SENSIRION
THE SENSOR COMPANY

Testing Guide

For Sensirion Differential Pressure Sensors

Introduction

Before design-in of a sensor, it is common practice to evaluate and qualify the sensor. The evaluation kits EK-P4 and EK-P5 are the best choice for quick and easy evaluation of Sensirion's differential pressure sensors. After a successful evaluation, many companies require an internal qualification of new parts and technologies.

Sensirion's differential pressure sensors utilize the thermal flow through technology to achieve the highest sensitivities at low pressures and flow. Because of its reliability and repeatability, it is the technology of choice for the most demanding applications, such as burner control, medical respiratory devices, automotive mass air-flow sensors, and many more.

The thermal flow through technology, often called 'the dynamic measurement principle', has many benefits compared to traditional technologies, such as membrane or diaphragm sensors. However, they also have a different absolute pressure and temperature dependency. Those different dependencies are beneficial in most applications, but they must be taken into account when the sensors are tested and are compared to references, which are often membrane-based sensors.

This guide aims to guide engineers through the testing and qualification process; describes best practices, pitfalls and common observed behavior that could be falsely interpreted as erroneous behavior of the sensor.

1 Test Pre-Conditions

For good test results, the following test pre-conditions are recommended:

- Sensors should be stored in original packaging until used for assembly.
- Test multiple sensors in parallel at the same time (2 to 20 pieces).
- Carefully monitor and track the temperature and absolute pressure during testing. These values might be required to calculate the temperature and pressure influence on the reference and/or device under test (DUT).
- Select a lab and an area in the lab that has a stable temperature, and does not have direct influences from air sources, such as fans or air conditioning.
- Tube length can have an influence on the measurement when the impedance of the tube is significant compared to the impedance of the thermal flow through sensor. Read our application note on tube lengths, and make sure that when tests are re-done, the same tube lengths and setup are used.
- Avoid heat sources and any undesired thermal coupling to the DUTs and reference.
- When noise or signal-to-noise-ratio is relevant for the test, make sure to select a reference that has at least an equal response and sampling time as the DUT. Sensirion's differential pressure sensors are very fast and sometimes appear to be noisy, when they actually just measure the noise that is existent in the test setup. The 'average till read' mode of the digital versions of the SDP3x and SDP8xx can help to suppress the noise on the sensor signal.
- Study the accuracy specifications of the reference. Even if the reference has been recently calibrated (which it should), it does not mean that the reference has 0% accuracy error.

2 Sensor Qualification vs Production Test

We assume two different cases for testing the SDP sensors: Sensor qualification and production test. In this section we look at the differences, and give recommendations for both cases.

2.1 Sensor Qualification

After evaluation of the sensor for the application, the customer wants to assure that Sensirion's sensors are within specification.

It is reasonable that when this is the first encounter with differential pressure sensors with the dynamic measurement principle, one wants to compare the SDP sensors with a familiar reference, such as a membrane type sensor. In this case, the following should be noted:

- Membrane type sensors often have no good sensitivity and repeatability at differential pressures below 100Pa.
- To compare membrane type sensors with SDP sensors, one must take note of temperature and absolute pressure compensation, as described in section 5.2.2.

It is therefore recommended to only do the absolute necessary sensor qualification tests against a membrane type reference, and do other tests against other SDP sensors, or sensor with the dynamic measurement principle.

2.2 Production Test

After soldering of the sensor on a PCB and assembly of the sensor in the end device, it might be necessary to check whether the sensor is still functional and within specifications.

The easiest test is the offset test as described in section 4.1. No additional equipment is required for this test, and it will detect most of the possible sensor failures.

In cases where sensor accuracy is crucial, an additional test point can be introduced. Only one test point is sufficient, even when the sensor is used bi-directionally. Because of the working principle of the sensor, it is extremely unlikely that asymmetric errors occur. The test can be implemented as per section 4.2.

To avoid the need of pressure and temperature compensation, or the regular recalibration of a reference, it is recommended to use two or three SDP sensors as reference, and replace the sensors one by one regularly. This is a very cost efficient, reliable and efficient way to check the implemented sensor in the end-product after assembly.

The test procedure could be implemented as following:

1. Check reference A and B against DUT
2. If result A == B == DUT (within certain limits)
   then DUT has passed the test
3. If result A == B != DUT
   then sensor in DUT has drifted or is not functional.
   Although unlikely, it could happen that both references A and B have drifted. After a sudden increase of failed DUTs, additional investigation is required.
4. If A == DUT != B or B == DUT != A
   then respectively reference A or B has most likely drifted, and should be replaced. If replacing reference A or B does not solve the problem, further investigation is required.

Note: Sensirion does not recommend re-calibrating the sensor in the production process.

3 Important Specifics of Sensirion Differential Pressure Sensors

3.1 Dynamic Measurement Principle

Sensirion's SDP sensors measure the differential pressure by means of a small flow through the sensor. For this reason, SDP sensors are only suitable in applications where the pressure is constantly maintained. While in most applications this condition is met, it often is not the case in the testing setup.

We recommend not using pressure pumps for testing, as they are designed to create a static pressure which is then renewed once the pressure drops below a certain threshold. When pressure pumps are used in a testing setup for SDP sensors, they often account for an oscillating pressure and therefore are not the ideal choice for an SDP testing setup.

Instead, we recommend using a mass flow controller to create a constant flow to the high pressure chamber, which will lead to a constant dynamic pressure, once the chamber's inflow and outflow are in balance.

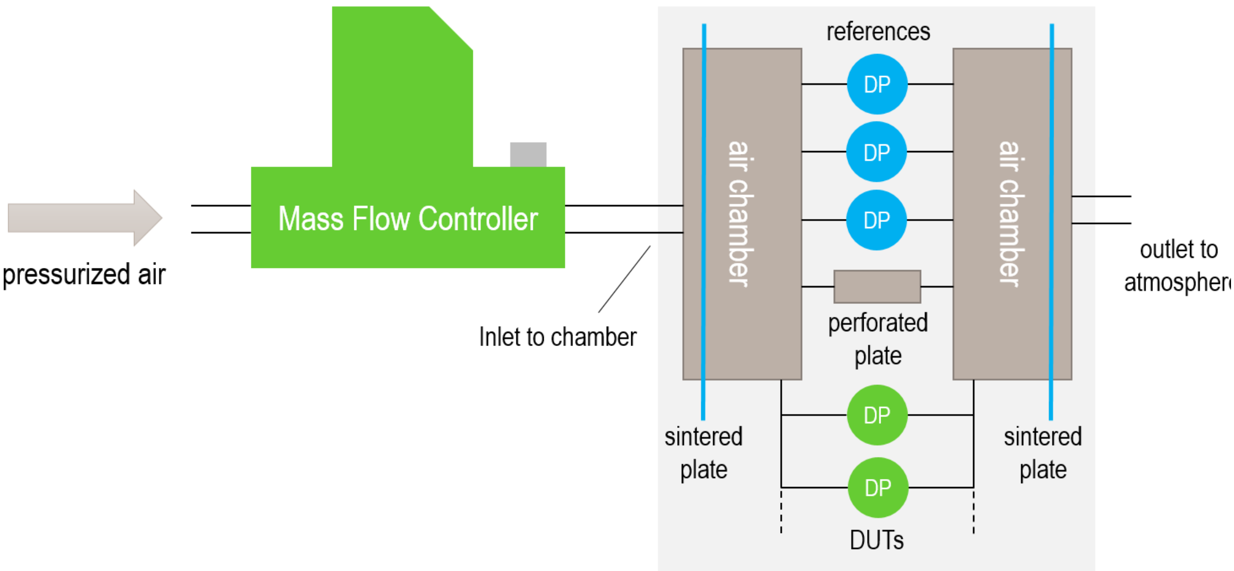


Figure 1: Schematic of recommended test setup

The sintered plate in the air chambers have the purpose of reducing the turbulence of in and outgoing flow of air. The perforated plate between both air chambers creates a reproducible pressure drop, which makes the setup less sensitive to the numbers of DUTs and references between the air chambers. Section 4.2 goes into more detail on the mechanical implementation of the air chambers.

3.2 Temperature Compensation modes

Sensirion offers two different types of temperature compensation for most of its SDP sensors. One is dedicated for the measurement of differential pressure, the other developed for the measurement of standard volume flow or mass flow in a bypass setup. We refer to the first one as "differential pressure temperature compensation" and the second one as "mass flow temperature compensation". For more detailed information and to choose the right temperature compensation for your application, there is a sensor selection guide available.

3.3 Measurement Frequency / Response Time

Sensirion's SDP8xx and SDP3x digital sensors have a measurement frequency of up to 2kHz, providing a measurement result every 0.5ms. This is much faster than most differential pressure sensors, including most high accuracy differential pressure meters, which might be used as reference devices in a laboratory. It is therefore possible, that a SDP sensor will measure pressure oscillations which the reference device cannot pick up.

When testing the accuracy of SDP sensors, the measurement frequency and the latency of the SDP sensor and the reference meter should match, especially when noise or signal-to-noise-ratio are relevant for the test. This can be achieved by using an equally fast reference device or by using the "averaging mode", which is available for the digital versions of the SDP3x and SD8xx sensors.

3.4 Differences between Sensor Models

Sensirion offers different sensor families for different applications and demands:

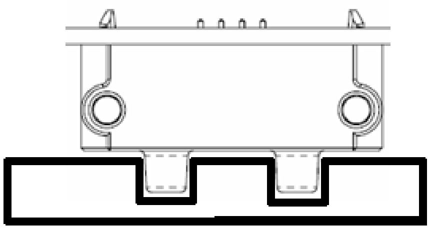
Sensor Family	Features	Specifics for testing
SDP3x	I^2C or analog output. Multiple temperature compensations modes available.	Designed for manifold connection, not for tubes. Thin tubes have a big influence on the accuracy. For more info see section 4.2.3. Avoid tubes when possible.
SDP8xx	I^2C or analog output. Multiple temperature compensations modes available for I^2C (digital) versions	Use the SDP81x sensors with barb connection when the test setup has tubes
SDP1000 and SDP2000	Analog output. Only with temperature compensation for differential pressure	Small supply voltage range. Supply voltage must be controlled and measured with extra care.

For more information on above sensors, consult the datasheets, which are available on www.sensirion.com

4 Testing setup

4.1 Offset testing

In order to test the offset of the differential pressure sensors, Sensirion recommends the following setup:



The ports of the SDP sensors have to be completely closed, for example as pictured above. Alternatively, the ports can be 'shorted' with a tube.

4.2 Span Accuracy Testing

In order to test the precision of SDP sensors, Sensirion recommends a setup as schematically described in Section 3.1, Figure 1. In Figure 2 an implementation of such setup is shown.

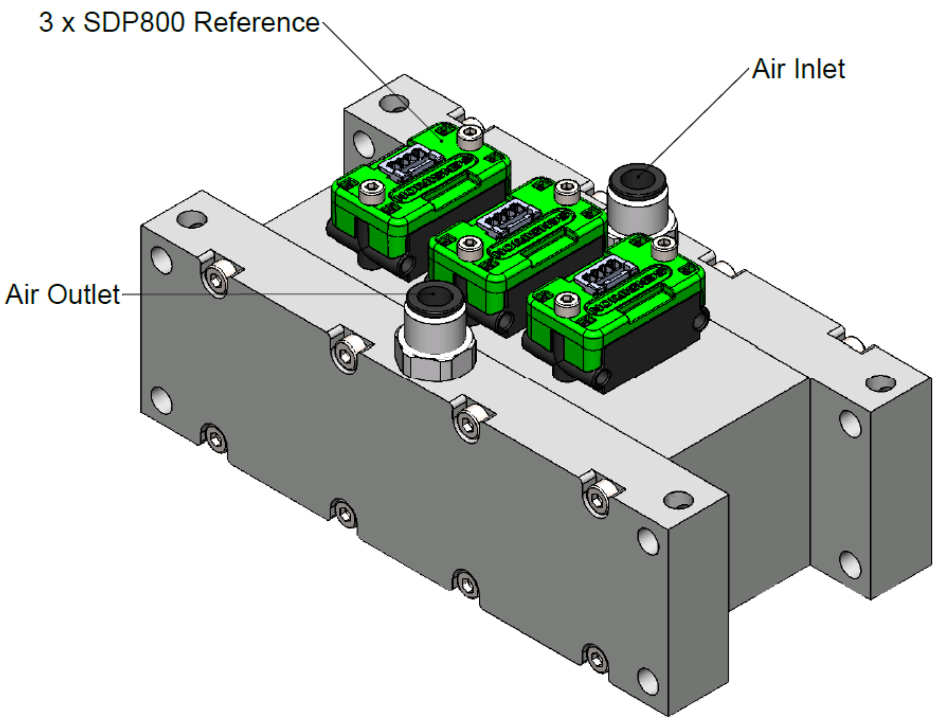


Figure 2: Test chambers

On the inside, as depicted in Figure 3, there are two air chambers, separated by a perforated plate. This plate has the function of generating a repeatable differential pressure for a given airflow. The sintered plates reduce the turbulence in the air chambers.

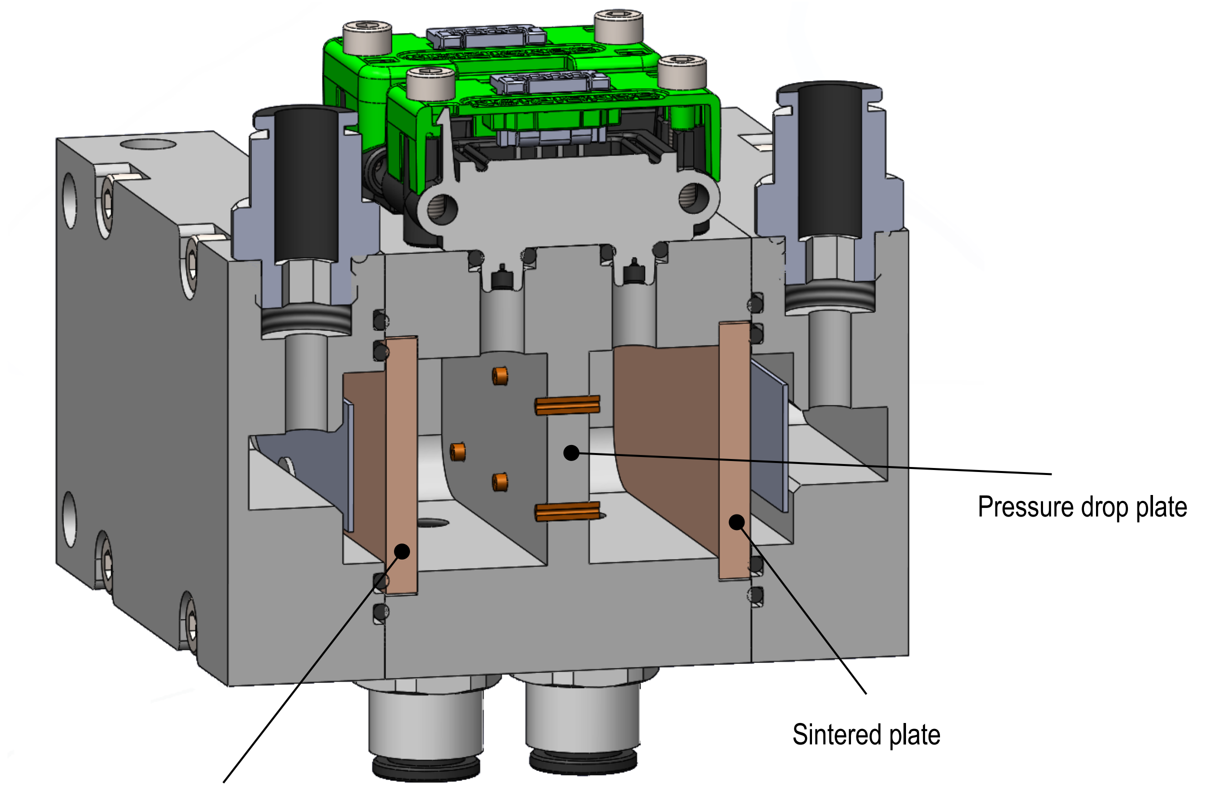


Figure 3: Cut of test chambers

Sensirion uses sintered plate type: Ampor-P BK 04.30.60 – bronze, filter class 60.

Contact your Sensirion account manager for a 3D CAD reference design.

4.2.1 General setup

- Use a two chamber measurement adapter, one chamber at high pressure, one at atmospheric pressure
- Connect the device under test (DUT) across the two chambers with a leak tight connection
- Connect the reference sensors across the two chambers

4.2.2 Pressure generation

- A Sensirion Mass Flow Controller (MFC) generates a stable air flow and is connected to the high pressure chamber. The low pressure chamber is connected to ambient.
- Set a flow at the MFC. This flow generates a differential pressure across the two measurement chambers.
  For the reference design, use the SFC5400 LA5 Air 10 ln/min Mass Flow Controller

4.2.3 Tube lengths

- If the DUT is connected to the pressure chamber with tubes, it might be necessary to compensate for the pressure drop in the tubes. See application note "Compensation of Pressure Drop in a Hose".
- In any case keep the tubes as short as possible.
  In the reference design a 6mm outer diameter tube has been used

4.2.4 References

- Use reference sensors with a similar accuracy and measurement frequency
- Sensirion recommends using SDP sensors as references
- Preferably use two or more reference sensors for redundancy

4.2.5 Readings

- When the pressure is constant and low noise, testing at least at three different differential pressure points is suggested

- When the pressure is not constant and the noise is significant it is advised to read out the sensor at the highest possible measurement speed and make many measurements

4.3 Testing Procedure for Sensors with I²C Interface

1. Power up the sensor and assure the supply voltage is as specified in the datasheet
2. Send a write header with the I²C address. The sensor must acknowledge the write header
3. Follow with a command. The sensor must acknowledge every byte of the command. If the sensor doesn't acknowledge all command bytes, it means the command is incorrect, or the sensor is not ready yet.
4. Read-out the measurement value at zero flow/DP
5. Read-out the measurement value at flow/DP set-point

4.4 Testing Procedure for Sensors with an Analog Interface

Analog sensors might seem to have benefits with respect to ease of use, but to compare the values of an analog DUT with a reference, a number of things have to be taken into account:

- Sensor accuracy and Integral non linearity (INL) of analog output of the sensor, which are described in the product datasheet
- Integral non-linearity of the ADC of the capturing device, or accuracy of the voltage multi-meter.
- The SDP3x-analog and SDP8xx-analog sensors are ratiometric. That means that the analog output voltage is proportional to the supply voltage, and thus the variations on the supply voltage have a direct influence on analog output signal.

The following test procedure is recommended:

1. Power up the sensor and assure the supply voltage is as specified in the datasheet
2. Wait for at least the specified power-up time. After the power-up time, the sensor must give out a voltage that is within the specified voltage output range.
3. Measure the supply voltage continuously, and take variations and noise into account for calculating the differential pressure.
4. Read out the output voltage with the capturing device or multi-meter and calculate to differential pressure according to the conversion formulas in the datasheet.

5 Interpreting Measurement Results

5.1 Comparing DUT and Reference Values

When comparing the values from the DUTs with the reference it is important to take into account the accuracies of both the DUTs and reference. Note that the accuracy of the Sensirion sensor is expressed in percent of measured value (%mv), or % of reading, which is different to % of full scale (%FS).

Example:

- DUT is SDP810-500Pa. Accuracy is better than 3%mv and 0.1Pa offset
- Reference device X has a range of 2000Pa. Accuracy is better than 0.5%FS

A certain flow with an MFC is applied and the DUT read out gives 95Pa and the reference 106Pa. This 11Pa difference looks large, but it is still within the combined specifications of both the DUT and reference:

- SDP810-500Pa: 95Pa +/- 3% and 0.1Pa offset, which results in range of 92.13Pa to 97.95Pa.
- Reference X: 0.5%FS of 2000Pa is 10Pa. Thus, reading of 106Pa could be any value between 96Pa and 116Pa.

Since these ranges overlap between 96Pa and 97.95Pa, the sensor can be within specifications. It must be noted that in this example the reference is not accurate enough to check the accuracy of the DUT in this pressure range, although its accuracy specification of 0.5%FS looks impressive at first glance.

5.2 Absolute Pressure and Temperature Compensation

For a detailed explanation about pressure and temperature compensation, refer to the SDP selection guide, which can be found on our website. In this section we focus solely on how to compensate for pressure and temperature in the test setup.

5.2.1 When Using a Sensirion DP Sensor as Reference

If another Sensirion DP sensor is used as reference, the pressure and temperature compensation is easy. Make sure that all sensors use a measurement command with the same temperature compensation. No absolute pressure compensation is necessary.

5.2.2 When Using a Membrane Sensor as Reference

In this case, the SDP sensors should use a measurement command with temperature compensation for differential pressure.

The absolute pressure must be compensated with the following formula:

$$dp_{eff} = dp_{sensor} \times \frac{966\text{mbar}}{p_{actual}}$$

dp_{eff} real dp in Pascal [Pa]

dp_{sensor} sensor output in Pascal [Pa]

p_{actual} actual system pressure in millibar [mbar]

The dp_{eff} can be compared to the measurement result of the membrane sensor type reference.

Revision history

Date	Version	Author	Changes
Sept 2018	V0.1	ANB	First version
Oct 2018	V0.2	ANB	Some clarifications and grammar fixes
Feb2020	V0.3	JGOE	Changed MFC clarified tube connection