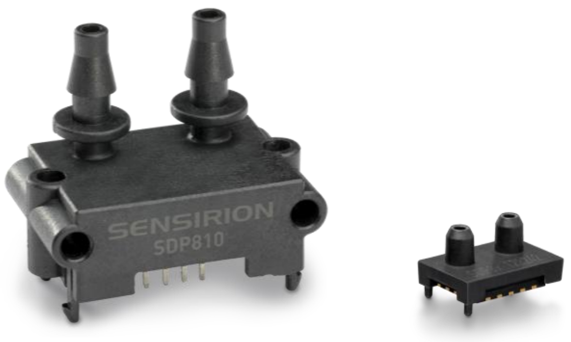
SDP Signal Compensation

How to compensate environmental influence on the sensor signal



Highlights

- Temperature compensation
- Altitude compensation
- Condensation

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 guide explains the influence of the ambient parameters temperature, ambient pressure and condensation on sensor precision. The document provides guidance on how to compensate for each of these ambient parameters.

Scan to provide feedback

Contents

1 Introduction

Sensirion's SDP sensor is based on the microthermal measurement principle: the sensing element consists of a heating element and two temperature sensors in equal distance to it. A gas flow that crosses this setup flows over the first temperature sensor, takes up heat from the heater and transports this heat over the second temperature sensor. This way, the gas flow creates a detectable temperature difference in the direction of flow (**Figure 1**). This temperature difference correlates to the mass flow of the gas crossing the sensing element.
While the physical measurement principle is based on mass flow rate, the SDP sensor is calibrated to differential pressure. This calibration offers several advantages for SDP sensor implementation: the SDP can be used in versatile configurations both as differential pressure sensor and as gas flow sensor in the bypass configuration. Additionally, its calibration makes it independent from manufacturing variations as is typical for standard mass flow sensors.
This application note introduces signal compensation strategies for changes in gas temperature, pressure, and humidity. It provides guidance on how to compensate the SDP signal for differential pressure, mass flow and volume flow measurements.

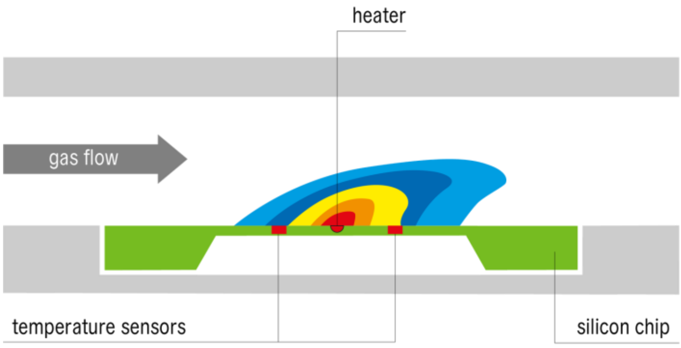


Figure 1. The SDP is a microthermal flow sensor. Its sensing element consists of a heater and two temperature sensors upstream and downstream of the heater.

2 Temperature compensation

Sensirion offers a whole range of differential pressure sensors with different sizes, pressure ports, interfaces, measurement ranges and configurations. Every single sensor features sophisticated temperature compensation to make the differential pressure measurement or the mass flow measurement independent of temperature changes. There are two ways how Sensirion corrects for temperature effects: "differential pressure temperature compensation" and "mass flow temperature compensation". This chapter explains the two compensation modes and helps select the appropriate compensation mode for your application.

2.1 *T* compensation for DP measurement

With temperature compensation for differential pressure the sensor outputs a signal that is temperature compensated for normal differential pressure measurements. Choose differential pressure temperature compensation if you measure differential pressure directly in your application (**Table 2**). Once selected with the appropriate measurement command, no further action is required to receive a temperature compensated differential pressure signal from the sensor.

2.2 *T* compensation for flow measurement

The SDP sensor is often implemented for flow measurements in a mainpass/bypass system (**Figure 2**). for details on the mainpass/bypass system, refer to the SDP Engineering Guide. In this system, the flow restrictor in the mainpass creates a pressure drop in the flow system. This pressure drop scales with flow. In most cases, the pressure drop-to-flow relationship itself is temperature dependent and absolute pressure dependent. This is inherent to the system and not to the sensor. The sensor itself has a temperature and ap dependency, too.

Under certain circumstances, the dependencies of the mainpass and the SDP sensor may counterbalance each other. A detailed discussion follows in the next section.

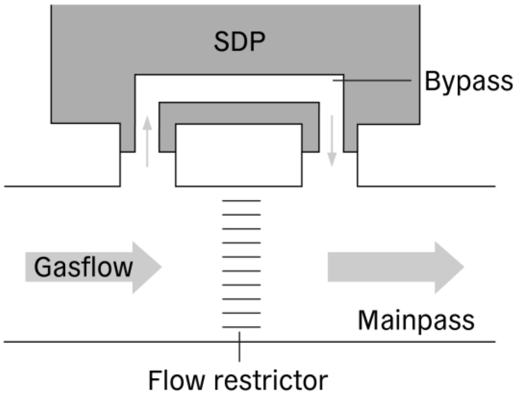


Figure 2. Mainpass/bypass system with SDP sensor for massflow determination.

Example: Let's assume a constant mass flow, $\dot{m}$. How does the sensor reading, dp_{sensor}, and the differential pressure of the system, dp_{real}, change when the temperature, T, and absolute pressure, p_{abs}, vary (**Table 1**)?

measurement condition			differential pressure result	
mass flow $\dot{m}$	absolute pressure p_{abs} [mbar]	temperature T [°C]	DP sensor reading dp_{sensor} [Pa]	real system DP dp_{real} [Pa]
constant	966	25	constant	$dp_{real} = dp_{sensor}$
	966	40		$dp_{real} > dp_{sensor}$
	1200	5		$dp_{real} < dp_{sensor}$

Table 1. At a constant mass flow, variations of temperature and absolute pressure change the real differential pressure in the system but not the sensor reading.

At a constant mass flow, the SDP sensor reading (dp_{sensor}) is a function of the mass flow only and otherwise independent of temperature and pressure. In contrast, the real differential pressure in the system (dp_{real}) changes with temperature and pressure.
The reason that sensor reading equals the real differential pressure in the system ($dp_{real} = dp_{sensor}$) in the first use case is that the sensor is calibrated at p_{abs} = 966 mbar and T = 25°C.
Depending on which physical quantity (differential pressure, mass flow or volume flow) is required, either temperature compensation for differential pressure or mass flow is suggested.

2.2.1 Mass flow

Choose mass flow temperature compensation if you measure mass flow in your application (**Table 2**). Once selected with the appropriate measurement command, no further action is required to receive a temperature compensated signal from the sensor.

The massflow temperature compensation included in the SDP sensor takes advantage of the microthermal measurement technology. It intrinsically relates to massflow. Therefore, with the temperature compensation for massflow selected, and provided a matching mainpass-bypass system, no additional temperature effects must be compensated for. For engineering guidance of a good mainpass-bypass system, refer to the SDP Engineering Guide.

2.2.2 Volume flow

The mass flow compensated differential pressure signal can be converted into a volume flow (**Table 2**). This requires density compensation. Information about the ambient pressure and temperature must be available to do so. The temperature can be read out from most digital SDP sensors. Consult the datasheet for temperature reading and the application note “SDP measurement parameters” for density compensation.
Sensirion recommends choosing temperature compensation for differential pressure if you are interested in volume flow and decide to omit compensation at the cost of reduced accuracy. It is much easier to convert the mass flow temperature compensated sensor signal to an accurate volume flow measurement. Nevertheless, the temperature compensation for differential pressure is a closer match to volume flow conversion if used uncompensated.

2.3 *T* compensation summary

Measurement parameter	differential pressure (DP)	mass flow (MF)	volume flow (VF)
Choice of sensor-internal temperature compensation	T comp for DP	T comp for MF	T comp for MF
Additional temperature compensation action required?	no	no	yes

Table 2. The selection of a suitable temperature compensation mode depends on the measurement parameter of choice.

2.4 Selection of a *T* compensation

Once you decide on a temperature compensation mode, you can select your choice by separate I^2C measurement commands of your digital SDP sensor. Analog SDP sensors have a configuration pin for temperature compensation selection. Details on the respective selection are listed in the datasheet of each SDP sensor.

3 Altitude Correction

Atmospheric pressure decreases with elevation above sea level. SDP sensors are calibrated at 425 m height above sea level and an atmospheric pressure of 966 mbar. The sensors are based on the microthermal measurement principle, which makes them intrinsic massflow sensors. Therefore, massflow measurements with SDP do not require altitude correction. A pressure correction must be applied for accurate direct differential pressure measurements or volume flow measurements for absolute pressures deviating from 966 mbar.

3.1 Altitude correction for DP measurement

Atmospheric pressure decreases with elevation above sea level. SDP sensors are calibrated at 425 m height above sea level and an atmospheric pressure of 966 mbar. If the sensor measures at a different elevation, the change in atmospheric pressure can influence the sensor reading (**Table 3**). If a very high precision on the dp measurement is required, such variations in atmospheric pressure (elevation above sea level) can be compensated by a correction factor according to the following formula:

$$dp_{cor} = dp_{sensor} * \frac{p_{cal}}{p_{amb}} \tag{1}$$

with
dp_{cor} = altitude-corrected differential pressure value [Pa]

dp_{sensor} = sensor output [Pa]
p_{cal} = absolute pressure at calibration = 966 [mbar]
p_{amb} = ambient pressure at the moment of measurement [mbar]

Example: At 750 m above sea level and a sensor reading of 40 Pa, the effective differential pressure is 41.8 Pa.

Altitude [m]	ambient pressure p_{amb} [mbar]	correction factor $(\frac{p_{cal}}{p_{amb}})$
0	1013	0.95
250	984	0.98
425	966	1
500	958	1.01
750	925	1.04
1500	842	1.15
2250	766	1.26

Table 3. Altitude correction factors for differential pressure reading at several heights above sea level.

3.2 Altitude correction for flow measurement

3.2.1 Mass flow

SDP sensors are based on the microthermal measurement principle, which makes them intrinsic massflow sensors. Therefore, massflow measurements with SDP do not require altitude correction.

3.2.2 Volume flow

Atmospheric pressure decreases with elevation above sea level. SDP sensors are calibrated at 425 m height above sea level and an atmospheric pressure of 966 mbar. If the sensor measures at a different elevation, the change in atmospheric pressure can influence the sensor reading. If an accurate measurement of the volume flow is required, such variations in atmospheric pressure (elevation above sea level) can be compensated by a correction factor according to the following formula:

$$Q = F(dp) * \frac{\rho_{char}}{\rho_{act}} \qquad 2$$

with
Q = volume flow
$F(dp)$ = flow in mainpass according to dp characterization
ρ_{char} = air density at characterization condition
ρ_{act} = air density at the moment of measurement

4 *T* and *p* compensation with membrane DP sensors

Different measurement technologies (SDP microthermal flow-through technology, membrane technology) require different temperature and pressure compensation strategies. The following tables provids an overview over necessary compensations for membrane DP sensors, that do not use the SDP's microthermal flow-through technology (Temperature compensation comparison: **Table 4**; pressure compensation comparison: **Table 5**).

***T* compensation** Sensirion SDP *vs* standard membrane-type DP sensors			
Measurement parameter	differential pressure (DP)	massflow (MF)	volume flow (VF)
Sensirion SDP	internal compensation with T comp for DP	internal compensation with T comp for MF	T comp for MF and conversion to volume flow
Standard Membrane-type DP sensor	**required** (if the sensor features no internal compensation)	**required** (both for the *T* dependence of the sensor AND for the *T* dependence of the dp/flow characteristic)	**required** (both for the *T* dependence of the sensor AND for the *T* dependence of the dp/flow characteristics)

Table 4. The Sensirion SDP sensor covers temperature compensation internally for DP and MF. This is different to many standard membrane-type DP sensors, where external temperature compensation is required.

***p* compensation** Sensirion SDP *vs* standard membrane-type DP sensors			
Measurement parameter	differential pressure (DP)	massflow (MF)	volume flow (VF)
Sensirion SDP	required	not required	required
Standard Membrane-type DP sensor	**not required**	**required**	**required** (if the flow restrictor has a non-linear characteristic) **not required** (if the flow restrictor has a pure linear characteristic)

Table 5. The Sensirion SDP sensor does not require ambient pressure compensation for massflow. This is different to many standard membrane-type DP sensors, where pressure compensation is required.

5 Condensation

When humid air is in contact with a surface, water droplets may form on this surface. This phenomenon is called condensation. In SDP applications, condensation is a specific case that occurs only under extreme humidity or temperature conditions. In medical applications, human breath can cause condensation as the exhaled air contains a lot of moisture. In HVAC applications, a significant temperature difference between outside and inside air can cause condensation as warm air contains more moisture than cold air. In SDP indoor applications, condensation usually does not occur as there are no extreme changes in humidity or temperature.
If you are facing a condensation problem in your application, the first step for fixing it is to understand the root cause of the problem. The most common condensation problem is water droplets that could run down into the sensor. In that case, we advise you to place the SDP sensor on the top side of the flow channel. That way, gravity pulls the water droplets down and away from the sensor ports. Another solution can be to guide condensation to a different place away from the sensor. This could be a sink to collect water droplets before they can enter the sensor.
If condensation takes place inside the sensor, we advise you to place the SDP sensor in a warmer area in the device. Condensation occurs in the coldest area of a flow system. Therefore, ensure that the sensor is not the coldest part in the flow system.

6 Other gases than air and nitrogen

The SDP sensor is calibrated for differential pressure measurements of air and nitrogen. If other gases than the calibration gases (air, nitrogen) shall be measured, the sensor reading might deviate from the actual pressure difference. In this case, a gas-dependent and sensor-specific conversion must be developed.

The SDP sensor is media-compatible with air, nitrogen, oxygen and other non-condensing gases.
The SDP sensor is not designed for flow measurement of liquids.
The SDP sensor is not designed for flow measurement of corrosive gases.

7 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)

8 Revision History

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

SENSIRION

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.

SENSIRION is only liable for defects of this product arising under the conditions of operation provided for in the data sheet and proper use of the goods. SENSIRION explicitly disclaims all warranties, express or implied, for any period during which the goods are operated or stored not in accordance with the technical specifications.

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.

Headquarters and Subsidiaries

Sensirion AG
Laubisruetistr. 50
CH-8712 Staefa ZH
Switzerland

phone: +41 44 306 40 00
fax: +41 44 306 40 30
info@sensirion.com
www.sensirion.com

Sensirion Inc., USA
phone: +1 312 690 5858
info-us@sensirion.com
www.sensirion.com

Sensirion Korea Co. Ltd.
phone: +82 31 337 7700~3
info-kr@sensirion.com
www.sensirion.com/kr

Sensirion Japan Co. Ltd.
phone: +81 45 270 4506
info-jp@sensirion.com
www.sensirion.com/jp

Sensirion China Co. Ltd.
phone: +86 755 8252 1501
info-cn@sensirion.com
www.sensirion.com/cn

Sensirion Taiwan Co. Ltd
phone: +886 2 2218-6779
info@sensirion.com
www.sensirion.com

To find your local representative, please visit
www.sensirion.com/distributors