AN5063
Application note

LPS33HW digital pressure sensor: guidelines for system integration

Introduction

The purpose of this application note is to introduce guidelines for the system and hardware integration of the LPS33HW water-resistant pressure sensor in the final customer application.

This document does not modify the content of the official datasheet. Please refer to the datasheet for parameter specifications.

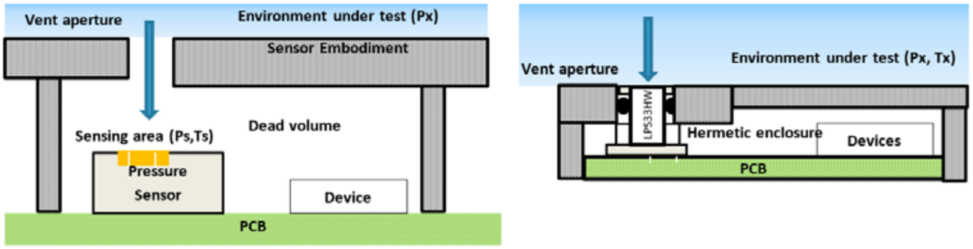
Contents

1 System integration

The integration of the LPS33HW pressure and temperature sensor in application systems such as portable devices (PDs) like smartphones, wearable devices, weather stations or industrial tools shall be implemented without compromising the performance of the sensor. System integration can be done by looking at the main mechanical and geometric parameters and the factors that influence the performance of the sensor and thus optimizing those.

The typical scenario for integration of pressure sensors is described in *Figure 1: "Pressure sensor system integration (a) standard pressure sensor, (b) LPS33HW water resistant pressure sensor "* where the housing of the sensor has to be designed in order to correspond as much as possible to the pressure and temperature conditions of the environment under test (Px, Tx) and the conditions around the sensor sensing area (represented by Ps, Ts), near the air inlet housing.

Figure 1: Pressure sensor system integration (a) standard pressure sensor, (b) LPS33HW water resistant pressure sensor



(a) Pressure sensor standard integration

(b) Water-resistant pressure sensor

The LPS33HW is featured as a water-resistant device which means that it can be exposed to water pressure without damage and recovers after stress from water pressure. In water-resistant application contexts such as smart watches and bracelets, it is a common design practice to have the pressure sensor in communication with the external environment through one hole and to keep it isolated from the other devices placed in the hermetic enclosure by means of an appropriate cylinder-shaped housing and the use of O-rings as shown in figure 1.b. More details are given in the next paragraphs.

In order to obtain reliable and consistent measurements, all parameters involved in the mechanical design must be dimensioned to provide robustness to air or water overpressure, to get maximum sensor exposure to the external environment, and to get the fastest response time, in terms of pressure and temperature, compatible with the required design specifications.

Every change in an environmental condition under monitoring must be consistently reflected in the sensor measurement as well as in the case of fast variations of pressure and temperature. Therefore, the design integration 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 heat sources, due to other devices close to the sensing area or the self-heating of the sensor. Changes in temperature are critical due to the fact that not only the temperature is influenced, but changes in temperature will also determine pressure deviations and, as a consequence, a slower response of the system.

Based on the considerations above, the design optimization consists of determining the:

- placement of the sensor in the system
- embodiment and housing of the sensor
- protection of the sensor from dust, water, or chemical solvents by a sensor chamber (in the presence of a harsh environment)

The elements above are further described in the following sections 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 for good design practices in order to have a successful integration of the sensor in the context of the final application.

2.1 Sensor placement

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

2.1.1 Exposure to the environment

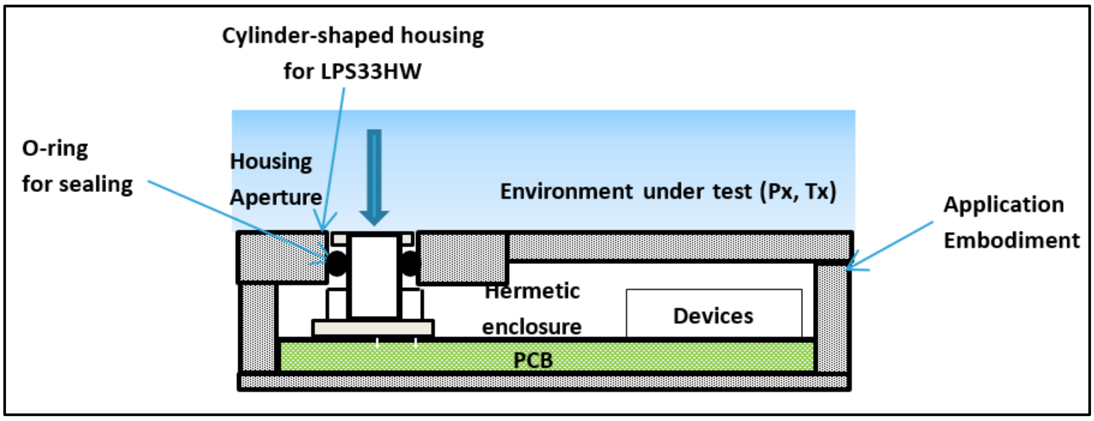
One key design rule is to maximize the exposure of the pressure sensor to the environment where pressure and temperature are measured. In other words, the sensor has to be positioned in such a way to react to rapid changes in environmental conditions and provide a reliable measurement following the dynamics of environmental changes.

The integration design of the pressure sensor clearly impacts the overall response time. Typically the design target is to match the pressure sensor performance according to the datasheet. The guidelines below are recommended, with reference to *Figure 2: "Pressure sensor integration and housing reference"* for achieving this objective:

1. Place the sensor to get the best connection with the environment under test, as close as possible to the vent apertures
2. A large dead volume will increase the response time, with a bigger contribution/delay to the pressure response time. It is therefore recommended to minimize the volume, trying to shape a tailored housing around the geometry of the sensor.
3. Vent apertures should be as large as possible.
4. The depth of the vent apertures must be minimized.

As a reference for system integration design, *Figure 2: "Pressure sensor integration and housing reference"* describes an example of the above recommendations.

Figure 2: Pressure sensor integration and housing reference



2.1.2 O-rings for sealing

In wearable and portable applications, it is necessary to add a sealing mechanism such as an O-ring in order to avoid that direct water or other liquids reach the PCB or other zones of the customer application as depicted in *Figure 2: "Pressure sensor integration and housing reference"*. For such applications the LPS33HW provides the possibility to seal and protect the embodiment by an O-ring placed at the groove location (mid part of the metal lid). Simulation results show that the surface contact pressure between an O-ring of 1 mm diameter and two contact sides (lid of the LPS33HW and plastic embodiment) is 1.45 Mpa by applying the geometries in *Figure 4: "Groove for O-ring, simulation with O-ring applied to LPS33HW"*. Therefore, sealing can be guaranteed until fluidic hydrostatic pressure is less than contact pressure (i.e. 10 bar (1 Mpa) ≤ 1.45 Mpa).

Figure 3: O-ring placement

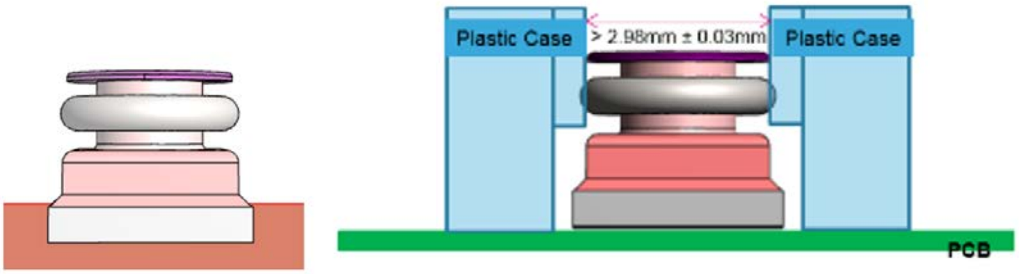
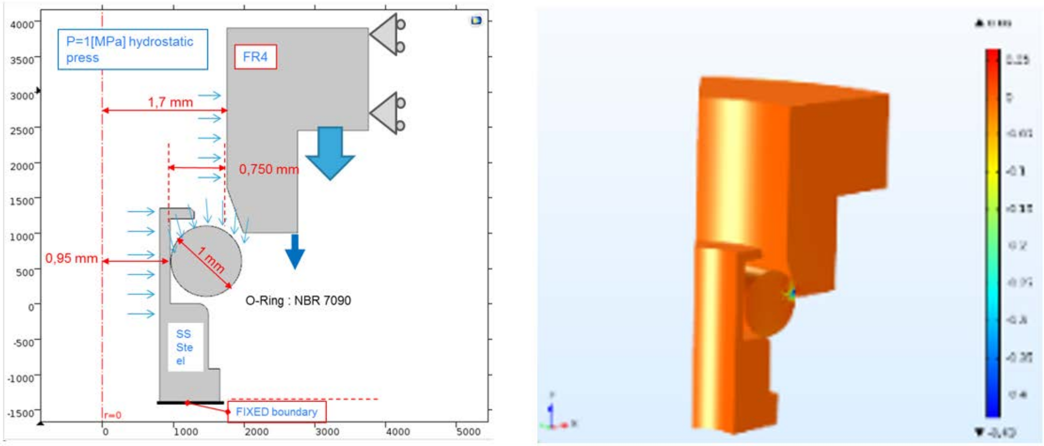


Figure 4: Groove for O-ring, simulation with O-ring applied to LPS33HW



The thickness of the O-ring needs to be sized in order to fit the housing and to apply a sealing force for resisting to 10 bar fluidic pressure according to the device specification. It is recommended to use an O-ring made of nitrile rubber 70 Shore A with an inner diameter from 1.15 mm (for example with thickness of 1.0 ± 0.03 mm) to 1.8 mm (for example with thickness of 0.8 ± 0.03 mm). The O-ring selection depends on the customer application geometries, specifically the cylinder-shaped housing geometries. The information provided above about the O-ring is given exclusively as general information and shall not be considered as qualified for any customer application.

2.1.3 Heat propagation

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

From a physical point of view, these local sources act as a thermal capacitor placed in parallel to the thermal model of the LPS33HW and they can contribute to the local temperature which is different from the environmental one.

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

2.1.3.1 Heat convection

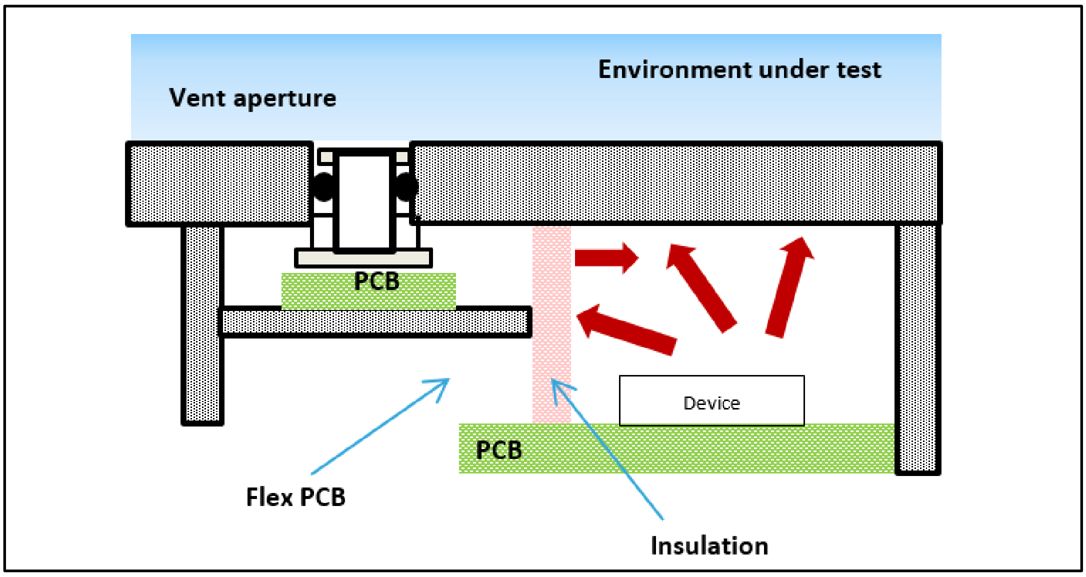
Local thermal sources around the sensor can modify the pressure and temperature measurement by radiating heat.

Typical sources are as follows:

- other sensors and devices close to the pressure sensor
- power management devices
- processors and microcontrollers
- LCD displays that, in particular, provide a significant temperature gradient between the environment and the dead volume inside the system

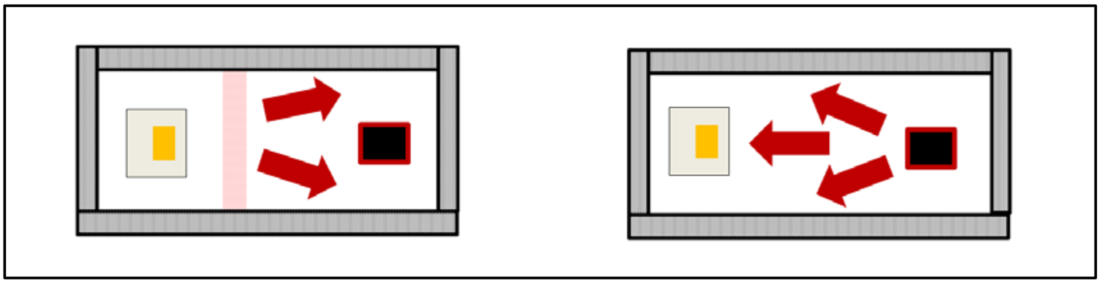
Therefore the sensor has to be placed at the correct distance from these sources, and to guarantee the appropriate isolation, it is recommended to adopt inside the embodiment, heat insulation structures as described in *Figure 5: "Insulation from heat implemented for protecting the sensor"*. A flexible PCB can be used to place the pressure sensor far from the main board and to position the LPS33HW as close as possible to the external environment.

Figure 5: Insulation from heat implemented for protecting the sensor



Looking at a section of the sensor housing, *Figure 6: "Top view of the sensor housing: on the left a correct design with insulation from heat, on the right an incorrect design"* depicts a correct design with the insulation 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 described, causing heating of the sensor because of the heat radiating from the component nearby.

Figure 6: Top view of the sensor housing: on the left a correct design with insulation from heat, on the right an incorrect design



The solution of a cooling channel is not applicable for water-resistant applications. It is important to emphasize that the LPS33HW has an embedded quadratic compensation that allows minimizing the effect of temperature in the measurement of pressure. In this context the recommended design is just to introduce a thermal insulation layer but without a cooling channel.

2.1.3.2 Heat conduction

Thermal conduction mostly occurs through the metal lines on the PCB and 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 7: "Examples of correct sensor placement on the PCB to obtain appropriate isolation from heat sources"* as an example of a proper design. On the left the devices generating heat are positioned as far as possible from the sensor. Thinner metal lines have been used which contribute to minimizing the thermal effect.

Figure 7: Examples of correct sensor placement on the PCB to obtain appropriate isolation from heat sources

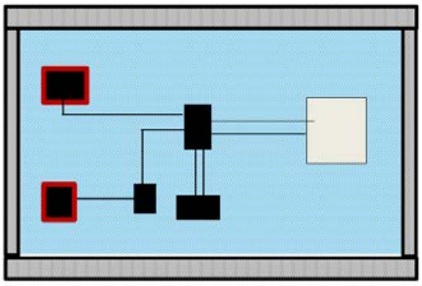
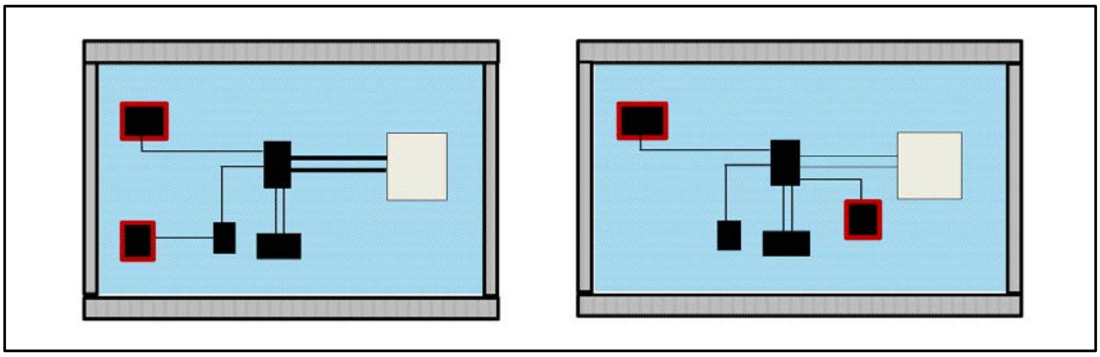


Figure 8: Example of incorrect sensor wiring on the PCB



In *Figure 8: "Example of incorrect sensor wiring on the PCB"*, the left side of the figure in the example shows that the wrong size of metal lines have been used. The bigger dimensions provide a higher level of heat conduction. On the right, the incorrect placement of the sensor, close to a device generating too much heat, deteriorates the performance of the sensor. In both cases of thermal mechanism propagation, an infrared-based thermal analysis of the whole system, running under different operating conditions, is the right approach for identifying the appropriate sensor location.

2.1.4 Mechanical stress

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

In other words, the final assembly must be free of hard contact or shearing forces between the LPS33HW and the cylinder of the housing.

Figure 9: Incorrect configuration for mechanical stress

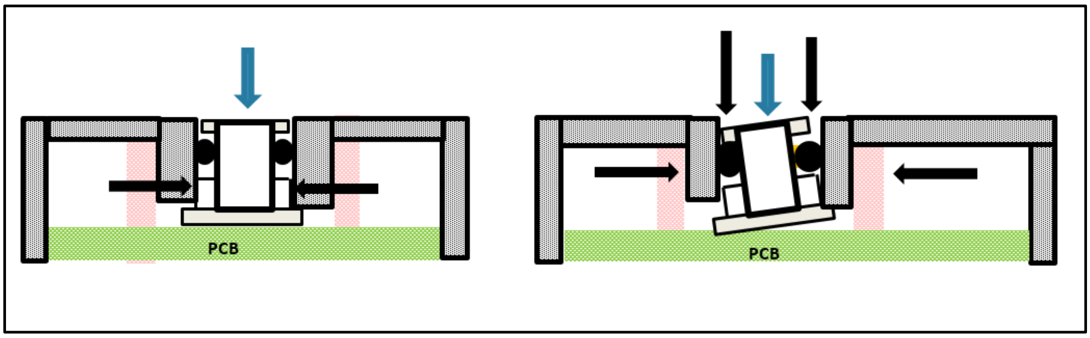


Figure 9: "Incorrect configuration for mechanical stress" above shows examples of incorrect integration where the embodiment structure is directly in contact with the sensor package, causing mechanical stress that can cause deterioration of the performance of the sensor. Thus, a minimal clearance has to be maintained to avoid any force applied to the sensor, also taking into consideration manufacturing tolerances.

2.1.5 Light exposure

Direct exposure of the sensor to light shall be avoided.

2.1.5.1 Sensor embodiment and housing

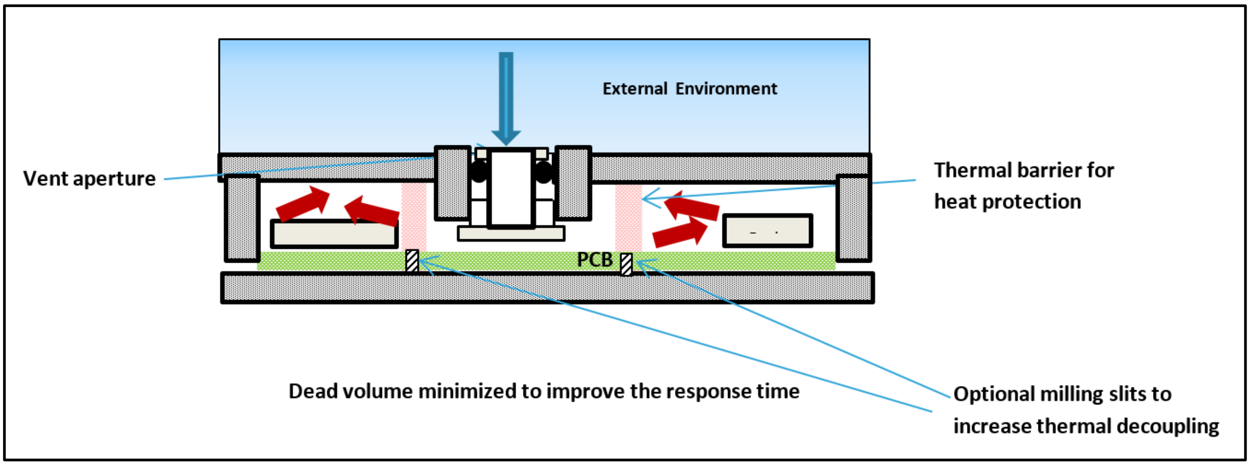
The sensor housing in the system shall match as much as possible the recommendations previously highlighted for sensor placement and, additionally, shall provide all the features required of the specific application (waterproof, water-resistant or resistant to a harsh environment).

Furthermore, the design of the customer application shall guarantee the circulation of air from the environment (outside) to the pressure sensor (inside). The more efficient the air circulation is in this path, the better the performance will be as well.

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.

Figure 10: "Example of correct sensor embodiment and housing" represents a summary of a correct example of sensor embodiment and housing. It also includes milling slits to increase thermal decoupling which is a solution for the specific case where the devices around the pressure sensor are generating too much heat.

Figure 10: Example of correct sensor embodiment and housing



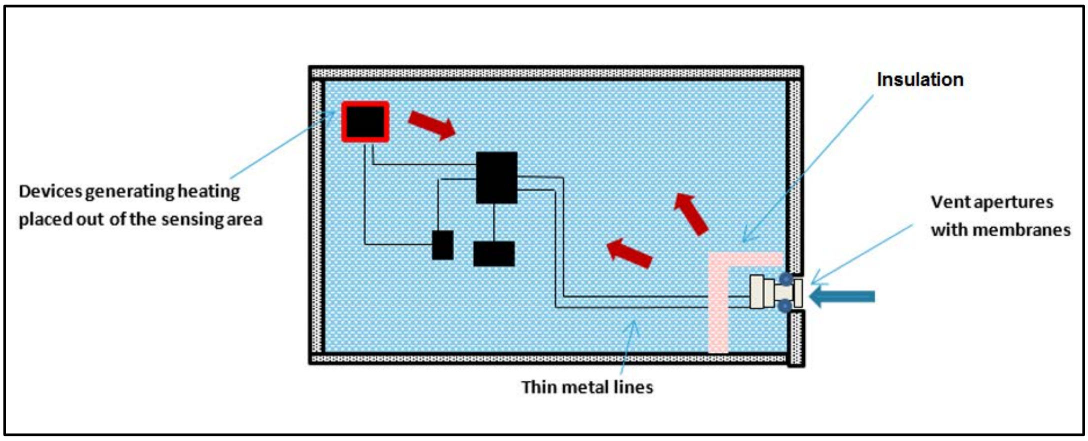
2.1.5.2 Sensor protection

An optional filter can be adopted as a protection of the sensor from dust or from chemical solvents in the presence of a harsh environment. The key parameter for this kind of implementation is the appropriate choice of the membrane according to customer design requirements and taking into account that the membrane material may cause a slower response time, in particular in terms of pressure response time.

3 Reference design: integration and housing on a PD

The example below describes how 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 such as display LCDs and microcontrollers that represent the more critical sources of heat. *Figure 11: "Integration of the LPS33HW in a sensor chamber with vent apertures"* depicts the integration of the sensor in a sensor chamber insulated from heat and with one vent aperture sealed by an O-ring.

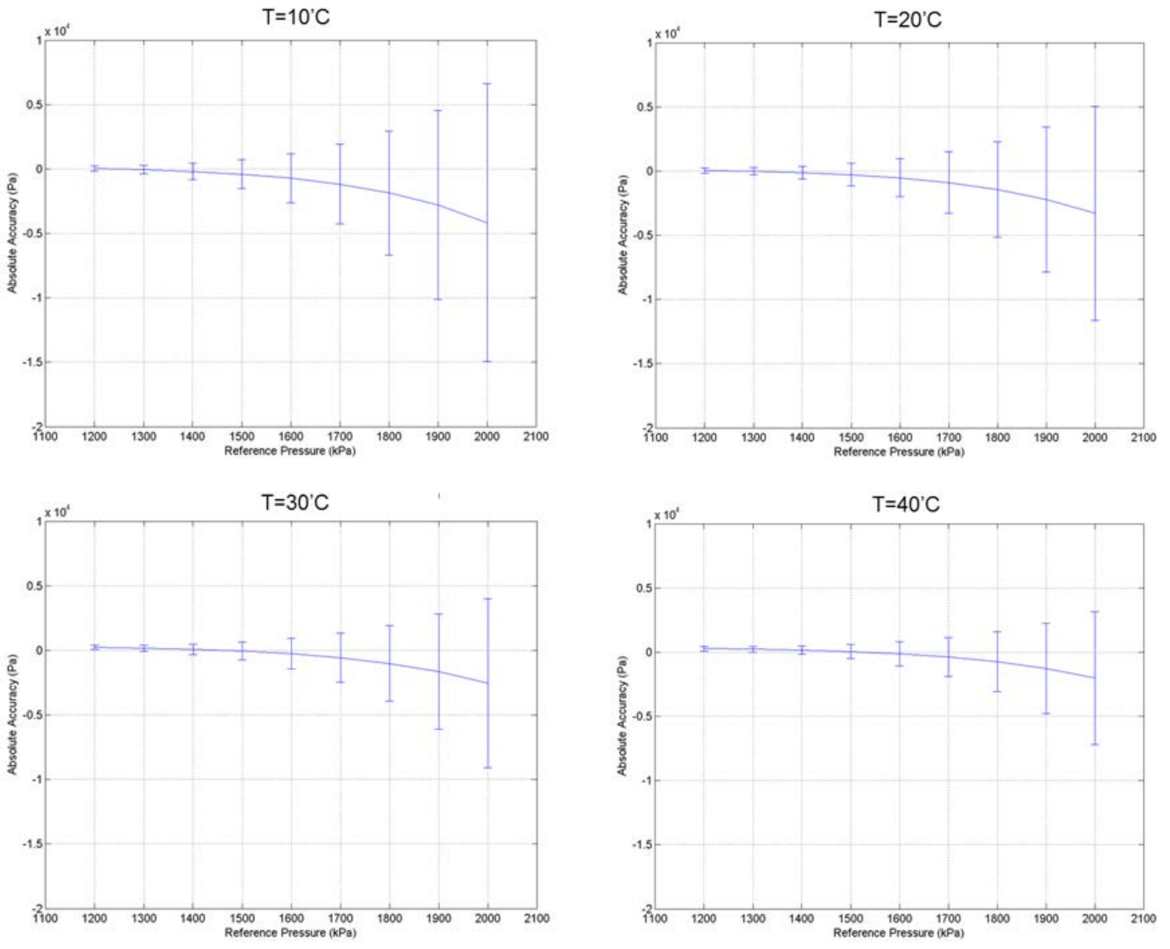
Figure 11: Integration of the LPS33HW in a sensor chamber with vent apertures



4 Accuracy over extended operating range

The LPS33HW datasheet specifies the full accuracy operating range from 260 mbar to 1260 mbar. The absolute accuracy variations in the range from 1200 mbar to 2 bar are indicated in the graphs below (*Figure 12: "LPS33HW absolute accuracy up to 2 bar (4 sigma) from 10 to 40 degrees Celsius"*) as the average of a relevant number of samples and the output of the pressure.

Figure 12: LPS33HW absolute accuracy up to 2 bar (4 sigma) from 10 to 40 degrees Celsius

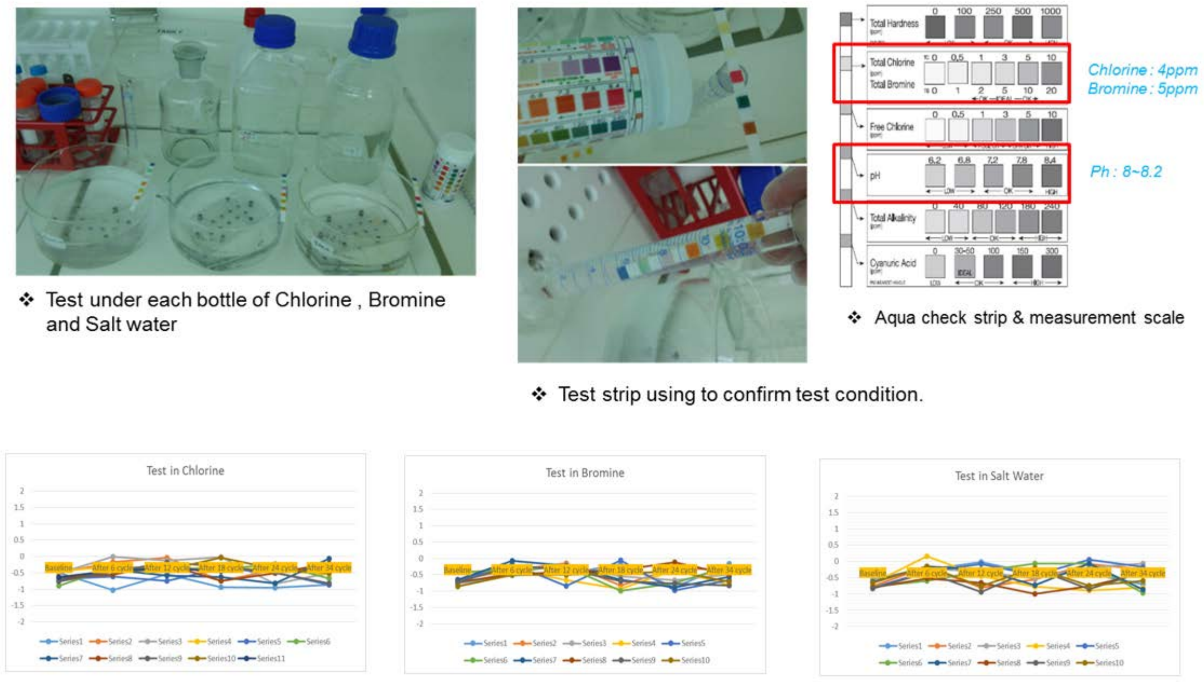


5 Robustness to corrosive agents

The LPS33HW was evaluated in a swimming pool and sea water to correspond to the applicative environments. Hot chlorine, bromine, and salt water tests were run on the LPS33HW which showed high robustness and no impact in accuracy nor other performance (see *Figure 13: "Chlorine, bromine and salt water tests"*). Specifically, the testing protocol included 34 cycles (34 days) where each test was composed of an immersion for 6 hours in each water condition and for the following 18 hours dried in a climatic chamber at 60°C, 60% rH.

Further tests with detergent water (commercial shampoo, hand soap and water mixed in) were performed, demonstrating the robustness of the LPS33HW to these kinds of potential corrosive agents as well.

Figure 13: Chlorine, bromine and salt water tests



❖ Test under each bottle of Chlorine , Bromine and Salt water

❖ Test strip using to confirm test condition.

❖ Aqua check strip & measurement scale

Finally, the LPS33HW even showed robustness to n-Pentane liquid for 72 hours. This test was performed in order to demonstrate the suitability of the LPS33HW for gas meter applications or other industrial applications. No physical damage was observed. The following table shows that the accuracy did not change after the exposure of the pressure sensor to this agent.

Table 1: Accuracy before and after n-Pentane liquid for 72h

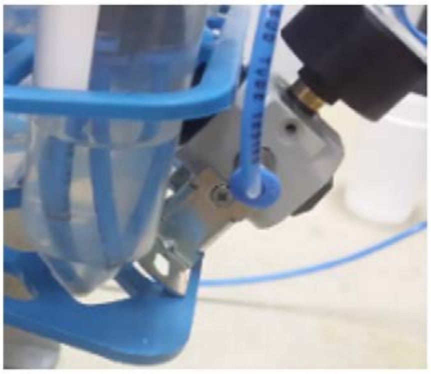
Mean P [sens]	Mean P [ref]	Accuracy P
992.42 hPa	993.95 hPa	-1.54 hPa
992.68 hPa	993.96 hPa	-1.28 hPa

6 Robustness to high air overpressure stress tests

The LPS33HW was submitted to 40 test cycles where each cycle lasted 10 minutes at 10 bar air overpressure and 10 minutes of ambient pressure. The device demonstrated robustness to these particular conditions. The device under test was immersed in water in order to observe potential leakage as bubble formations (*Figure 14: "Four LPS33HW immersed in water with 3 mm tube for air overpressure"*). Further tests were run on the water-resistance specification (15 bar) and again the device showed no failures.

The device was tested by plugging a tube of 3 mm that fits perfectly with the LPS33HW metal lid. Air overpressure was forced into the device hole while the device was immersed in water in order to verify leakage by observing potential bubble formations.

Figure 14: Four LPS33HW immersed in water with 3 mm tube for air overpressure



In most of the real-use cases, the 10 bar overpressure lasts less than 2 seconds[a] and then the ambient pressure is applied for 2 seconds again (e.g. operating during swimming with short and repeatable hydro-dynamic pressure variations), the device shows a negligible recovery time of the initial performance as shown in *Figure 15: "LPS33HW recovery emulating swimming operating mode"*.

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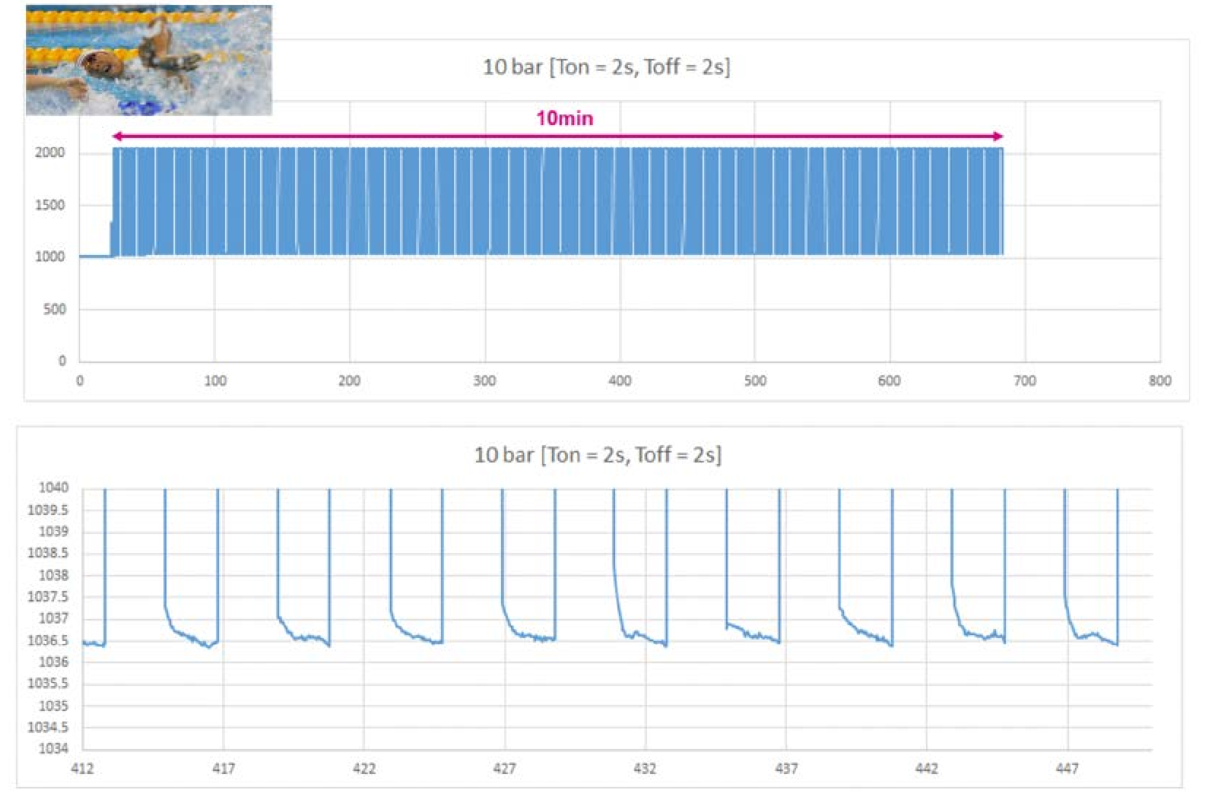
[a] Some recovery time might be necessary in case of prolonged overpressure conditions.

Figure 15: LPS33HW recovery emulating swimming operating mode



7 Revision history

Table 2: Document revision history

Date	Version	Changes
28-Aug-2017	1	Initial release

IMPORTANT NOTICE – PLEASE READ CAREFULLY