

**LPS22HB/LPS25HB digital pressure sensors: hardware
guidelines for system integration**

Introduction

The purpose of this application note is to introduce guidelines for the hardware integration of STMicroelectronics's LPS22HB and LPS25HB pressure sensors in the final customer's application.

Contents

1 System integration 5

2 Mechanical design rules 7

 2.1 Sensor placement 7

 2.1.1 Exposition to the environment 7

 2.1.2 Heat propagation 8

 2.1.3 Mechanical stress 12

 2.2 Sensor embodiment and housing 13

 2.3 Sensor protection 15

3 Reference design: integration and housing on a personal device 16

4 Use case and configuration example for the LPS22HB 18

 4.1 Main device settings 20

5 Use case and configuration example for the LPS25HB 22

 5.1 Main device settings 22

6 Revision history 25

List of tables

Table 1: ODR configuration	18
Table 2: FIFO mode selection	21
Table 3: ODR configuration	22
Table 4: Temperature resolution configuration.....	23
Table 5: FIFO coefficient filter.....	23
Table 6: FIFO MEAN MODE configurations for different application scenarios.....	24
Table 7: Document revision history	25

List of figures

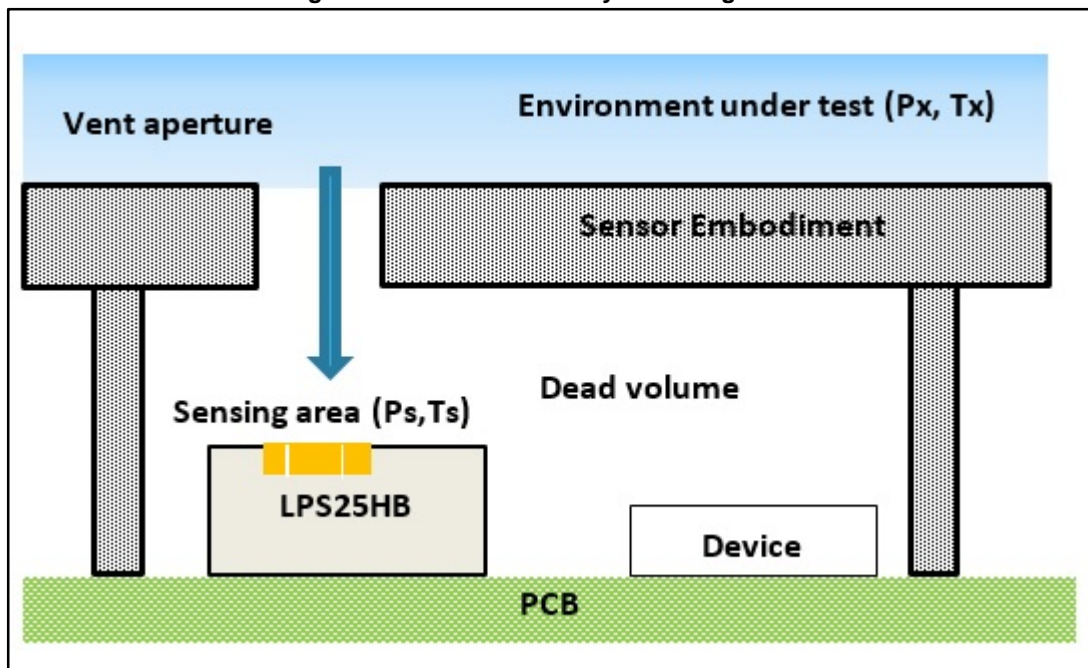
Figure 1: Pressure sensor system integration5
Figure 2: Pressure sensor integration and embodiment reference8
Figure 3: Pressure sensor integration and embodiment with vent channel.....8
Figure 4: Heating isolation implemented for protecting the sensor9
Figure 5: Top view of the sensor housing: on the left a correct design with the heat isolation, on the right a wrong design.....10
Figure 6: Sensor with a correct sensor placement on the PCB to get the appropriate isolation from heat sources 10
Figure 7: Sensor with a bad wiring on the PCB 11
Figure 8: Sensor wiring with wrong placement on the PCB 11
Figure 9: Bad configuration for mechanical stress (a) 12
Figure 10: Bad configuration for mechanical stress (b) 12
Figure 11: Good configuration for avoiding mechanical stress and reducing the dead volume (a) 12
Figure 12: Good configuration for avoiding mechanical stress and reducing the dead volume (b) 13
Figure 13: Example of good sensor embodiment and housing 14
Figure 14: Example of good sensor embodiment and housing with airflow channel 14
Figure 15: Example of a bad sensor embodiment and housing 15
Figure 16: Integration of the digital pressure sensor device in a sensor chamber with two vent apertures 16
Figure 17: Device integration reference in a portable device 17
Figure 18: CTRL_REG1 writing procedure..... 19
Figure 19: One Shot procedure20
Figure 20: FIFO moving average filter scheme23

1 System integration

The LPS22HB/LPS25HB pressure and temperature sensors' integration in application systems such as portable devices like smartphones, wearable devices, weather stations or industrial equipments shall be implemented without compromising the sensor performances. The system integration can be done by looking at the main mechanical and geometrical parameters and the factors that influence the sensor performance and thus optimizing those.

The typical sensor integration scenario is described in *Figure 1: "Pressure sensor system integration"* where the embodiment of the sensor has to be designed in order to get as much as possible the correspondence 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 sensor sensing area, nearby the air inlet houses.

Figure 1: Pressure sensor system integration



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

Every change in the condition under test must be reflected as a sensor consistent measurement, also in the case of fast pressure and temperature variations. Therefore, the integration design must guarantee the environment conditions matching with 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 heating sources, like other devices close the sensing area, the self-heating of the sensor. Changes in temperature are critical because 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:

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

The above 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 below, to provide a set of basic rules such as good design practices for a successful integration of the sensor in the final application context.

2.1 Sensor placement

The sensor placement has a direct impact on the sensor performance as follows, in terms of sensor link to the environment, thermal propagation mechanism, and mechanical stress.

2.1.1 Exposition to the environment

To maximize the exposition with the environment where to measure pressure and temperature, the sensor has to be placed in static and dynamic working condition.

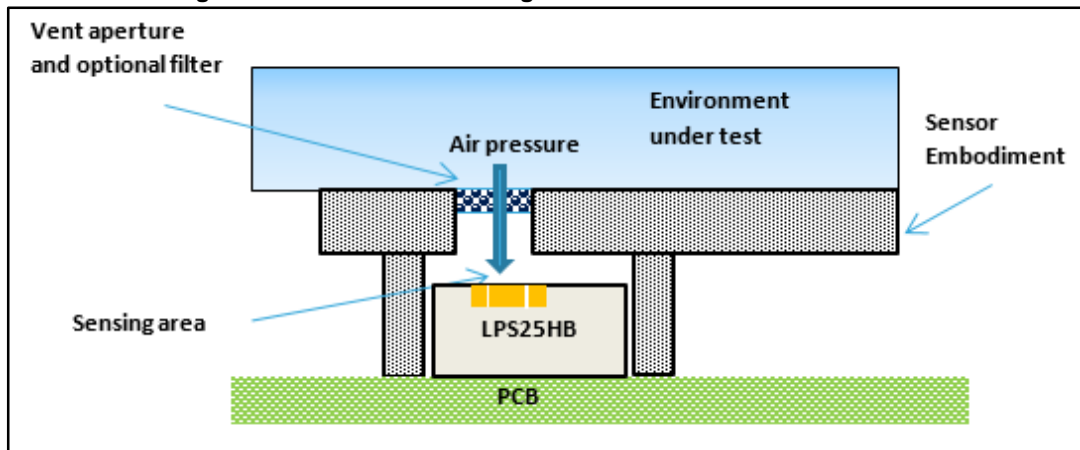
In **static conditions**, or steady-state, after a change of the pressure and the temperature environment and their stabilization, sensing conditions must be the same as the conditions under test, or very close to the target value, depending on the application tolerance and specifications.

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 sensor integration design, the overall response time will be modified, and the final performance shall match the target specifications. In general, target is to avoid design with a response time lower than the product specifications. In order to maximize the sensor performance in static and dynamic conditions after system integration, depending on the design specifications the below guidelines are suggested, with reference to [Figure 2: "Pressure sensor integration and embodiment reference"](#):

1. Place the sensor to get the best connection with the environment under test, as close as possible to the vent aperture
2. Large dead volume will increase the response time, with a bigger contribute to the pressure response time; therefore is recommended to minimize the volume, trying to shape a tailored housing around the sensor geometry
3. Vent aperture should be as large as possible; an order of magnitude lower than the sensing element geometry represents a reasonable integration form factor.
4. The depth of the vent aperture must be minimized.

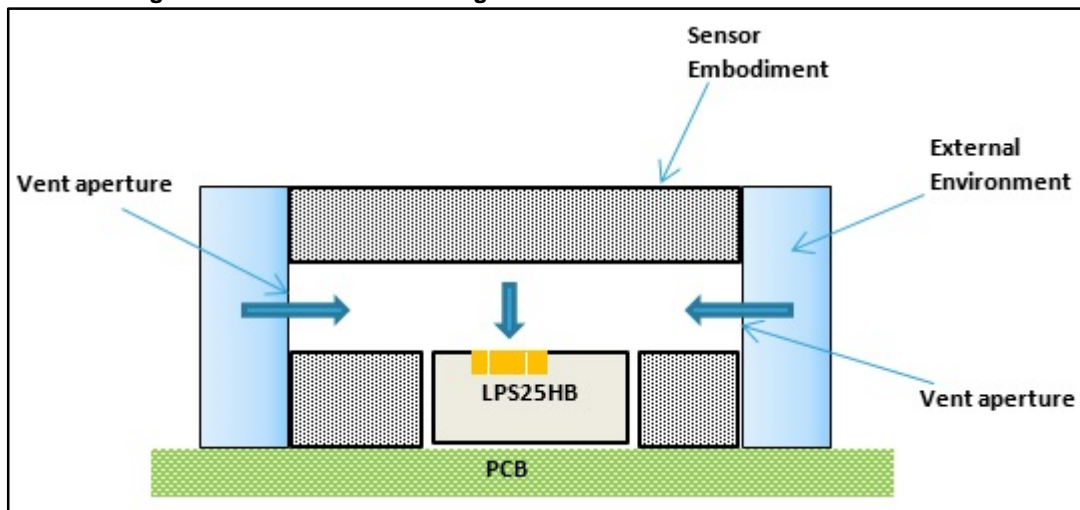
As a reference for integration design, [Figure 2: "Pressure sensor integration and embodiment reference"](#) describes an example of the above recommendations. In order to maximize the environment connection and therefore to get a fast response time, the volume around the sensor (dead volume) is minimized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

Figure 2: Pressure sensor integration and embodiment reference



A different implementation, more expensive but more efficient in terms of sensing performances is the design with an air flow structure, described in [Figure 3: "Pressure sensor integration and embodiment with vent channel"](#). The design with multiple vent apertures is a more expensive solution, but providing, depending on the design specifications, a faster response time.

Figure 3: Pressure sensor integration and embodiment with vent channel



It is useful to underline that the sensor can work properly even if it is placed in customer's application system without considering any dedicated hole (vent aperture) unless that one is not hermetically sealed. The design guidelines reported above are for getting out top performances.

2.1.2 Heat propagation

The presence of heating sources near the sensor can deteriorate the performances by modifying pressure and temperature measurement as well as generating thermal gradients around the sensing area affecting the correct measurement in static and dynamic conditions.

We report design guidelines for avoiding this effect, but, we remark that the increasing temperature impacts on performances and is strongly attenuated by the embedded temperature compensation of LPS22HB and LPS25HB devices.

From a physical point of view, these local sources act like a thermal capacitor placed in parallel to the thermal model of the LPS25HB and they can give a contribution to the local temperature that is different from the environmental one.

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

- Heating convection

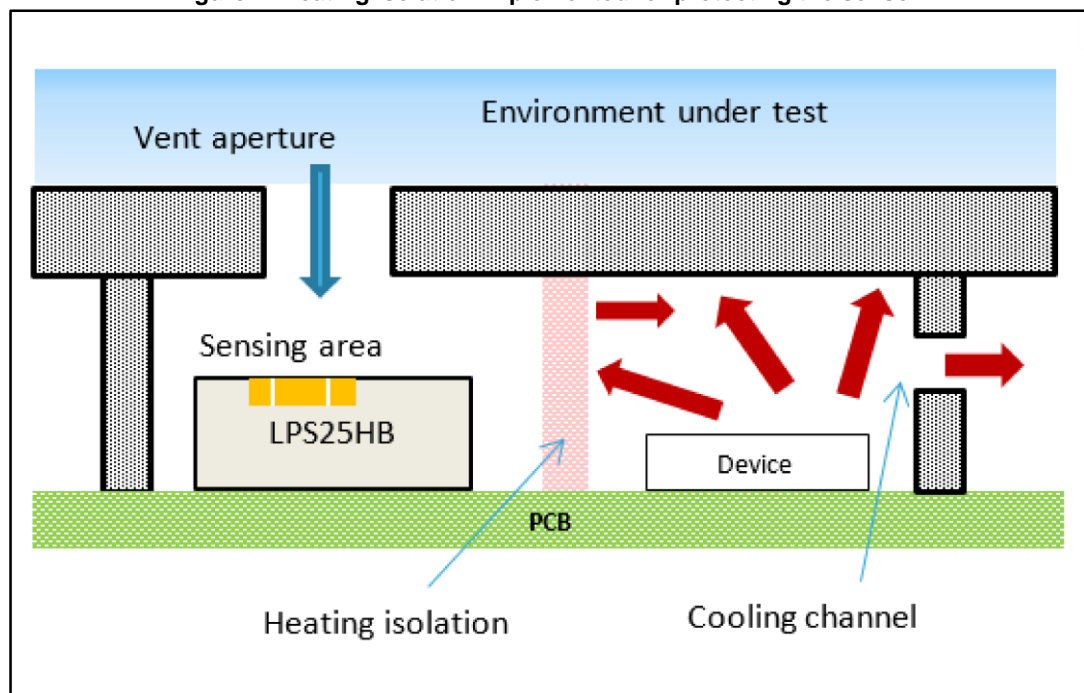
Local thermal sources around the sensor can modify the pressure and temperature measurement by heating radiation.

Typical sources are as follows:

- other sensors and devices like close 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

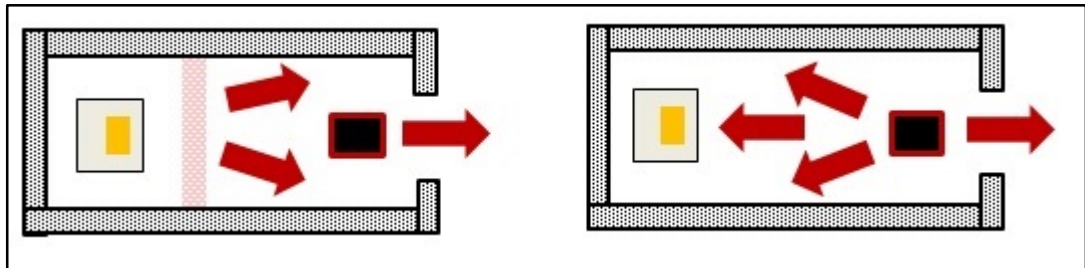
Therefore the sensor has to be placed at the correct distance from these sources, and to guarantee the appropriate isolation, it is recommended to adopt inside the embodiment, heating isolation structures as described in [Figure 4: "Heating isolation implemented for protecting the sensor"](#). It also suggested, according to the specific layout to implement as well vent aperture close the heat source, acting as cooling channels.

Figure 4: Heating isolation implemented for protecting the sensor



Looking at a section of the sensor housing, [Figure 5: "Top view of the sensor housing: on the left a correct design with the heat isolation, on the right a wrong design"](#) shows a good design with the heating isolation 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, a wrong design is described, determining the sensor heating because of the heat radiation coming from the component nearby.

Figure 5: Top view of the sensor housing: on the left a correct design with the heat isolation, on the right a wrong design



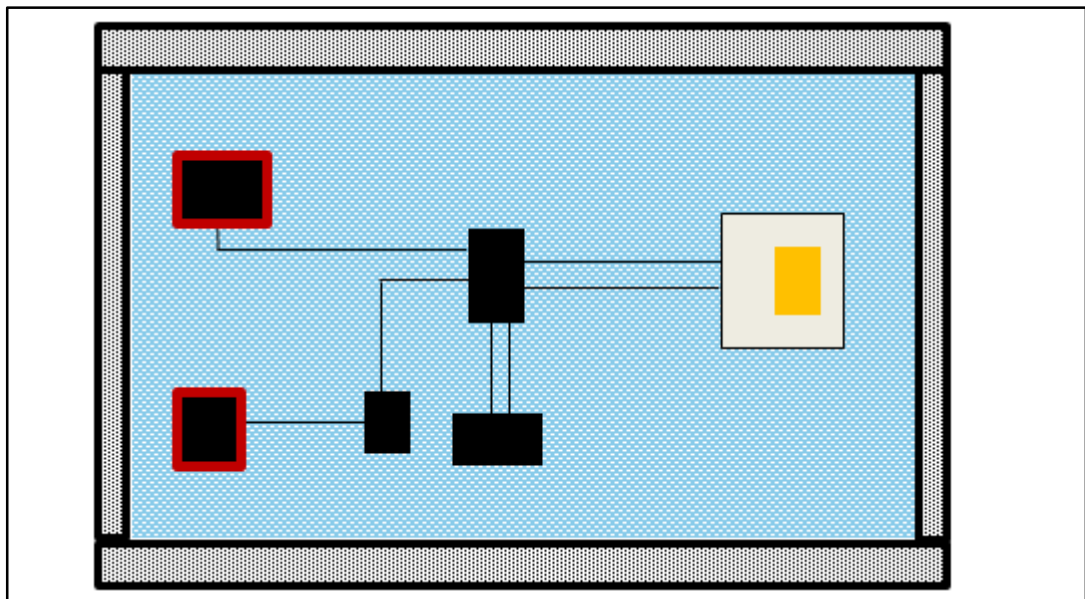
Heating conduction

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 appropriate distance among the sensor and potential heat sources, avoiding metal areas near and under the device.

A good design rule is provided in [Figure 6: "Sensor with a correct sensor placement on the PCB to get the appropriate isolation from heat sources"](#). As an example of good design, it describes the positioning of the devices on the left, generating heat as far as possible from the sensor, and in [Figure 8: "Sensor wiring with wrong placement on the PCB"](#) a wrong layout with the devices generating heat too close to the sensor. In both cases thinner metal lines are adopted.

Figure 6: Sensor with a correct sensor placement on the PCB to get the appropriate isolation from heat sources



2.1.3 Mechanical stress

The sensor placement shall avoid any mechanical force applied on the sensor, direct due to a wrong mechanical system design, or indirect due to the user interaction with the system like in the case of wearable or portable device.

Figure 9: Bad configuration for mechanical stress (a)

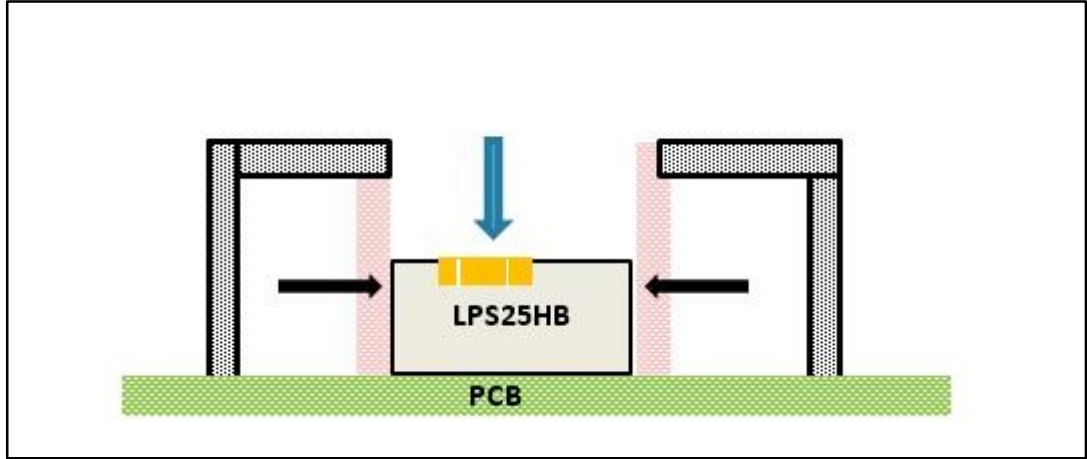


Figure 10: Bad configuration for mechanical stress (b)

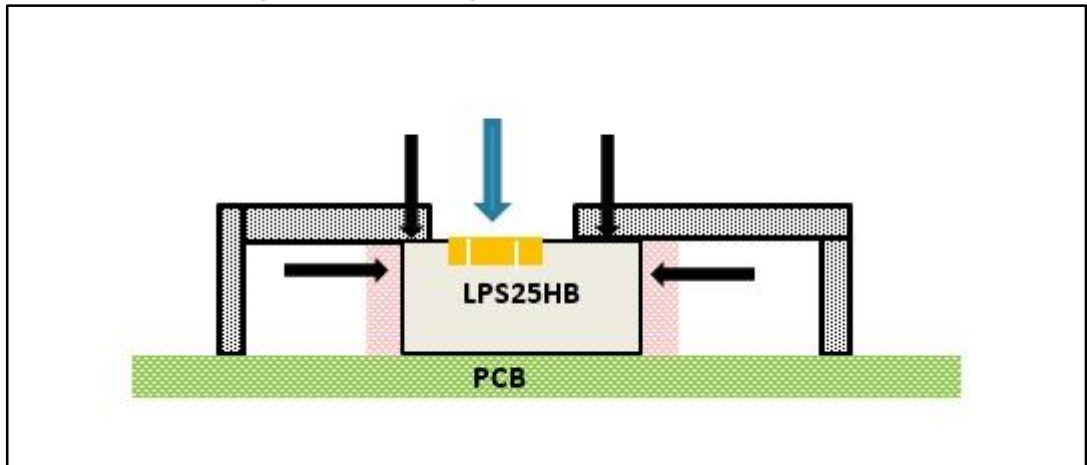


Figure 11: Good configuration for avoiding mechanical stress and reducing the dead volume (a)

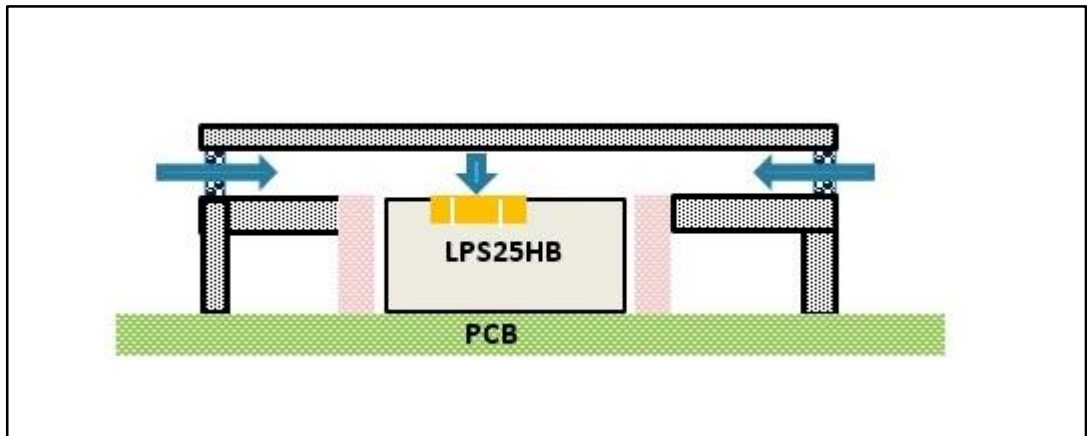
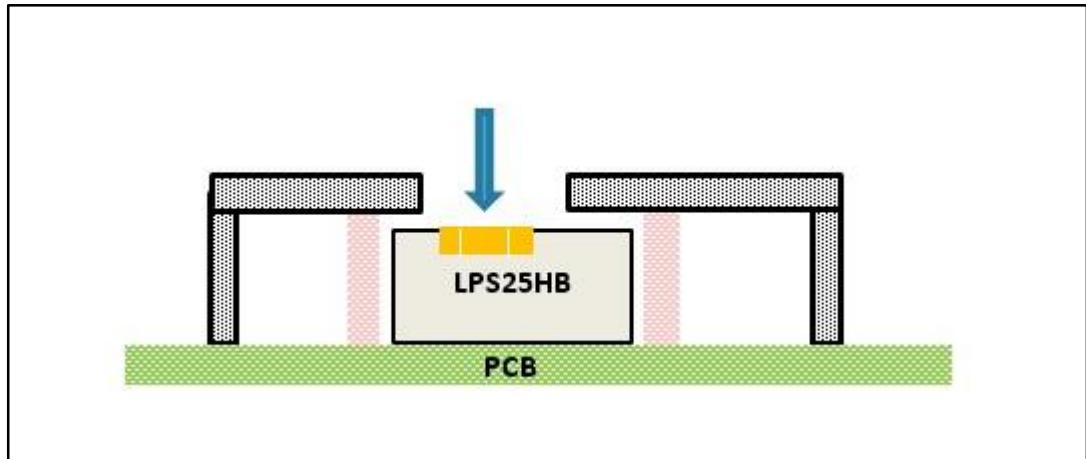


Figure 12: Good configuration for avoiding mechanical stress and reducing the dead volume (b)



The figures above show correct and incorrect integration cases where, with the goal to reduce the dead volume around the sensor to improve the pressure response time, the embodiment structure is directly in contact with the sensor package, creating a mechanical stress that can deteriorate the sensor performance. A minimal clearance has to be maintained as in [Figure 11: "Good configuration for avoiding mechanical stress and reducing the dead volume \(a\)"](#) and [Figure 12: "Good 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.

2.2 Sensor embodiment and housing

The sensor embodiment in the system shall match as much as possible the recommendations highlighted above for the sensor placement and, on top of that, has to provide all the features of specific application like waterproof, water resistant or resistant to harsh environment, in case it is required.

Furthermore, the customer device design shall guarantee the air circulation from the environment till 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. More efficient is the air circulation in this path, better the performances 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 pictures below represent a summary of a good case versus a bad case of sensor embodiment and housing. In [Figure 13: "Example of good sensor embodiment and housing"](#) a good design is described including also an optional filter membrane and PCB cut to increase the thermal decoupling, that is a solution for specific case where the devices around the pressure sensor are generating too much heating.

Figure 13: Example of good sensor embodiment and housing

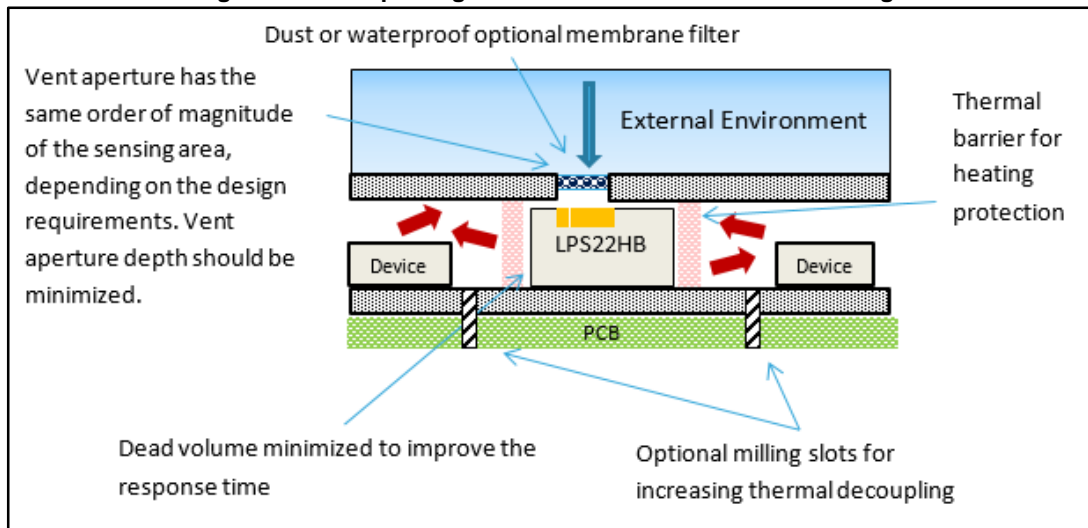


Figure 14: Example of good sensor embodiment and housing with airflow channel

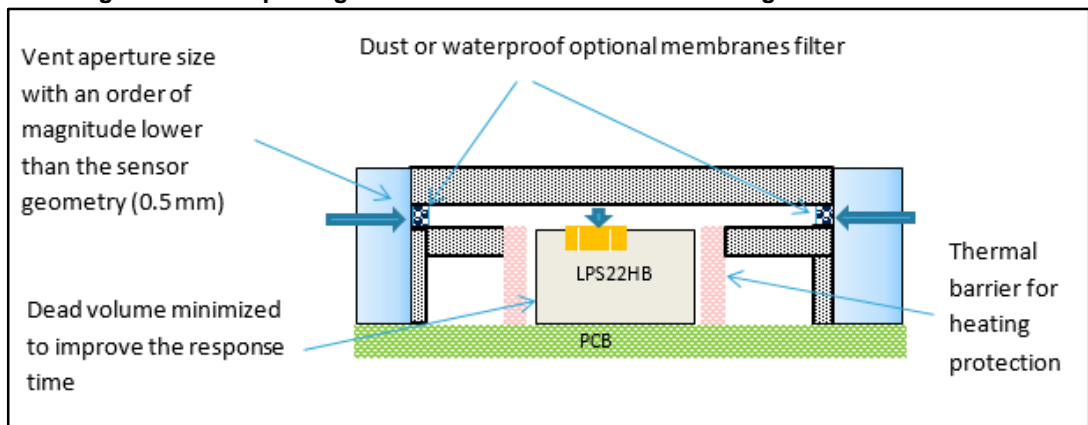
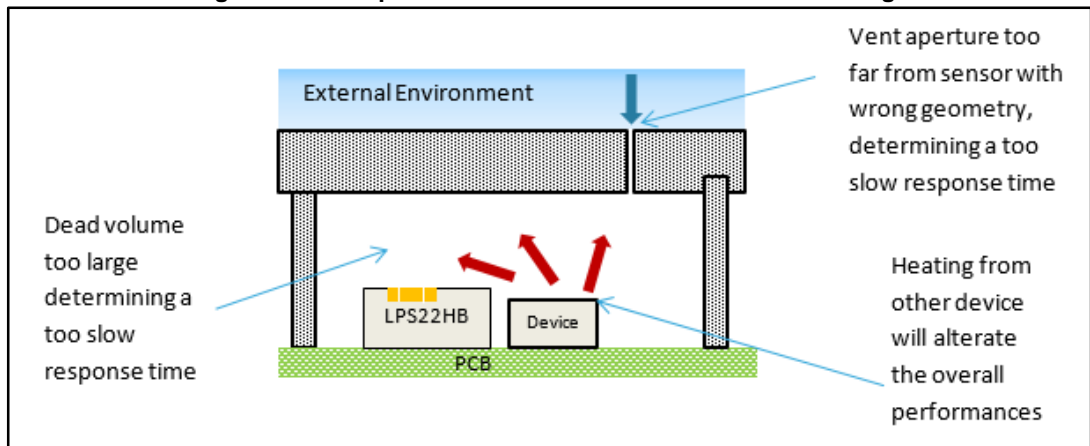


Figure 14: "Example of good sensor embodiment and housing with airflow channel" describes a good design, related to the more efficient implementation with two vent apertures to get a better connection with the external environment under test that results in a higher efficiency in terms of response time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

In Figure 15: "Example of a bad sensor embodiment and housing" a wrong design is described, with a very low efficiency of the final design, in terms of response time and the sensor under the effects of heating coming from other devices.

Figure 15: Example of a bad sensor embodiment and housing



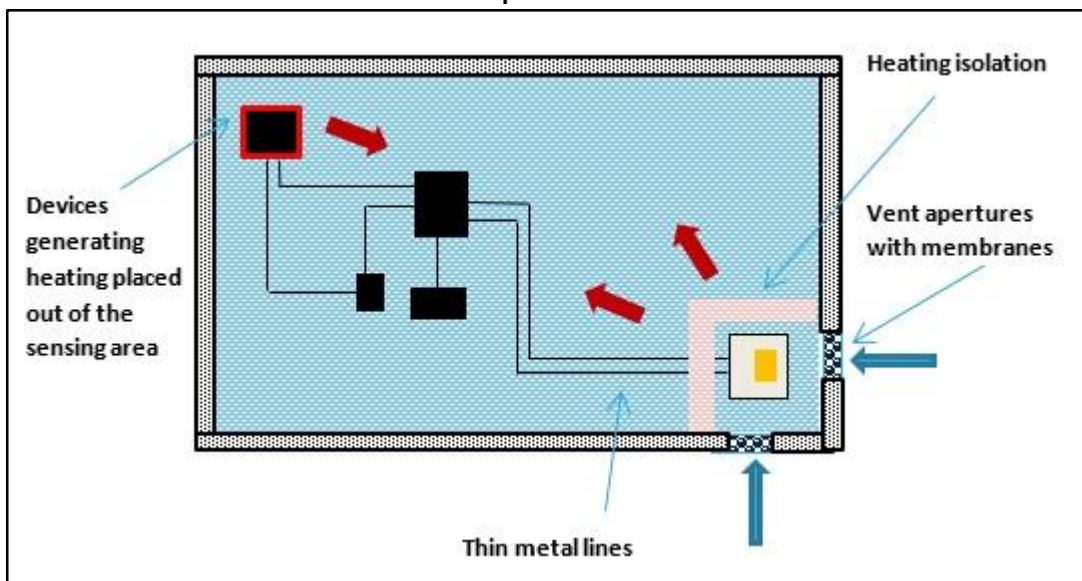
2.3 Sensor protection

An optional filter can be adopted as sensor protection from dust, water, or chemical solvent by a sensor chamber, in presence of harsh environment or for water proof application. The key parameter 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 will provide a slower response time, in particular in term of pressure response time. The sensor integration should protect the sensor from the light as well, therefore inside the application; the sensor should be housed in a dark place, where the light cannot reach the sensing element.

3 Reference design: integration and housing on a personal device

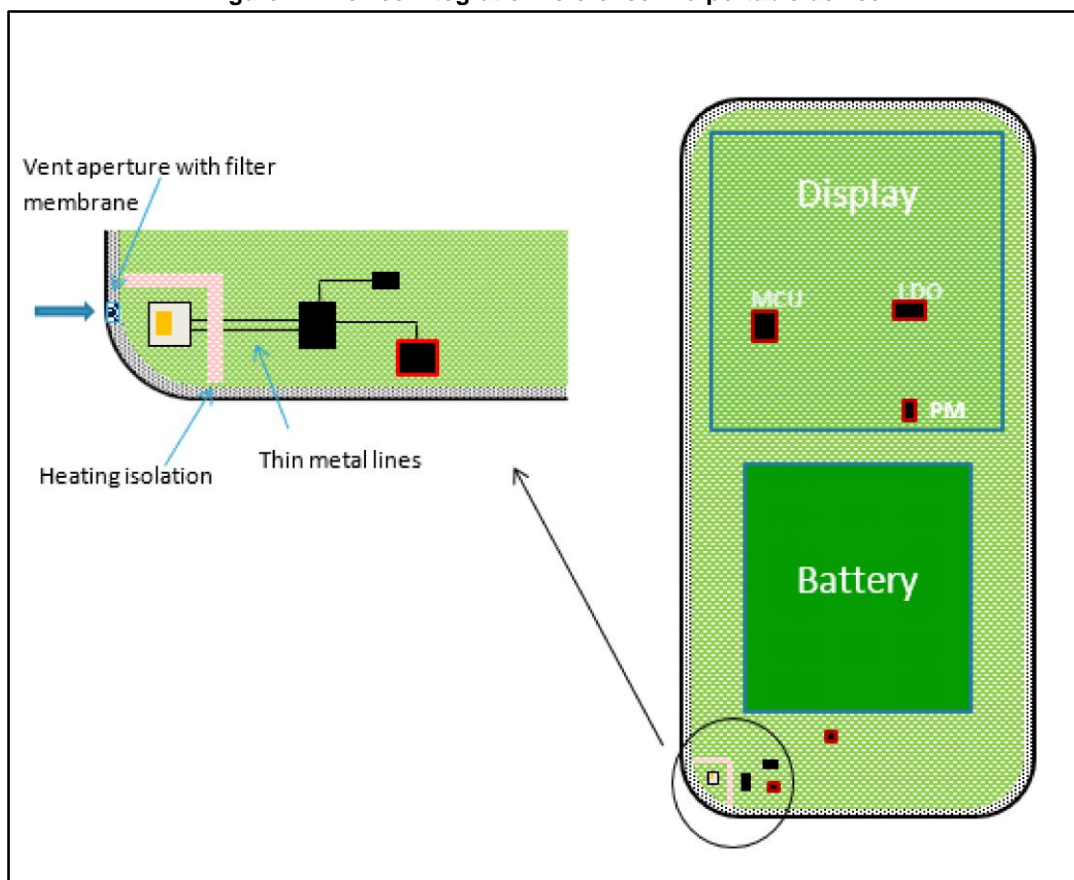
The example below describes how the sensor placement is implemented by following the basic rules described in this document above; in other words by mounting the sensor as far as possible from the main heating sources present on the board like display LDO and microcontroller that represent the more critical sources of heating. In [Figure 16: "Integration of the digital pressure sensor device in a sensor chamber with two vent apertures"](#) is shown the integration of the sensor in a sensor chamber isolated from the heating 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 case of 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 recommendation, [Figure 17: "Device integration reference in a portable device"](#) describes 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 heating sources. 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



4 Use case and configuration example for the LPS22HB

The LPS22HB provides great flexibility to the designer and can be configured depending on the specific application requirements. Requisites such as resolution, power consumption, acquisition and measurement times can be set accordingly to the application context. LPS22HB can operate in two different modalities:

- Power Down modality
- Continuous modality

In Power Down modality, no measurements are taken; this is the default sensor configuration:”. ODR bit [6:4] of CTRL_REG1(0x10h) set to 000.

In Continuous mode, the device is able to detect pressure and temperature data, depending on the defined data output frequency. In particular 2 operation modes are available as continuous modality:

- One-shot mode
- Active mode

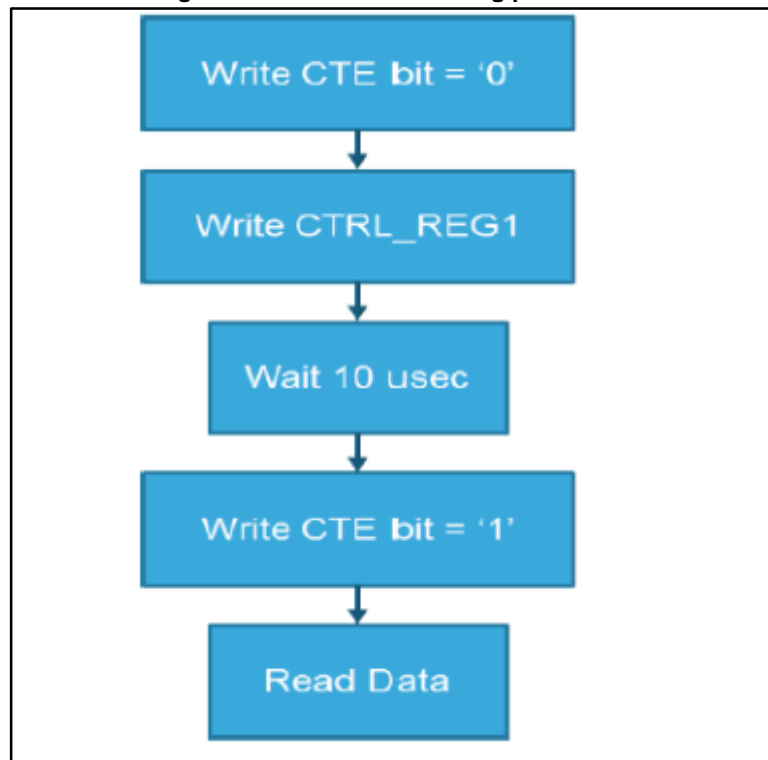
In continuous modality, measurements data output are available on the output register with a refresh frequency defined by the selected output data rate (ODR [2, 0] bits of CTRL_REG1 (0x10)) as described in table:

Table 1: ODR configuration

ODR2	ODR1	ODR0	Pressure (Hz)	Temperature (Hz)
0	0	0	One shot	
0	0	1	1 Hz	1 Hz
0	1	0	10 Hz	10 Hz
0	1	1	25 Hz	25 Hz
1	0	0	50 Hz	50 Hz
1	0	1	75 Hz	75 Hz

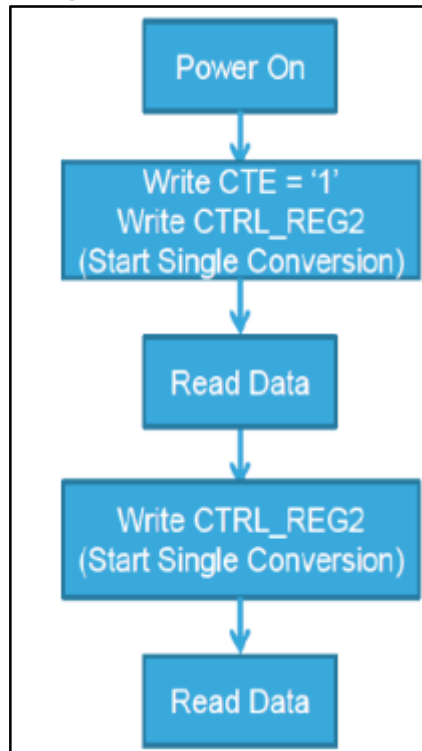
Modification of configuration of CTRL_REG1 (10h) register has to be done with the following writing procedure: – write CTE bit in CONFIG (43h) register to 0x00 (default value is ‘0’)– write CTRL_REG1– wait 10 usec– write CTE bit n CONFIG (43h) register to 0x20 After these operations, it is possible read output data (pressure and temperature) as showed in the following figure;

Figure 18: CTRL_REG1 writing procedure



At device boot, the ODR[2,0] bits default configuration loaded is '000' and the device goes in Power down mode-To get a single measurement of pressure and temperature the ONE_SHOT bit in CTRL_REG2 (0x11h) has to be set. Once the measurement is acquired, the ONE_SHOT bit is self-cleared to the default value "0" (Idle), the new data are available in the output registers, the STATUS_REG(0x27h) bits are updated and the device goes back in power-down mode.The one shot procedure is described below and showed in figure 16.– write CTE bit in CONFIG (43h) register = '1'– start One-Shot conversion by toggling the ONE_SHOT bit in CTRL_REG2 (0x11h)

Figure 19: One Shot procedure



In active mode, according to the ODR configuration selected, different pressure and temperature resolution profiles are available as described in the next section.

4.1 Main device settings

In Active and One shot mode, depending on the specific application, a set of configuration settings is available, ranging from low power to ultra-high resolution profiles. The right trade-off among, resolution, output data rate and power consumption has to be identified, in order to make the sensor suitable for the specific design requirements.

The main parameters that can be configured for the specific usage are as follows:

- Resolution
- Current consumption
- FIFO Mode Output Data Rate
- Low Pass Filter

In The register RES_CONF (0x1Ah), the LC_EN bit allows to select two possible configurations: Low Noise Mode (default) or Low Current Mode.

The configuration can be modified for adapting the output resolution and the power consumption of the sensor to the design specifications. In the first case the resolution is higher than resolution in Low Current mode. Conversely the low current mode is suggested for applications in which the power consumption has to be low at disadvantage of the output resolution.

In addition, to further improving the power saving, the embedded 32-slot of 40-bit data FIFO, to store the pressure and temperature output values, can be utilized by setting the FIFO mode. This allows consistent power saving for the system, since the host processor does not need to continuously poll data from the sensor, but it can wake up only when needed and burst the significant data out from the FIFO. This buffer can work according to

seven different modes as described in table 1. The FIFO buffer is enabled when the FIFO_EN bit in CTRL_REG2 (11h) is set to '1' and each mode is selected by the FIFO_MODE[2:0] bits in FIFO_CTRL (14h). Programmable FIFO threshold status, FIFO overrun events and the number of unread samples stored are available in the FIFO_STATUS (26h) register and can be set to generate dedicated interrupts on the INT_DRDY pad using the CTRL_REG3 (12h) register.

Table 2: FIFO mode selection

F_MODE2	F_MODE1	FMODE0	FIFO mode selection
0	0	0	Bypass mode
0	0	1	FIFO mode
0	1	0	Stream mode
0	1	1	Stream to FIFO mode
1	0	0	Bypass to Stream mode
1	0	1	Reserved
1	1	0	Dynamic stream mode
1	1	1	Bypass to FIFO mode

As far as the ODR setting is concerned, ranging in active mode among 1,10,25,50, 75 Hz, it has to be defined looking at the target power consumption, and the appropriate data output refresh time. Finally, a low pass filter on pressure data can be enabled by setting the EN_LPFP bit in CTRL_REG1 (10h) with two possible selectable cutoff ODR/9 and ODR/20 (bit LPF_CFG of CTRL_REG1). Keep in mind that in order to modify CTRL_REG1 register the procedure described in figure 15 has to be used.

5 Use case and configuration example for the LPS25HB

The LPS25HB provides great flexibility to the designer and can be configured depending on the specific application requirements. Requisites such as resolution, power consumption, acquisition and measurement times can be set accordingly to the application context.

The LPS25HB can operate in two different modalities:

- Power Down modality
- Continuous modality

In Power Down modality, no measurements are taken; this is the default sensor configuration PD [7] bit of CTRL_REG1 (0x20) set to “0”.

In Continuous mode, the device can detect pressure and temperature data, depending on the defined data output frequency.

In particular, two operation modes are available as continuous modality:

- One-shot mode
- Active mode

In continuous modality, measurements data output are available on the output register with a refresh frequency defined by the selected output data rate (ODR [2, 0] bits of CTRL_REG1 (0x20)) as described in table

Table 3: ODR configuration

ODR2	ODR1	ODR0	Pressure (Hz)	Temperature (Hz)
0	0	0	One shot	
0	0	1	1 Hz	1 Hz
0	1	0	7 Hz	7 Hz
0	1	1	12.5 Hz	12.5 Hz
1	0	0	25 Hz	25 Hz

At device boot, the ODR[2,0] bits default configuration loaded is ‘000’ and the device goes in one-shot mode, that allows to get a single measurement of pressure and temperature, by toggling the ONE_SHOT bit in CTRL_REG2 (0x21). Once the measurement is acquired, the ONE_SHOT bit is self-cleared to the default value “0” (Idle), the new data are available in the output registers, the STATUS_REG(0x27) bits are updated and the device goes back in power-down mode.

In active mode, power-down bit set to “1”, according to the ODR configuration selected, different pressure and temperature resolution profiles are available as described in the next section.

5.1 Main device settings

In Active and One shot mode, depending on the specific application, a set of configuration settings is available, ranging from low power to ultra-high resolution profiles. The right trade-off among, resolution, output data rate and power consumption has to be identified, to make the sensor suitable for the specific design requirements.

The main parameters that can be configured for the specific usage are as follows:

- Resolution
- FIFO moving average filter
- Output Data Rate

The register RES_CONF (0x10), bits AVGT [1: 0] e AVGP[1:0] allows to select the number of Pressure and Temperature samples acquired on each measurement cycle (oversampling) for implementing an average by the internal DSP. As a result of this internal processing, according to the selected number of samples, the noise figure can be modified for adapting the output resolution of the sensor to the design specifications.

Table 4: Temperature resolution configuration

AVGT1 bit [3] @(0x10)	AVGT0 bit [3] @(0x10)	Nr of samples
0	0	8
0	1	16
1	0	32
1	1	64

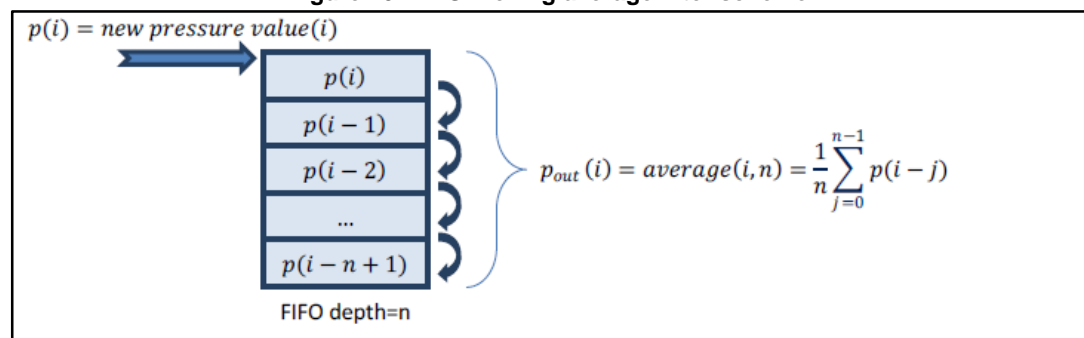
In addition, to further improve the resolution by changing the noise figure, the hardware moving average filter can be utilized by setting the FIFO mean mode FIFO_CTRL (0x2E) bits F_MODE [2:0]. In this FIFO configuration, called “**low noise mode**”, the data measurements processed by the internal DSP are stored in the FIFO and then filtered according to the selected number of samples, that represents the FIFO filter coefficients (through the bits WTM_POINT[4:0] , FIFO_CTRL (0x2E)), as described in not found.

Table 5: FIFO coefficient filter

WTM_POINT[4..0]	FIFO Coefficient filter
00001	2
00011	4
00111	8
01111	16
11111	32

The figure below provides a schematic description of the FIFO moving average filter.

Figure 20: FIFO moving average filter scheme



As far as the ODR setting is concerned, ranging in active mode among 1, 7, 12.5, 25 Hz, it has to be defined looking at the target power consumption, and the appropriate data output refresh time.

Based on these three main device settings, in order to make simpler the sensor use in the application context, some recommendations are provided, as a guidelines for different applications in the domain of portable device (PD) such as smartphone or wearable, of weather stations for applications like barometric pressure measurement, or more in general, of elevator and floor change detection functions, drop detection and indoor navigation as well.

Table 6: FIFO MEAN MODE configurations for different application scenarios

Use case	Device mode description	FIFO filter coefficient	Pressure over sampling	Temperature over sampling	ODR [Hz]	RMS noise (hPa)
Indoor navigation	Ultra high resolution	32	512	64	25	0.008
Portable device dynamic	Very high resolution	16	512	64	25	0.011
Portable device Low Power	High resolution	8	512	64	25	0.015
Elevator / Floor change detection	Standard resolution	4	512	64	25	0.020
Fall detection	Standard resolution	2	512	64	25	0.027
Weather monitoring	Low resolution	off	8	8	12.5	0.15
Weather monitoring PDA Low power	Low power and low resolution	off	8	8	1	0.15

In the column "Device mode description", the recommended configurations when the device is working in FIFO MEAN MODE are provided, as combination of FIFO length, temperature and pressure oversampling for optimizing the noise figure accordingly to the selected "use case". An appropriate ODR setting is suggested to optimize the corresponding power consumption.

Of course, together with the suggested use cases, different configurations can be chosen, in terms of oversampling, ODR and FIFO coefficients, to better match the specific application scenario.

6 Revision history

Table 7: Document revision history

Date	Revision	Changes
20-Aug-2015	1	Initial release.
16-Dec-2015	2	Document updated to include LPS22HB.

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