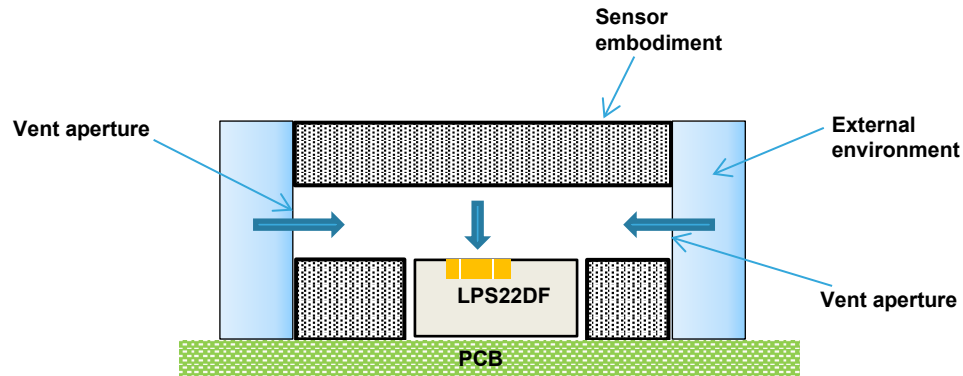
As a reference for design integration, [Figure 2](#) describes an example of the above recommendations. In order to maximize the environmental exposure and therefore to get a fast response time, the volume around the sensor (dead volume) is minimized and the vent size aperture has the same order of magnitude as the sensing area. A filter membrane protection has been added, in order to protect the sensor from water or a harsh environment.

**Figure 2. Pressure sensor integration and embodiment reference**



A different implementation, more expensive but more efficient in terms of sensing performance, is the design with an air flow structure, described in the following figure. The design with multiple vent apertures is a more expensive solution, but provides, depending on the design specifications, a faster response time.

**Figure 3. Pressure sensor integration and embodiment with vent channel**



It is useful to emphasize that the sensor can work properly even if it is placed in the final application without considering any dedicated hole (vent aperture) unless it is not hermetically sealed. The design guidelines previously outlined are to maximize top performance.

### 2.1.2 Heat propagation

The presence of heat sources near the sensor can deteriorate its performance by modifying pressure and temperature measurements as well as generating thermal gradients around the sensing area that affect the correct measurement in static and dynamic conditions.

We recommend design guidelines in order to avoid these effects, but we remark that an increase in temperature impacts performance and is strongly attenuated by the embedded temperature compensation of the LPS22DF device.

From a physical point of view, these local sources act like a thermal capacitor placed in parallel to the thermal model of the LPS22DF and they can contribute to the local temperature, which is different from the environmental temperature.

Depending on the location of the heat sources and the propagation of the heating mechanism, we can distinguish heat transfer related to different mechanisms as described below.

- Convection heat

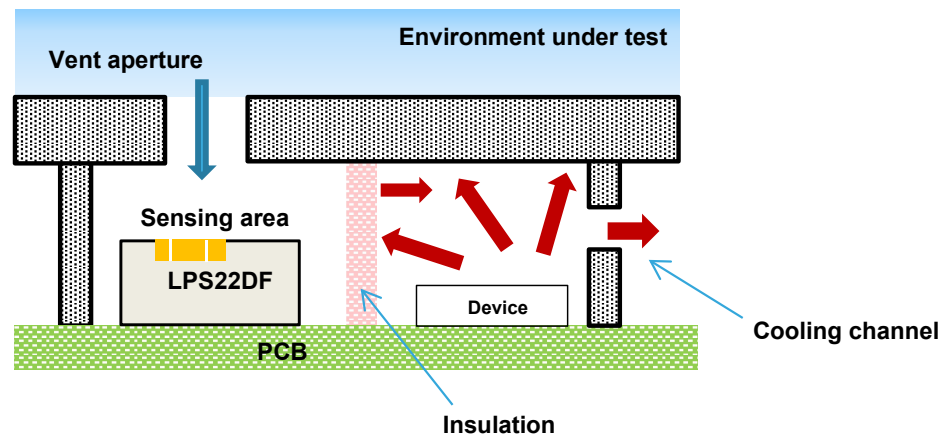
Local thermal sources around the sensor can modify the pressure and temperature measurement by their radiant heat.

Typical sources are as follows:

- Other sensors and devices close to the pressure sensor
- Power management devices
- GPS modules
- Processors and microcontrollers
- LCD displays that, in particular, provide a significant temperature gradient between the environment and the dead volume inside the system.

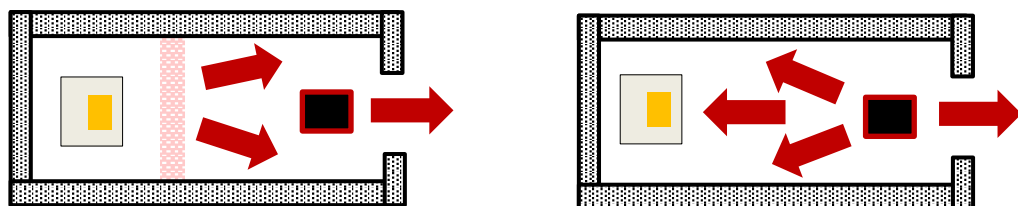
Therefore, the sensor has to be placed at the correct distance from these sources and in order to guarantee the appropriate isolation, it is recommended to adopt some insulating structures inside the embodiment as described in [Figure 4](#). It is also recommended, according to the specific layout, to implement a vent aperture close to the heat source, which acts as a cooling channel.

Figure 4. Insulation implemented for protecting the sensor



Looking at a section of the sensor housing, Figure 5 shows a correct design with the insulating structure on the left; the heat source is far from the sensor and a thermal protection structure is placed in the middle. On the right, an incorrect design is depicted, indicating heating of the sensor because of the radiant heat coming from the component nearby.

Figure 5. Top view of the sensor housing: on the left a correct design with insulation, on the right an incorrect design without insulation



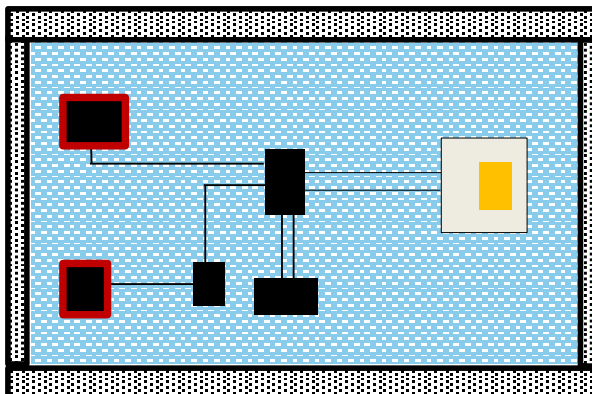
### Heat conduction

Thermal conduction mostly occurs through the metal lines on the PCB and through the PCB itself.

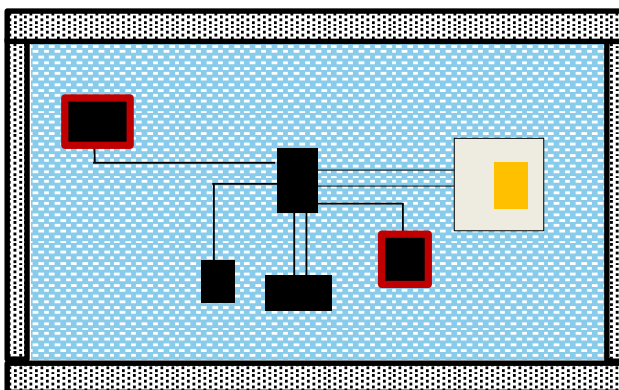
In order to reduce this effect, we recommend adopting thin metal lines around the sensor, at an appropriate distance from the sensor and potential heat sources, avoiding metal areas near and under the device.

A good design rule is provided in Figure 6. As an example of a correct design, it describes the positioning of heat-generating devices, on the left, as far as possible from the sensor, and Figure 7 illustrates an incorrect layout with heat-generating devices placed too close to the sensor on the right. In both cases thinner metal lines have been adopted.

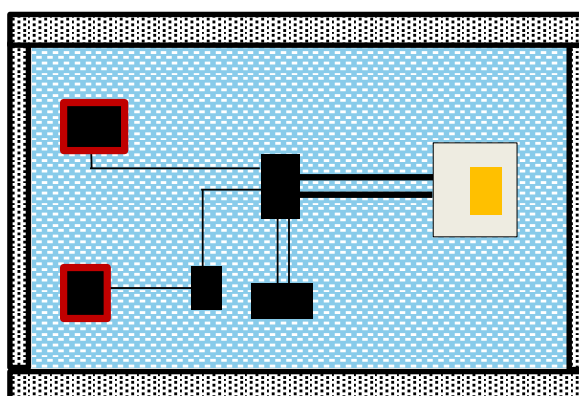
**Figure 6. Correct placement of sensor on the PCB to isolate from heat sources**



**Figure 7. Incorrect placement of sensor on the PCB**



**Figure 8. Incorrect wiring to sensor on the PCB**



In [Figure 8](#) an incorrect size of metal lines has been adopted, the bigger dimensions provide a higher level of heat conduction. In [Figure 7](#), the incorrect placement of the sensor, close to a device generating too much heat, results in a deteriorated performance of the sensor.

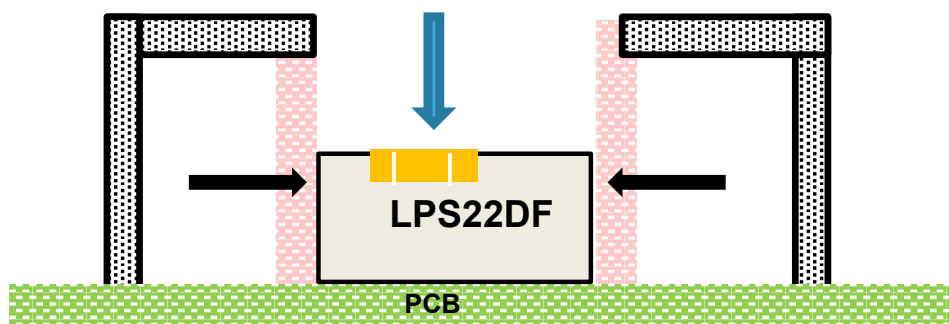
In both cases of thermal transfer, an infrared-based thermal analysis of the whole system, executed while running under different operating conditions, is the right approach for identifying the appropriate sensor location.

### 2.1.3 Mechanical stress

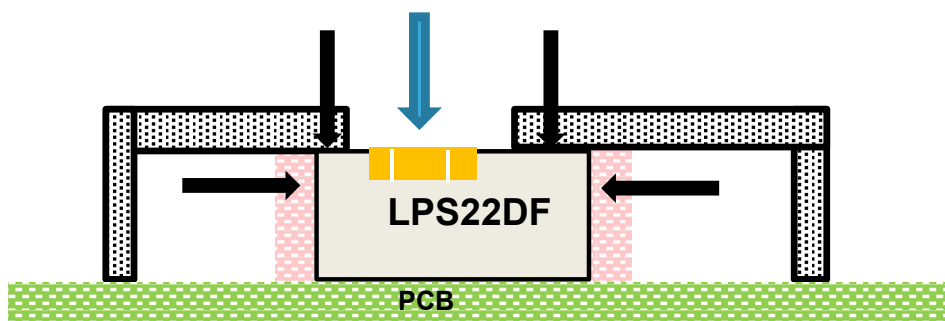
Placement of the sensor shall be to avoid any mechanical force applied to it, either directly due to incorrect mechanical system design, or indirectly due to user interaction with the system in the case of wearables or portable devices.

The following figures show correct and incorrect integration cases where, with the goal of reducing the dead volume around the sensor to improve the pressure response time, the embodiment structure is directly in contact with the sensor package, creating mechanical stress that can deteriorate the performance of the sensor. A minimal clearance has to be maintained as in Figure 11. Correct configuration for avoiding mechanical stress and reducing the dead volume (a) and Figure 12. Correct configuration for avoiding mechanical stress and reducing the dead volume (b) to avoid any force applied on the sensor and minimize the dead volume as well.

**Figure 9. Incorrect configuration for mechanical stress (a)**



**Figure 10. Incorrect configuration for mechanical stress (b)**



**Figure 11. Correct configuration for avoiding mechanical stress and reducing the dead volume (a)**

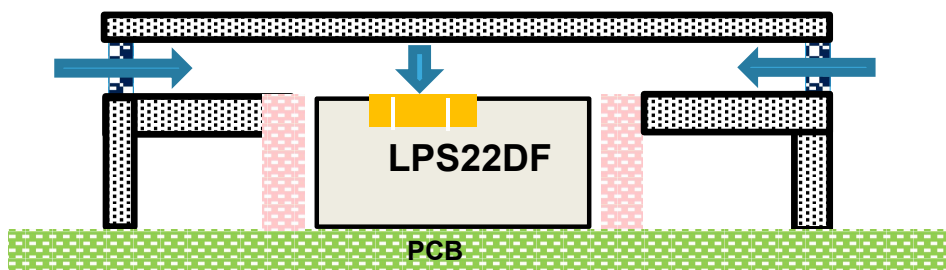
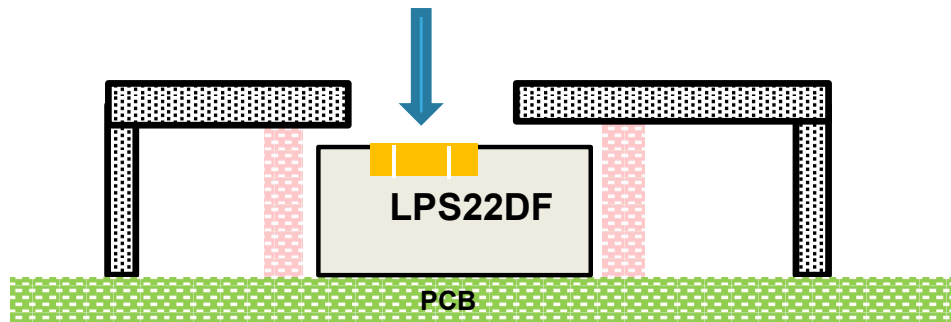


Figure 12. Correct configuration for avoiding mechanical stress and reducing the dead volume (b)



## 2.2 Sensor embodiment and housing

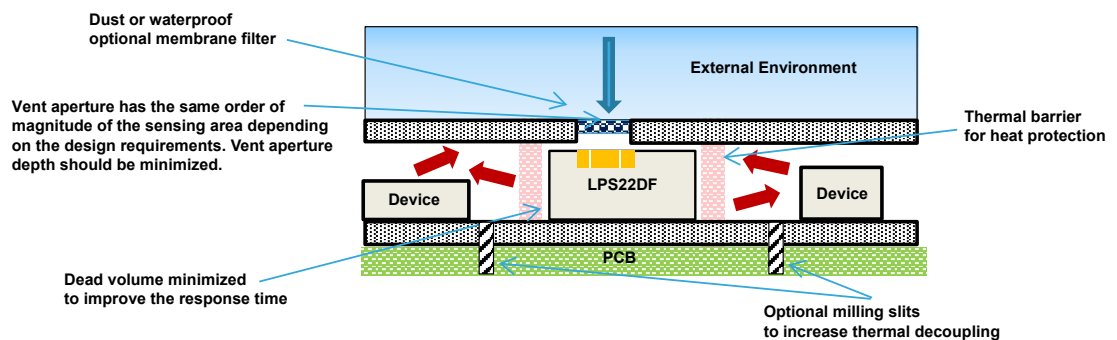
The sensor embodiment in the system shall match as much as possible the recommendations previously highlighted for the placement of the sensor and, additionally, has to provide all the features required of a specific application such as rendering it waterproof, water-resistant, or resistant to a harsh environment.

Furthermore, the customer design of the device shall guarantee the air circulation from the environment to the sensing area, first from the environment (outside) to the customer device (inside), then internally from the aperture to the sensor housing and sensing element as well. The more efficient the air circulation in this path, the better the performance will be.

The air path shall be well identified and sized in order to maximize the airflow, and as a result, the final performance of the integrated system.

The figures below represent a summary of a good case versus a bad case of sensor embodiment and housing. In Figure 13 a good design is described including also an optional filter membrane and PCB cuts to increase thermal decoupling which is a solution for the specific case where the devices around the pressure sensor are generating too much heat. Attention has to be paid to material heat conduction properties to avoid overheating the pressure sensor. Optional "milling slits" can also be adopted.

Figure 13. Example of correct sensor embodiment and housing





**Figure 14. Example of correct sensor embodiment and housing with airflow channel**

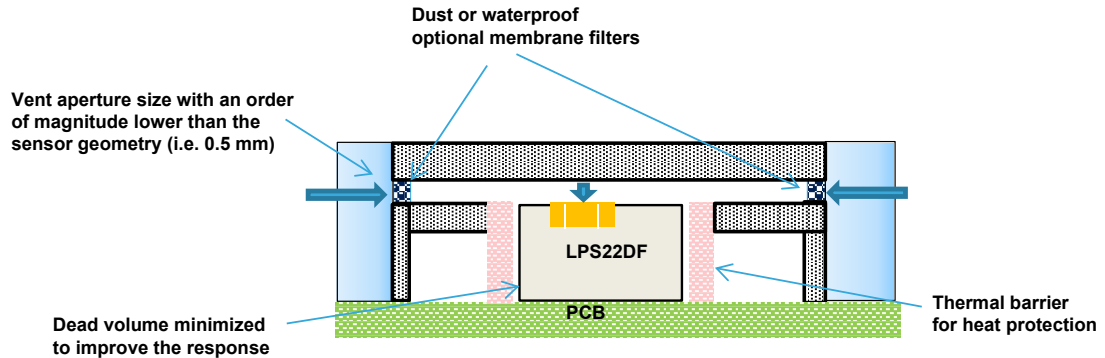
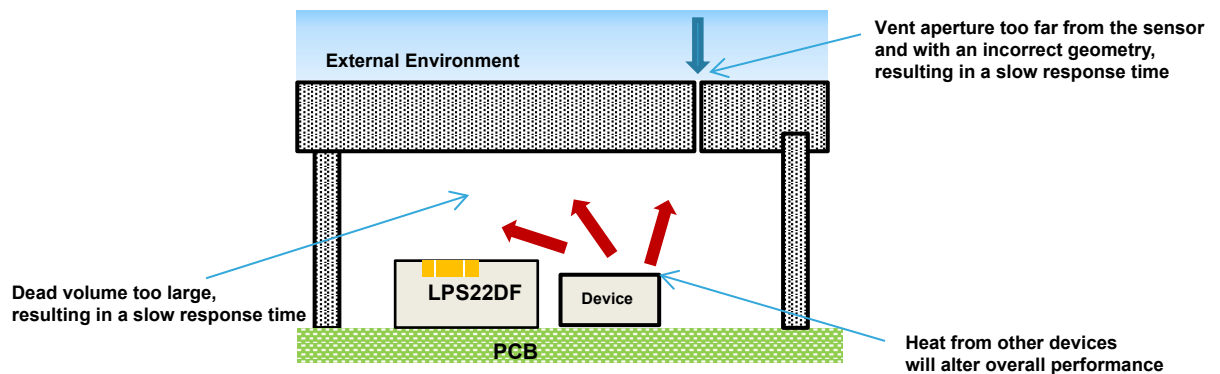


Figure 14 describes a good design, related to a more efficient implementation with two vent apertures in order to get better exposure to the external environment under test that results in higher efficiency in terms of response time and an extremely small dead volume. In this example the size of the vent apertures is an order of magnitude less than the dimension of the sensor, for example an aperture of 0.5 mm provides a good response time and an excellent level of integration for a PD application.

In Figure 15, an incorrect design is illustrated, with a very low efficiency of the final design, in terms of response time and the sensor under the effects of heat coming from other devices.

**Figure 15. Example of incorrect sensor embodiment and housing**



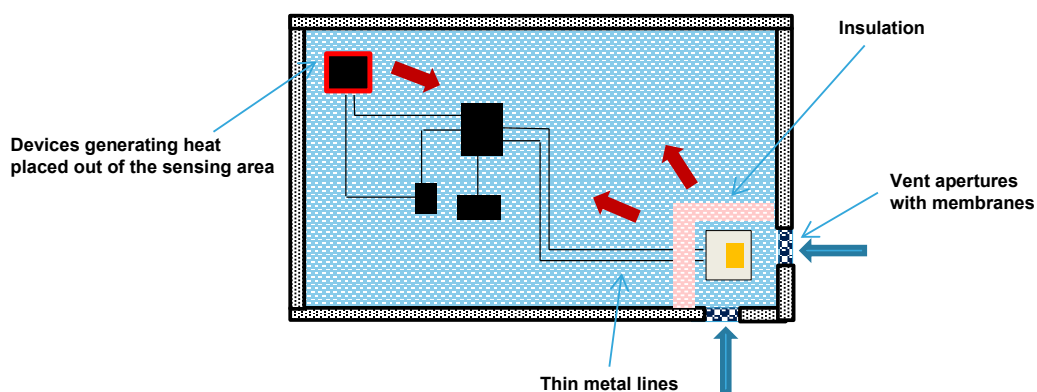
## 2.3 Sensor protection

An optional filter can be adopted to protect the sensor from dust, water, or chemical solvents in the presence of a harsh environment or if needed for waterproof applications. The key factor for this kind of implementation is the appropriate choice of the membrane, according to the design requirements and taking into account that the membrane material provides a slower response time, in particular in terms of pressure response time. The integration of the sensor should protect it from light as well, therefore, inside the application the sensor should be housed in a dark place where light cannot reach the sensing element.

### 3 Reference design: integration and housing in a personal device

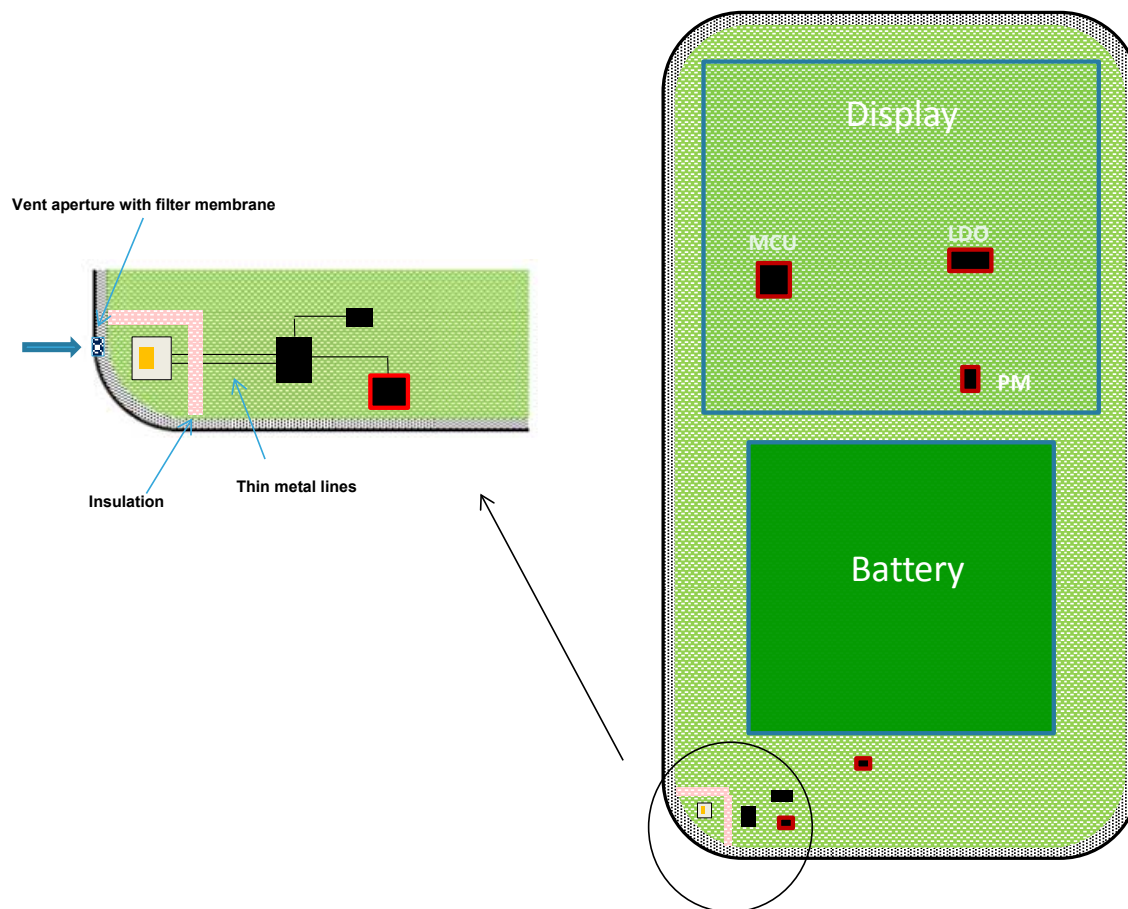
The example below describes how the sensor placement is implemented by following the basic rules described in this document, in other words by mounting the sensor as far as possible from the main sources of heat present on the board like the display, PM modules, GPS modules, LDO, and microcontroller that represent the more critical sources of heat. Figure 16 illustrates the integration of the sensor in a sensor chamber isolated from heat sources and with two vent apertures covered with filter membranes. This solution provides at the same time an efficient response time and a good protection from dust and light. In the case of a waterproof device, a sensor chamber with one vent aperture is preferred.

**Figure 16. Integration of the digital pressure sensor device in a sensor chamber with two vent apertures**



Based on the above recommendations, Figure 17 depicts the integration in a portable device of the digital pressure sensor in the bottom left corner. In this solution, a single vent aperture has been adopted (diameter in the range of 0.5 mm), placing the sensor in the left corner to simplify the integration with the mechanical case and to maintain the right distance from other sources of heat. A filter membrane is also inserted for dust and water protection, depending on the specific application.

Figure 17. Device integration reference in a portable device



## Revision history

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Date	Version	Changes
18-Jul-2023	1	Initial release

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