SDP Engineering Guide

How to integrate, test and evaluate the SDP sensor

Highlights

- design-in process
- general do's & don't's
- applicable to all SDP sensors
- mechanical integration
- leakage, overpressure & dust

A precise measurement of gasflow often is key for the success of bringing a technology into everyday life. Sensirion's unique CMOSens technology fulfills exactly this ambition for Sensirions Differential Pressure (SDP) sensor series: high measurement precision at low gas flows is coupled with fast measurement speed. The SDP is a microthermal flow sensor, ready for versatile use as differential pressure sensor or as gasflow sensor in your application. This versatility enables optimal use of the sensor in various gasflow systems.

This Engineering Guide provides recommendations for evaluation, testing and integration of Sensirion Differential Pressure sensors. It is applicable to all SDP sensors.

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Contents

1 Choose the right SDP for your application

Sensirion offers several Differential Pressure sensors. The sensors differ in measurement range, interface, dimension, market applicability, and other parameters (**Table 1**).

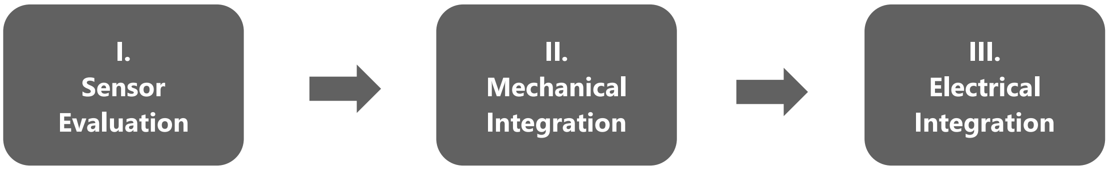
	SDP8xx	SDP3x
Applications	Medical HVAC	Medical Drones Consumer
Measurement Range	up to 500 Pa	up to 1500 Pa
Interface	digital I^2C & analog	digital I^2C & analog
Dimensions	29 x 18 x 23.5 mm	8.5 x 5.5 x 5.15 mm
Port connection	tube & manifold	manifold

Table 1. Impression of SDP sensor series. Details on sensor parameters are listed in the respective datasheets.

Sensirion SDP sensors are suited to measure differential pressure, or massflow and standard volume flow in a bypass configuration. Several sensor versions are available of each product family, optimized to suit your specific sensor need. SDP sensors have high repeatability and small sensor-to-sensor variation. Measurement of the zero-flow point is extremely accurate and stable. This special SDP characteristic makes re-zeroing obsolete and leads to an outstanding dynamic measurement range.
Please refer to the SDP Selection Guide for a detailed overview of all our SDP sensors.

2 Recommendations for the design-in process

At Sensirion, we have years of experience in supporting our customers with the integration of a sensor into an application. The following flowchart shows our recommended design-in Process:



Please note that some process steps will need iterations. Typically, after the first tests of the final device performance, the mechanical and electrical sensor integration need adjustments. The following sections will guide you through each process step.

2.1 Sensor evaluation

As a first step in the design-in process, we recommend you familiarize yourself with the sensor in a tabletop test setup. Further measurements in a specific lab environment (gasflow channel) or in a specific user scenario (flow system of final device) are possible with the same test setup. Please consider the ESD (Electrostatic Discharge) protection requirements during sensor evaluation.

The evaluation method of your Differential Pressure sensor of choice depends on whether it has a digital or an analog interface. The SDP is commonly used in digital versions.

Digital sensor evaluation

The fastest way to start an experiment is the SDP evaluation kit. It connects to your computer through the SEK-SensorBridge, and the Sensirion ControlCenter Software. Alternatively, we also offer an Arduino library, RaspberryPi drivers, and Python drivers for your SDP experience on GitHub. Please refer to Chapter 8 below to find all relevant information.
Sensirion recommends starting testing with the SDP8xx evaluation kit. It features easy handling and provides straightforward connection of the sensor to a lab bench test setup. While it comes with the SDP810-500 Pa sensor, you can also connect and test any other digital SDP8xx sensor version.

Analog sensor evaluation

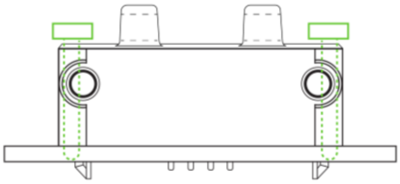
For evaluation of analog sensor versions, you can use a multimeter and lab power supply.

2.2 Mechanical integration

The mechanical integration of the sensor into your system design includes several considerations. This section provides a brief description of common aspects of mechanical SDP integration. A detailed discussion on some of the aspects follows in separate chapters.

2.2.1 Sensor mounting

No mechanical force shall be applied to any part of the sensor during assembly or usage.
Only applicable to SDP8xx: In case the sensor is mounted to the PCB with screws, Sensirion recommends a torque of 0.1 Nm (max torque of 0.2 Nm). It is important to mount the sensor on a flat surface. The screws shall be fastened before soldering the pins to avoid mechanical forces on the pins.



2.2.2 Sensor positioning

Sensor positioning in a gasflow system

The SDP sensor outputs best measurement results at laminar flow conditions. Therefore, Sensirion recommends placing the sensor at a spot in the flow channel with the least flow disturbances: keep the sensor at a distance to gasflow sources (i.e. blowers) and avoid bends and kinks in flow tubes leading to and from the sensor. Such measures keep the share of turbulent flow at a minimum and improve laminar flow conditions for sensor reading.
If your flow system contains a gas filter, place the sensor behind this filter. Cleaner gas flowing through the sensor has a positive effect on sensor lifetime.

Sensor orientation

The signal quality of the SDP sensor is independent of its mounting orientation.
Nevertheless, if heavy dust conditions should be of concern in your application, you can limit sensor exposure to dust by taking some basic considerations for sensor orientation into account. A detailed discussion on countermeasures for dust exposure can be found in Chapter 7.

2.2.3 Sensor port connection

Port sealing

The sensor ports must be sealed properly during a measurement. If the gasflow system leaks, the signal output of the sensor deviates from the real system pressure difference. Leaks in the gasflow system may result in misreadings. Refer to Chapter 4.1 on details for port sealing.

Tube connection

Some SDP sensors (SDPxxx) have tube ports for tube connections. If you plan tube connections for your design-in, follow recommendations on tube connection in Chapter 4.2.

2.2.4 Differences between direct DP measurement *vs*. massflow measurement

The design-in process differs if you target a differential pressure measurement or a massflow measurement. For a direct differential pressure measurement, each sensor port connects to a separate pressure zone in the system. For a massflow measurement, the SDP sensor acts as a bypass to the main flow channel of the gasflow system. A detailed discussion on flow channel design for mainpass – bypass configuration is given in Chapter 3.

2.3 Electrical integration

2.3.1 Sensor Connection

All SDP sensors can be soldered to a printed circuit board (PCB). The SDP8xx sensor additionally offers a solution for cable connection.

Soldering

Detailed information on sensor soldering and pin assignment can be found in the respective datasheets and handling instructions of each SDP sensor. Please refer to the datasheet of your sensor for further instructions.

Cable

The SDP8xx sensor series can be soldered to a PCB or can be connected with cables. The SDP800 series cap is available to make an easy and secure connection between the cable and the sensor.

When connecting the sensor with a cable, always ensure to minimize signal distortion and to eliminate electromagnetic interference. Keep the connection between the SDP sensor and the microcontroller unit as short as possible. In general, cables should be ≤20 cm. The use of a shielded cable avoids that noise is coupled into the signal lines. However, shielded cables also add parasitic capacitance and can contribute to signal distortion.

2.3.2 Pull-up resistor for digital SDP sensors

For digital I^2C operation of the SDP sensor, an external pull-up resistor is required on the SDA and SCL pin, if not included in the I/O circuit of the microcontroller unit.

Note that a proper hard reset of the sensor requires powering down SCL and SDA lines as well. If the design of the system’s circuitry allows cutting off the sensor from power to enforce a hard reset, the pull-ups must be placed between the power switch and the sensor. Preferably, the supply line is actively pulled down to ground in order to discharge the sensor's internal decoupling capacitors completely.

2.3.3 Electrostatic discharge (ESD)

The sensor shall only be handled in ESD protected areas (EPA) under protected and controlled conditions. Refer to the Handling Instructions of your sensor for details on ESD.

2.4 General remark on the difference between flow-through technology and membrane technology

Sensirion's SDP sensor series is based on the microthermal measurement principle: the sensor detects a pressure difference *via* temperature measurements of a continuous gas stream through the sensor (refer to the application note on SDP Measurement Parameters for details). In contrast, many differential pressure sensors are based on the membrane measurement principle: a sensor detects a pressure difference *via* a pressure-sensitive membrane between two separate pressure chambers inside the sensor.
If a customer switches their system from membrane technology to flow-through technology, this fundamental difference in the measurement principle (air flow through the sensor *vs*. separate pressure chambers in the sensor) must also be considered for a successful design-in strategy of the SDP sensor. The following points should be considered:

Measurement accuracy

Based on the flow-through measurement principle, Sensirion's SDP sensors have the highest sensitivity at low differential pressures and have no zero-point drift. Accordingly, the design of the gasflow system can be optimized for a low differential pressure (and thus for a low flow rate through the sensor). This is fundamentally different from membrane sensors: they show lower sensitivity at low differential pressure.

Drift

SDPs have no moving parts inside the sensor. The only thing in motion is the gas flowing through the sensor. This is the reason for the SDP's excellent zero-point offset stability and long lifetime in the field. A recalibration or other maintenance work becomes obsolete.
Membrane sensors function through a mechanically flexible sensing element. Over lifetime, the sensing element fatigues. Regular recalibration of the zero-point and maintenance throughout sensor lifetime is often necessary to hold measurement accuracy at its specified level.

Sensor tube connection

SDP sensors measure the differential pressure *via* a gasflow. This gasflow can induce a pressure difference in the tube and can thus impact the measurement signal. For details, refer to Chapter 4.2.
For membrane sensors, there is no flow through the tubes. Therefore, there is no influence of tubes on the differential pressure measurement signal.

Overpressure

For membrane sensors, it is common to specify a common mode pressure. It describes the maximum pressure between both chambers before the measurement membrane is damaged. Since SDP sensors do not have such a measurement membrane, this problem is of no concern to SDP sensors.
For SDP's we specify allowable overpressure and rated burst pressure. For details, refer to Chapter 5.

3 SDP design-in for gasflow measurement

SDP sensors are based on the microthermal measurement principle and are fully calibrated for differential pressure reading. They can be used for differential pressure measurement but can also be implemented in a gasflow system to measure massflow or volume flow. For details on all three measurement parameters refer to the application note on SDP Measurement Parameters.

For a direct differential pressure measurement, each sensor port connects to a separate pressure zone in the system. However, as there will be a small flow through the sensor, the SDP sensor is not suited for applications where airtight separation between the two measurement zones is required.

For a massflow measurement, the SDP sensor acts as a bypass to the main flow channel of the gasflow system. Therefore, the actual massflow is measured indirectly by the SDP sensor mounted in a bypass. If your application targets a gasflow measurement, Sensirion advises optimizing the flow system design accordingly.

3.1 What is a bypass configuration?

The SDP sensor is commonly used to measure mass flow. As such, it is installed in the bypass configuration (**Figure 1**): The flow channel of a system is the mainpass. A flow restrictor in the mainpass creates a pressure increase upstream of the flow restrictor and a pressure decrease downstream of the flow restrictor. The SDP sensor connects to each pressure zone with one port (upstream and downstream of the flow restrictor). If a gas flows through the mainpass, a small gas stream flows through the SDP sensor that acts as the bypass. The sensor measures a pressure difference.
Sensirion's SDP sensors allow for a very accurate flow measurement in such a bypass configuration because they have the highest sensitivity at low differential pressures and have no zero-point drift.

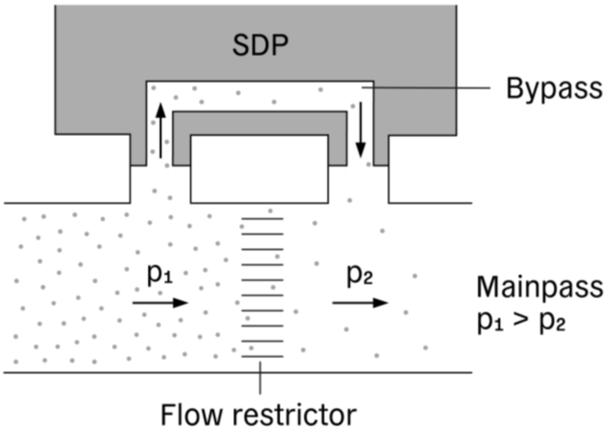


Figure 1. The SDP bypass configuration for massflow measurements consists of three elements: the mainpass of the flowing gas, a flow restrictor that builds up a pressure difference in the mainpass, and the bypass through the SDP sensor, that connects to each pressure zone with one port respectively.

3.2 System design for massflow measurements

Each gasflow system consists of several elements. Such elements can be the mainpass, the flow restrictor, tubes that connect the sensor to the mainpass, the sensor itself, *etc*. The goal of a good system design is to identify and (if possible) modify the impact of each element on the system performance. A design review and system characterization must be performed each time an element of the system changes.

3.2.1 Workflow for the design of a mainpass/bypass system

Design steps for a successful massflow measurement with the SDP sensor:

1. Design the gasflow system including a pressure drop element in the mainpass.
2. Introduce the SDP sensor to the flow system in bypass configuration. The measurement mode of the SDP shall be adjusted to temperature compensation for massflow (refer to respective SDP datasheets for details).
3. Ensure that you have the capability to adjust a stable flow over the whole range of your use case.
4. Ensure that you have an external reference capable of measuring the massflow through your system.
5. Measure the gasflow through the system and read the SDP sensor signal over multiple measurement points over the whole range of your use case.
6. Correlate the gas massflow through the mainpass with the SDP sensor signal (**Figure 2**).

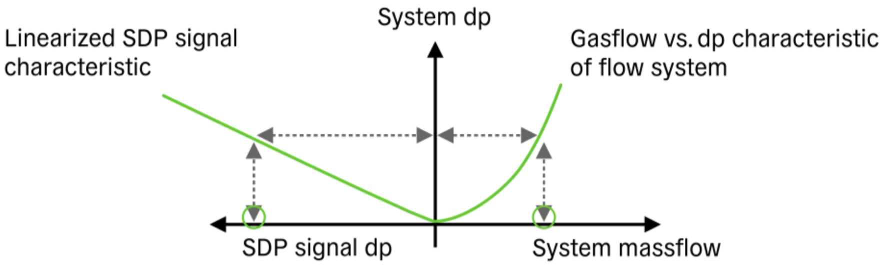


Figure 2. During the design-in process of the SDP sensor for gasflow measurement, the SDP signal is correlated to the massflow through the mainpass.

Important Notices

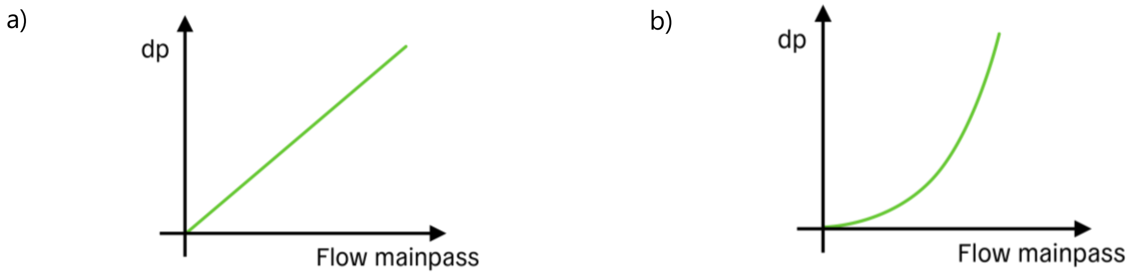
- Designing a mainpass-bypass system with good performance is a challenging process that requires a high level of expertise and development effort.
- Please note that all gasflow systems differ strongly between each other. Specific statements on system design with general validity are hardly possible. Instead, Sensirion outlines main aspects for an optimized gasflow system design.
- A typical design process of a gasflow system commonly involves several iteration steps until the engineer derives the optimum system setting.
- A high proportion of laminar flow characteristics optimizes signal-to-noise ratio, especially in the low flow range.
- Gas temperature and gas pressure can influence measurement accuracy. If high measurement accuracy is required, a separate massflow-to-dp characterization may be taken for different temperature and pressure conditions.
- System characterization: Thanks to the fact that all SDP's are calibrated for differential pressure, the correlation of differential pressure reading to massflow in the mainpass may be executed only on sample basis during the characterization of the system. In case the mainpass manufacturing is very reproducible, the initial correlation can be adopted to all devices with the same flow system and must not be repeated for every device separately.
- Single-device system calibration: In case of high accuracy requirements or device-to-device variations in the mainpass geometry, a calibration and/or adjustment of every single system may be necessary. In some cases, a single-point calibration may be sufficient.

3.2.2 The influence of linear and quadratic gasflow

The flow conditions in the mainpass have a major influence on the measurement performance of the mainpass-bypass system.

In a purely laminar flow, only wall friction generates a pressure drop. This friction scales linearly with the flow.

In a purely turbulent flow, kinematic effects (*i.e.* acceleration and deceleration) generate a pressure drop. These effects scale quadratic with flow velocity (**Figure 3**).
Commonly, a flow system has a mixed flow characteristic with linear and quadratic contributions. You can influence the proportion of laminar and turbulent flow with a targeted design of the flow restrictor in the mainpass. For details refer to Chapter 3.2.3.



linear flow characteristic of gasflow in mainpass and dp reading in bypass

quadratic flow characteristic of gasflow in mainpass and dp reading in bypass

Figure 3. A typical flow profile of a gasflow system consists of both linear (a) and quadratic (b) flow contribution.

3.2.3 Three design elements: bypass, mainpass & flow restrictor

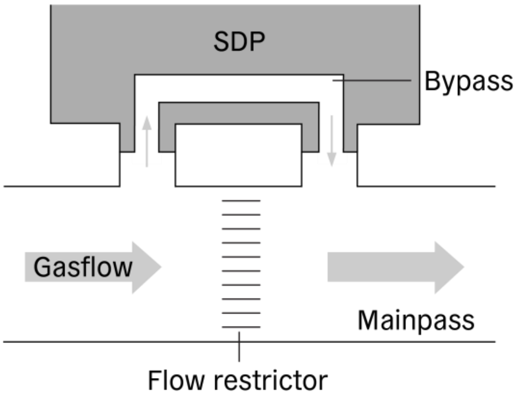


Figure 4. A flow system with SDP sensor has three main components: the bypass, the mainpass and the flow restrictor in the mainpass.

The bypass: SDP sensor

The SDP sensor is calibrated to differential pressure. The signal output is fully linearized. For this reason, small variations in the flow channel dimensions of the sensor have no effect on the flow profile of the mainpass/bypass system.
As the SDP sensor is calibrated for differential pressure, the dp-to-flow characteristic has a significant device-to-device variation. However, as a rule of thumb the flow through the SDP sensor can be approximated as listed in **Table 2**.

Sensor series	approximate pressure-to-flow characteristic	
	100 Pa	500 Pa
SDP8xx	33 – 43 sccm	90 – 115 sccm
SDP3x	25 – 32 sccm	65 – 85 sccm

Table 2. Approximation of the differential pressure-to-flow characteristic for different SDP sensor series.

The mainpass: main flow channel

A smart design of the mainpass can support SDP measurement performance. The following points should be considered for mainpass design:

- The gas flow through the mainpass shall be significantly larger than the gas flow through the bypass.
- Good inlet conditions to the flow restrictor are key for stable and reproducible flow measurement. Therefore, avoid bends and kinks close to the flow restrictor.
- Fans, blowers, valves, or other flow sources may create noise and turbulence. Therefore, place the sensor as far away as possible from the flow source. This is especially important when the flow source is placed upstream of the SDP sensor.

Flow restrictor in mainpass

The purpose of the flow restrictor is to create a pressure drop in the mainpass. A pressure drop across sensor ports is necessary to induce flow through the sensor. In principle, any design that creates a pressure drop in the mainpass can be used as flow restrictor for massflow measurement in bypass configuration. Already existing elements in the mainpass can also serve as a flow restrictor. However, it is important to note that every flow restrictor has its own flow profile with linear and quadratic contributions. Accordingly, the flow restrictor design has an impact on sensor performance.

Sensirion’s SDP sensors have a high sensitivity at low differential pressure and no zero-point drift. This allows to optimize a flow restrictor design that is specifically designed for low differential pressure. A flow restrictor that induces only a small differential pressure over the sensor ports has the following advantages:

- An increase in energy efficiency due to a reduction of pressure drop in the system.
- A reduction of gasflow through the sensor, which also reduces the amount of dust flowing through the sensor.

Sensirion’s recommendation for a suitable flow restrictor design:

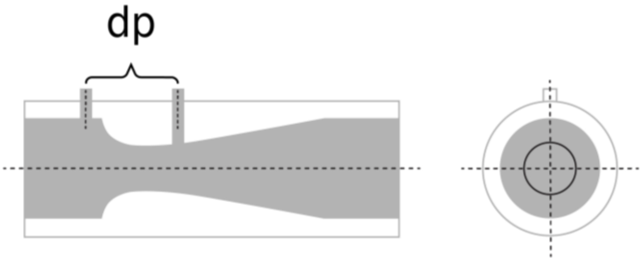
- A flow system has a mixed flow characteristic with linear and quadratic contributions. You can influence the proportion of laminar and turbulent flow with a targeted design of the flow restrictor in the mainpass.
- For a higher linear flow contribution, the wall surface parallel to the flow of a pressure drop element shall be maximized and cross-section perpendicular to the flow shall be minimized.

The perfect flow restrictor design is always a compromise between several parameters: direct product parameters that may be considered are the required dynamic measurement range, the available space in the mainpass, or the maximum allowed added pressure resistance of the flow system. Indirect product parameters are engineering effort, processability, and production costs.

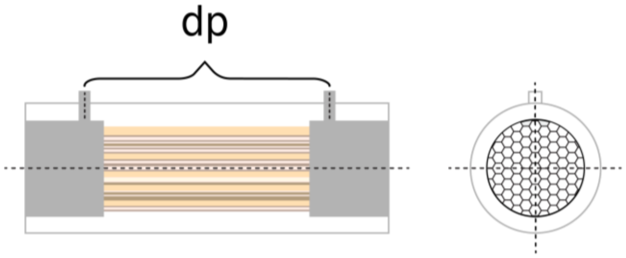
Possible flow restrictor designs are shown below:

Simple flow restrictor
Flow characteristic: quadratic
Design: simple

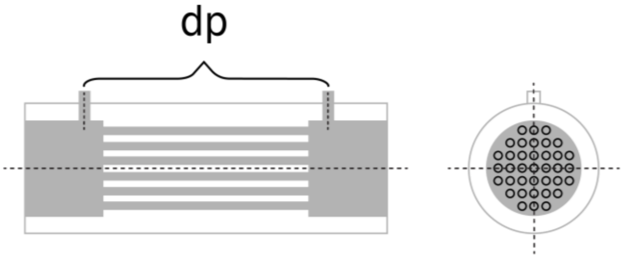
Venturi
Flow characteristic: quadratic
Design: suitable if small pressure drops are required



Honeycomb or other lamellar built-up
Flow characteristic: linear
Design: recommended for highest dynamic ranges



Bundles of tubes
Flow characteristic: linear and quadratic contribution
Design: good trade-off between high dynamic range and low production costs; can be adjusted by changing number of tubes and inner tube diameters.



3.2.4 Gasflow measurement against ambient

In some applications, the differential pressure is measured against ambient pressure. Often, this kind of design is implemented in small devices. In this configuration (**Figure 5**), the SDP inlet port is kept open to ambient. Only one port connects to the mainpass. Already existing structures in the mainpass can act as flow restrictor. This design-in requires a precise differential pressure measurement over the entire dynamic range.

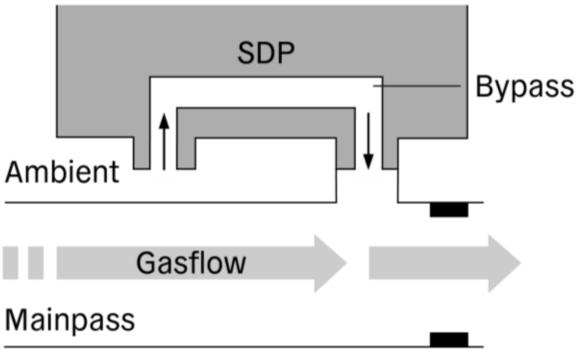


Figure 5. In some applications, the sensor inlet port is kept open to ambient. Only the outlet port connects to the mainpass.

In the same way, the SDP can also be integrated with a venturi nozzle as flow restrictor (**Figure 6**). In this design, air always flows into the sensor from ambient regardless of the flow direction in the mainpass. Contaminated gas from the mainpass will not enter the sensor. The disadvantage of this design is the high quadratic flow contribution from the Venturi nozzle. It can increase measurement noise and provides less sensitivity at low flows.

It is important to note that any additional pressure drop upstream or downstream of the venturi nozzle, intended or by accident, would cause major deviations from the sensor signal and the true gasflow through the mainpass.

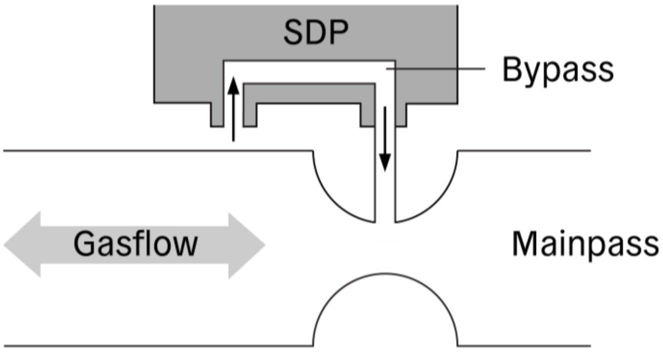


Figure 6. When measuring massflow against ambient, a venturi nozzle can act as flow restrictor. The benefit of this design is that contaminated air from ambient is less likely to enter the mainpass. The disadvantage is the strong quadratic flow contribution of the nozzle.

4 Sensor port connection

SDP sensors are available with two different port types: manifold and barb (**Figure 7**). Availability of the port type depends on SDP sensor size and varies between SDP sensor families.

Manifold ports are designed for direct integration to the flow path of a device. Below a certain sensor size, this is the only connector available. Barb ports are designed to best fit with tubes.

manifold ports
for direct integration to the flow system

barb ports
for tube connection

Figure 7. SDP manifold ports and SDP barb ports: different aspects must be taken into account for the design integration of each port type.

4.1 SDP sensor with manifold ports

Manifold ports allow for a direct design-in of the sensor to the flow path. No additional tubes are required. Challenges for the integration of an SDP sensor with manifold ports are air-tight sealing to avoid leakage of the gasflow, and stress-relief mechanism to avoid damage of the ports.

SDP sensors with manifold ports are not designed for direct use with tubes. Where tube connection is necessary, Sensirion recommends using an adaptor piece or using a SDP sensor with barb ports.

4.1.1 Integration manifold ports

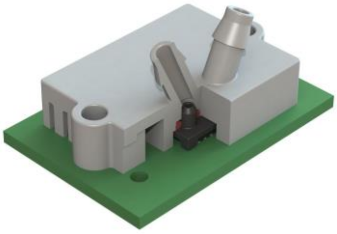
Three configurations are possible for the integration of SDP sensors with manifold ports: direct integration, a rigid adaptor, or a soft adaptor between flow path and sensor ports.

Direct integration

The SDP sensor with manifold ports can be directly integrated to a flow channel or gas chamber. When the sensor is directly integrated, the sensor ports must be sealed properly to avoid gas leakage. For details refer to Chapter 4.1.2.

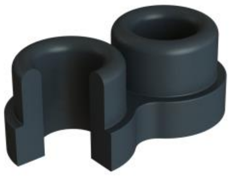
Rigid sensor adaptor

A rigid adaptor made of hard plastic can be used to connect the sensor ports to the flow channel. This integration strategy can help simplify the assembly process. Such an adaptor piece can also be designed to allow for tube connection.



Soft sensor adaptor

A soft adaptor made of silicone, or a similar material can be used to connect the sensor ports to the flow channel. The soft adaptor ensures a flexible connection that allows for stress relief. Such an adaptor piece can also serve as a sealing between sensor and flow channel.

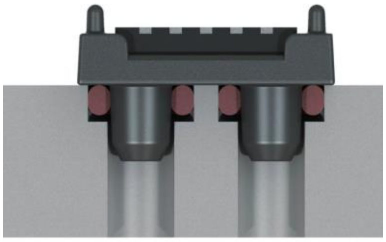


4.1.2 Port sealing

For sealing manifold sensor ports, Sensirion recommends four possible sealing strategies: radial sealing, axial sealing, gasket sealing, or a soft sealing adaptor.

Radial sealing

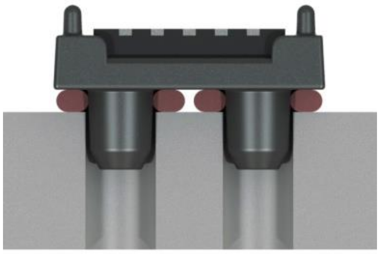
For radial sealing, one O-ring around each port ensures a gas-tight connection between the sensor and the flow channel. Grooves in the flow channel accommodate the O-rings around the ports. The sensor lies flat on the flow channel housing.



Recommended O-ring dimensions:

	SDPxx	SDP8xx
inner O-ring diameter	2 mm	3.5 mm
outer O-ring diameter	4 mm	6.5 mm
O-ring cross-section	1 mm	1.5 mm

Axial sealing

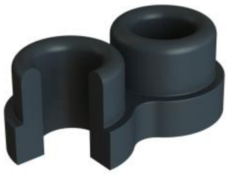


For axial sealing, one O-ring around each port ensures a gas-tight connection between the sensor and the flow channel. The sensor does not lie flat on the flow channel housing as in radial sealing. Instead, it lies on the O-rings. Therefore, it is important to ensure constant but not excessive contact pressure. This guarantees a tight connection without mechanical stress on the sensor. A soft sealing material is recommended.
Sensirion recommends preferring radial over axial sealing whenever possible.

Gasket sealing

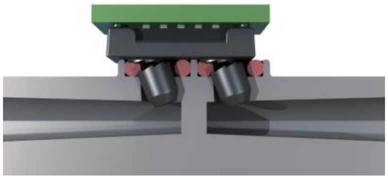
For gasket sealing, a flat soft sealing material is punched to fit the sensor. The gasket sealing is positioned between the sensor and the flow channel housing.

Sealing adaptor



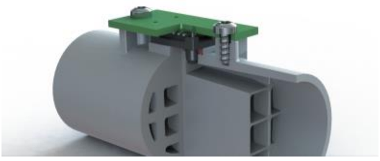
A fourth sealing strategy is sealing the sensor ports with a soft sealing adaptor. The adaptor connects the sensor with the manifold of the flow channel housing. Such a design can help reduce mechanical stress on the sensor.

4.1.3 Stress relief on ports



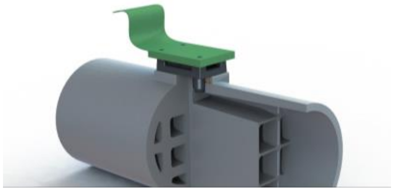
A manifold SDP is a robust component. In most cases, an SDP with manifold ports is solidly fixed to a device *via* the soldering to the PCB. In its role as gasflow sensor, it is not only fixed to the PCB, but also tightly connected to the flow channel of the device. Under certain circumstances, i.e. a fall to the ground, this double connection of the sensor to the device can induce (peak) stresses specifically on the ports of the sensor. For that reason, it is important to consider stress relief mechanisms during the design-in of a manifold SDP sensor. A rigid connection of the sensor to the device PCB, paired with a rigid connection of the sensor ports to the flow channel with no stress-relief mechanism, can lead to sensor damage. This is to be avoided. Three strategies for stress relief are recommended by Sensirion: a rigid sensor connection, a flexible PCB connection, or a flexible port connection.

Rigid sensor connection



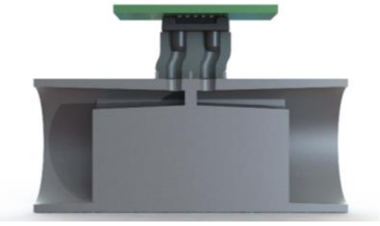
Shear stresses on the sensor ports can be prevented if the flow channel housing connects to the PCB with a rigid connector. Possible rigid connectors are clip-in pins, screws, or glue.

Flexible-PCB connection



Shear stresses on the sensor ports can be prevented if the PCB print is only firmly attached to the sensor and electrical connection is *via* flex-prints or cables.

Flexible port connection



Shear stresses on the sensor ports can be prevented if the connector between flow channel housing and sensor ports are flexible (soft and bendable material). The flexibility of the soft and flexible port connector prevents the build-up of stress on the sensor ports.
A sealing adaptor as mentioned above can also serve as flexible port connector.

4.2 SDP sensor with barb ports

Barb ports allow for a direct connection of the sensor to tubes. Barb ports are available with the SDPxxx sensor series. Sensirion recommends tubes with an inner diameter of 4 mm for SDP8xx series. Sensirion does not recommend connecting tubes with the SDPxx series. For port connection of SDPxx sensors, please refer to the previous chapter on SDP sensor with manifold ports.

4.2.1 Tube influence on differential pressure measurement

With the microthermal measurement principle, a small gas stream flows through the sensor. Tubes that guide the gasflow to and from the sensor can influence the flow characteristics of the gasflow system. This can lead to a small deviation of the differential pressure reading. The extent of this deviation depends on the tube dimensions (length and inner diameter) and the tube shape.
Tube Dimensions: In general, shorter and wider tubes have a smaller impact on differential pressure signal deviation. For SDP8xx sensors, the measurement error is ≤ 1.5 % if the inner tube diameter is 4 mm and the tube length is ≤ 1 m. See below for a detailed calculation of the measurement error for your tube of choice.
Please note, that such detailed considerations must only be taken into account if an absolute dp value in Pa is required with absolute accuracy, *and* the dp measurement needs to be very accurate.
When you implement the SDP sensor as massflow sensor, the tube contribution to the pressure difference is already considered during massflow system characterization (refer to Chapter 3). A separate tube characterization is not necessary.

Tube Shape: In general, kinks in the tube should be avoided. They can impact the measurement.

4.2.2 Calculation of pressure drop in a tube

The SDP sensor measures the pressure difference between the inlet and outlet port of the sensor. The sensor cannot resolve the influence of separate parts of the surrounding flow system (like flow tubes) on the total pressure difference.
Every tube creates a pressure drop for the gas that flows through it (**Figure 8**). The pressure drop for non-turbulent gasflow through a long, narrow tube with circular cross-section, dp_{tube}, is described by the Hagen-Poiseuille law. This law describes the following dependencies of tube dimensions on pressure drop:

- The pressure drop is proportional to the combined tube length of inlet and outlet tube, $L = L_1 + L_2$, and the gasflow, q.
- The pressure drop is inverse proportional to the 4th power of the inner tube diameter, D.

In order to determine the pressure drop over your tube of choice, follow these steps:

1. Connect the sensor ports to the tube you want to test.
2. Perform a measurement and read the DP from the sensor.
3. Calculate the contribution of the tubes to the DP of the flow system:

$$dp_{tube} = dp_{sensor}\left(\frac{1}{1+\varepsilon} - 1\right) \qquad 1$$

with

$$\varepsilon = -\frac{64}{\pi}\frac{L}{D^4}\frac{\eta_{air}}{\rho_{air}}\frac{q_c}{dp_{sensor}}\left(\sqrt{1+\frac{8\,dp_{sensor}}{dp_c}}-1\right) \tag{2}$$

$$\eta_{air} = \big(18.205 + 0.0484 * (T[°C] - 20)\big) * 10^{-6}\,Pa * s \tag{3}$$

$$\rho_{air} = (1.1885 * p_{abs}) * \frac{293.15}{(273.15 + T[°C])}\frac{kg}{m^3} \tag{4}$$

$$q_c = 6.17 * 10^{-7}\,\frac{kg}{s} \tag{5}$$

$$dp_c = 62\,Pa \tag{6}$$

with
$L = L_1 + L_2$ = total tube length [m] (sum of inlet and outlet tube length)
D = inner tube diameter [m]
η_{air} = air viscosity at temperature T [°C]
ρ_{air} = air density at temperature T [°C]
dp_{sensor} = DP sensor reading in [Pa]
p_{abs} = absolute air pressure of operation environment [bar]
q_{c} and dp_{c}: sensor-specific constants for massflow and DP for SDP8xx series

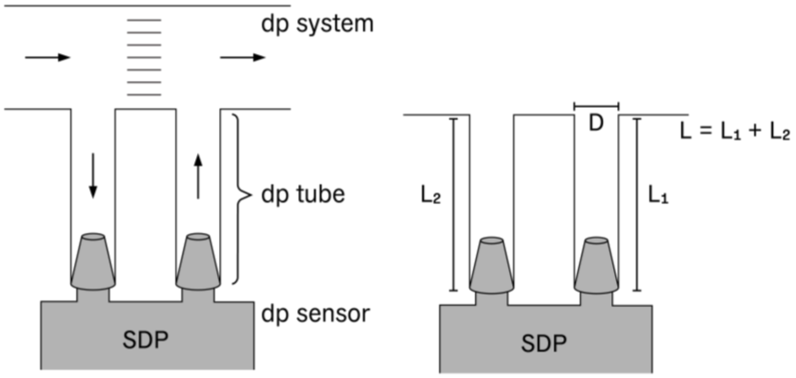


Figure 8. The tube parameters length (L), and diameter (D) influence the difference between differential pressure of the system (dp_{system}), and differential pressure reading of the sensor (dp_{sensor}).

Let us assume the following use case: During the design-in of the SDP sensor, you compare two tubes of different diameters (D = 4 mm *vs.* D = 5 mm). The length L of the tubes is not settled yet. The absolute pressure, p_{abs}, inside your flow system is 1 bar and the temperature, T, is 25 °C. The pressure reading of the SDP sensor, dp_{sensor}, is 250 Pa. You use the Hagen-Poiseuille law to calculate the influence of different tube dimensions on the pressure reading:
From the pressure p_{abs}, and the temperature T, you can derive air viscosity, η_{air}, and air density, ρ_{air}:

$$p_{abs} = 1\,bar\,; T = 25°C \quad\rightarrow\quad \eta_{air} = 1.8447 * 10^{-5} Pa * s\,;\ \rho_{air} = 1.1686\,\frac{kg}{m^3}$$

Now, take the sensor-specific parameters, m_{c} and dp_{c}, and the SDP sensor reading, dp_{sensor} = 250 Pa into account to derive ε and the pressure drop of the tubes (**Table 3**):

tube dimension	deviation of measurement signal		
D = 4 mm, L =	ε	dp_{tube}	deviation
3 m	-0.0443	11.59 Pa	-4.6 %
1 m	-0.0148	3.76 Pa	-1.5 %
0.5 m	-0.0074	1.86 Pa	-0.7 %
0.1 m	-0.0015	0.36 Pa	-0.1 %

Table 3. Gasflow tubes can lead to a sensor signal deviation. The extent of the deviation depends on the tube dimension.

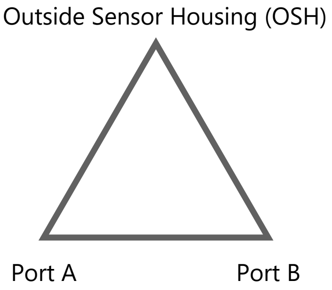
5 Overpressure

SDP sensors are designed for use under ambient atmospheric pressure. Under this condition, SDP sensors operate well. At pressures much larger than ambient atmospheric pressure (or at peak pressures in the system), the sensor can be damaged. Sensor damage through overpressure can lead to signal drift and leakage of the sensor. To avoid sensor damage from overpressure, overpressure specifications of the sensor must be considered during the design-in phase of the sensor.

Specifications on overpressure and burst pressure can be found in the respective datasheets of each SDP product.

5.1 Overpressure definitions

The specifications for allowable overpressure and rated burst pressure can be visualized by a triangle. In this triangle, the differential pressure on any leg (A-OSH, B-OSH, A-B) must not exceed the overpressure or burst pressure specifications defined in the product datasheet.



5.1.1 Allowable overpressure

The allowable overpressure, p_{max}, defines the maximum allowable pressure difference between each sensor port and the outside of the housing. Sensor operation below the allowable overpressure will not damage the sensor.

5.1.2 Rated burst pressure

The rated burst pressure, p_{burst}, defines the pressure difference between each sensor port and the outside of the housing above which the sensor can burst open. Irreversible damage to the sensor and significant leakage of the gasflow can occur.

In the range between p_{max} and p_{burst}, the sensor might drift and show small leaks.

5.1.3 Common mode pressure

A common mode pressure is often mentioned for membrane-based differential pressure sensors. This pressure is not relevant for thermal flow-through sensors like the SDP sensor. Here, this information is covered by the allowable overpressure.

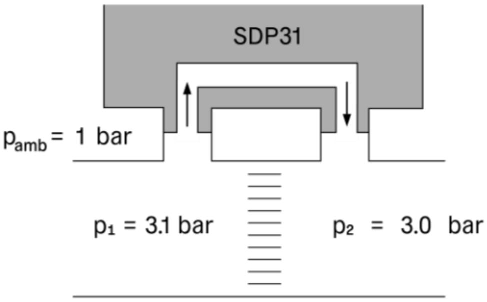
5.2 Overpressure calculation example

We illustrate overpressure considerations for the design-in phase of a SDP31 sensor. We discuss one use case with two different design-in strategies.
The specifications of the sensor are:

- allowable overpressure p_{max} = 1 bar
- rated burst pressure p_{burst} = 3 bar
- maximum measurement range dp_{max} = 500 Pa

Case 1: sensor is out of specification

In this example, the SDP31 is placed over a pressure drop element in a flow channel with following conditions:



- absolute pressure p_1 = 3.1 bar on one port
- absolute pressure p_2 = 3.0 bar on the other port
- sensor is placed in ambient with an absolute pressure of p_{amb} = 1 bar

Figure 9. In this example, the SDP31 is exposed to strong pressure differences.

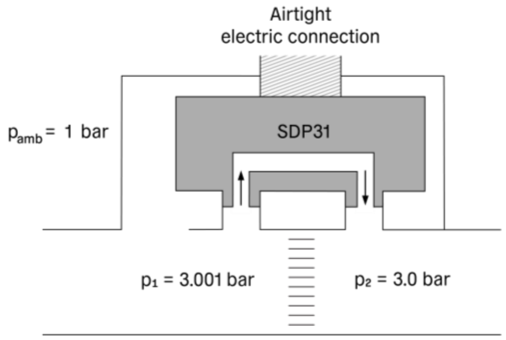
Let's analyze the system (**Figure 9**):

- The pressure difference between the ports ($p_1 - p_2$) is: 3.1 bar – 3 bar = 0.1 bar = 10 kPa. This is out of the maximum measurement range of the sensor (500 Pa). The sensor is saturated and outputs dp = 546.1 Pa. The difference of 0.1 bar between the sensor ports is smaller than the allowable overpressure. Therefore, the saturation will not damage the sensor.
- The pressure difference between port 1 and the outside sensor housing (ambient air) ($p_1 - p_{amb}$) is: 3.1 bar – 1.0 bar = 2.1 bar. This pressure difference exceeds the allowable overpressure by 1.1 bar. Therefore, the sensor might drift and show small leaks. However, the pressure difference does not exceed the burst pressure.
- The pressure difference between port 2 and the outside sensor housing (ambient air) ($p_2 - p_{amb}$) is: 3 bar – 1 bar = 2 bar. This pressure difference exceeds the allowable overpressure by 1 bar. Therefore, the sensor might drift and show small leaks. However, the pressure difference does not exceed the burst pressure.

Conclusion: In this example, the design-in of the SDP31 needs to be changed. The pressure difference between the outside ambient pressure and the respective port pressures exceeds the allowable overpressure specification of the sensor. It does not exceed the burst pressure specification.

Case 2: sensor is in specification

In this example, the SDP31 is placed over a pressure drop element in a flow channel with following conditions. Different to the first example, the sensor is not placed in ambient. Instead, it is encapsulated to the outside and connected to the flow channel in an airtight manner:



- absolute pressure p_1 = 3.001 bar on one port
- absolute pressure p_2 = 3.0 bar on the other port
- sensor is encapsulated airtight with an absolute pressure outside the airtight design of p_{amb} = 1 bar

Figure 10. In this example, the design-in of the SDP31 shields the sensor from strong pressure differences in its surrounding.

Let's analyze the system (**Figure 10**):

- The pressure difference between the ports ($p_1 - p_2$) is: 3.001 bar – 3 bar = 0.001 bar = 100 Pa. This is within the measurement range of the sensor. The sensor outputs *dp* = 310.6 Pa, assuming a gas temperature of 25 °C. Refer to the application note on SDP Signal Compensation for more details.
- The pressure difference between port 1 and the outside sensor housing is: 3.001 bar – 3.001 bar = 0 bar. Thanks to the encapsulation design, there is no pressure difference between port 1 and the outside of the sensor. Therefore, the pressure difference does not exceed the allowable overpressure nor the burst pressure.
- The pressure difference between port 2 and the outside sensor housing is: 3.001 bar – 3.0 bar = 0.001 bar. This pressure difference is much smaller than the allowable overpressure and the burst pressure of the sensor. Neither pressure specifications are exceeded.

Conclusion: In this example, the design-in of the SDP31 meets both the allowable overpressure and burst pressure specifications of the sensor. The sensor will not drift or leak due to overpressure damage.

6 Leakage

If the sensor leaks, the signal output deviates from the real system pressure difference. Such misreading must be avoided. To avoid sensor leakage, two main aspects should be considered:

- To avoid gasflow leakage at the ports, the sensor ports must be sealed properly (Chapter 4).
- To avoid gasflow leakage from sensor damage, the sensor must operate within the overpressure specifications given in the datasheet (Chapter 0). Else, the sensor can leak and show irreversible drifts.

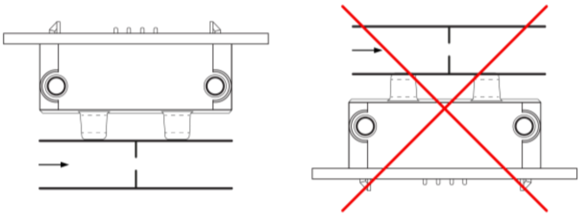
7 Dust

Dust is ubiquitous and can be encountered everywhere in everyday life. In usual amounts, dust has no influence on SDP sensor performance. At continuously high levels of dust, it can accumulate inside the sensor over its lifetime and lead to signal drift.

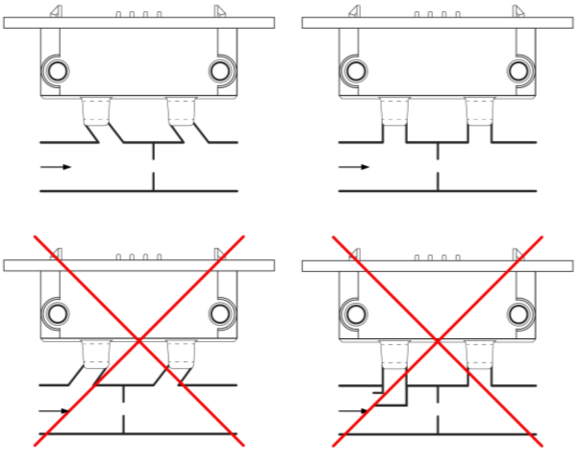
If high dust levels should be of concern in your application, you can limit sensor exposure by taking some basic design-in strategies into account.

Sensor orientation in flow system

- Gravity pulls dust particles towards the bottom side of a gasflow channel, where it might accumulate over time. Whenever possible, place the sensor on the top side of the gasflow channel to avoid dust sedimentation into the sensor.



- Dust is heavier than the surrounding gasflow. You can use this higher momentum of inertia to your advantage: If the inlet to the sensor points against the direction of flow, dust will not be dragged into the sensor.



Gasflow design

A small gasflow transports less dust than a strong gasflow. Therefore, design your gasflow system so that the amount of gasflow through the sensor is as low as possible. Sensirion's SDP sensors have the highest sensitivity at low differential pressures and have no zero-point drift. This may seem counter-intuitive to those users, who worked with DP sensors based on membrane technology before. Refer to Chapter 2.4 for more details on the difference between thermal flow-through technology and membrane technology.
A high sensitivity at low differential pressure and no zero-point drift allow for a very accurate flow measurement in a bypass configuration at very low pressure drops. A pressure drop of 50 Pa or less is plenty to still have an excellent dynamic range. For some flow systems, even a target of a 5-10 Pa pressure drop in the usual working range may be appropriate. Note that a further decrease in pressure drop increases signal susceptibility to turbulences that can be present in the flow system (caused by bad inlet conditions, *etc.*).

Dust filter

In case none of the above-listed strategies can be successfully applied in the flow system design, Sensirion recommends implementing filters to prevent dust contamination.
If a filter is installed, it should sit in front of the sensor, so that only clean air reaches the sensor. Consider that a filter can act as a pressure drop element for the gasflow. Therefore, it can impact the measurement. To limit this effect, the pressure drop of the filter must be small compared to the pressure difference of the measurement.
A suitable dust filter must be adapted to the properties of the dust it is intended to filter (particle size, dust type, dust quantity, *etc.*). These parameters are defined by the ecosystem in which the sensor is placed and not by the sensor itself. Consequently, the choice of a suitable dust filter is up to the design-in engineer and cannot be defined by Sensirion.

8 Further Information

Useful Resources

- Product catalog [Product catalog (sensirion.com)]
- Technical download [Technical download (sensirion.com)]
- SDP sensor evaluation [Differential pressure evaluation (sensirion.com)]
- GitHub [Sensirion AG · GitHub]
- FAQ [FAQ (sensirion.com)]
- Technical Customer Support [Support contact (sensirion.com)]

Sensor calibration

Thanks to the stability of the MEMS-based sensor element and the robust mechanical design, Sensirion Differential Pressure Sensors, SDP, do not drift and do not require recalibration in the field.
High manufacturing standards used during production ensure that our Differential Pressure Sensors are extremely reliable and have a very low failure rate. This is supported by field surveys and measurements.

Common pressure units

Unit	Conversion to 1 Pa	Conversion to 500 Pa
Pascal (Pa)	1 Pa	500 Pa
Bar (bar)	10×10^{-6}	0.005
atmosphere (atm)	9.8×10^{-6}	4934×10^{-6}
Pound-force per square inch (psi)	0.145×10^{-3}	72.5×10^{-3}
Inch of water (inH_2O)	0.004	2

Table 4. Conversion table for 1 Pa and for 500 Pa to other pressure units.

9 Revision History

Date	Version	Pages	Changes
Jan 2024	0.1	all	Initial version
June 2024	1.0	all	Release

Important Notices

Warning, Personal Injury

Do not use this product as safety or emergency stop devices or in any other application where failure of the product could result in personal injury. Do not use this product for applications other than its intended and authorized use. Before installing, handling, using or servicing this product, please consult the data sheet and application notes. Failure to comply with these instructions could result in death or serious injury.

If the Buyer shall purchase or use SENSIRION products for any unintended or unauthorized application, Buyer shall defend, indemnify and hold harmless SENSIRION and its officers, employees, subsidiaries, affiliates and distributors against all claims, costs, damages and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if SENSIRION shall be allegedly negligent with respect to the design or the manufacture of the product.

ESD Precautions

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take customary and statutory ESD precautions when handling this product. See application note “ESD, Latchup and EMC” for more information.

Warranty

SENSIRION warrants solely to the original purchaser of this product for a period of 12 months (one year) from the date of delivery that this product shall be of the quality, material and workmanship defined in SENSIRION’s published specifications of the product. Within such period, if proven to be defective, SENSIRION shall repair and/or replace this product, in SENSIRION’s discretion, free of charge to the Buyer, provided that:

- notice in writing describing the defects shall be given to SENSIRION within fourteen (14) days after their appearance;
- such defects shall be found, to SENSIRION’s reasonable satisfaction, to have arisen from SENSIRION’s faulty design, material, or workmanship;
- the defective product shall be returned to SENSIRION’s factory at the Buyer’s expense; and
- the warranty period for any repaired or replaced product shall be limited to the unexpired portion of the original period.

This warranty does not apply to any equipment which has not been installed and used within the specifications recommended by SENSIRION for the intended and proper use of the equipment. EXCEPT FOR THE WARRANTIES EXPRESSLY SET FORTH HEREIN, SENSIRION MAKES NO WARRANTIES, EITHER EXPRESS OR IMPLIED, WITH RESPECT TO THE PRODUCT. ANY AND ALL WARRANTIES, INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSLY EXCLUDED AND DECLINED.

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SENSIRION does not assume any liability arising out of any application or use of any product or circuit and specifically disclaims any and all liability, including without limitation consequential or incidental damages. All operating parameters, including without limitation recommended parameters, must be validated for each customer’s applications by customer’s technical experts. Recommended parameters can and do vary in different applications.

SENSIRION reserves the right, without further notice, (i) to change the product specifications and/or the information in this document and (ii) to improve reliability, functions and design of this product.

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