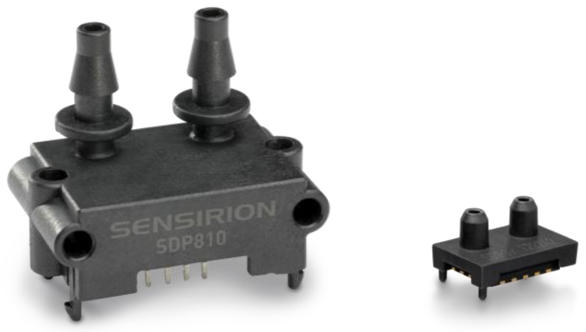
SENSIRION

SDP Measurement Parameters

How to get the most out of the SDP sensors' versatility



Highlights

- Differential Pressure
- Mass Flow
- Volume Flow

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 different SDP measurement parameters and provides general guidance on their respective implementation methods.

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 all read-out parameters covered by the SDP sensor. It provides an overview of the advantages of each and hints on general design-in considerations for each implementation case.

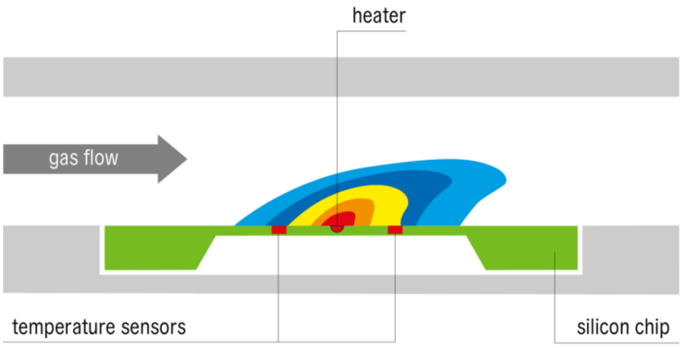


Figure 1. The SDP is a microthermal flow sensor. Its sensing element consists of a heater and two temperature sensors upstream and downstream of the heater.

2 Differential Pressure

2.1 Definition

Differential pressure is a measure of the pressure difference between two separate zones of a system. In a simplified physical interpretation, pressure difference describes the difference in the molecular density of a gas (**Figure 2**). The signal read-out of the SDP sensor is Pascal (Pa), the SI-unit for pressure.

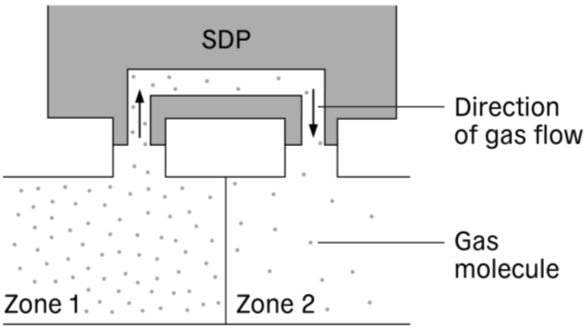


Figure 2. A different molecular density in separate zones of a system leads to a pressure difference between these zones. This difference is defined as differential pressure and can be measured with Sensirion's differential pressure sensor SDP.

2.2 SDP Integration

For measuring the pressure difference between two pressure zones of a system, the SDP sensor connects to each pressure zone with one port. If a pressure difference is present in the system, a small gas stream flows from the zone of higher pressure through the sensor to the zone of lower pressure. The sensor detects and measures a pressure difference. In case both zones have the same pressure, no gas flows through the sensor. The sensor detects no pressure difference, and the sensor reading is dp = 0 Pa.
If the two pressure zones are two closed containers, the SDP sensor is not suited to measure the pressure difference between them: the small gas stream through the sensor would connect the otherwise separated containers and equalize the pressure difference between both zones with time.

2.3 Advantages

Measuring differential pressure with the SDP sensor follows a straight-forward approach and is easy to implement.

2.4 Considerations

Sensirion's SDP sensor is based on the microthermal measurement principle. For that reason, a pressure difference can only be detected if a pressure difference (and with it a small gas flow through the sensor) is present. A pressure change in an overall, closed system (i.e. a tank) cannot be detected with this sensor. The reason is that both sensor ports would connect to the same pressure zone. The pressure difference between the ports would be dp = 0 Pa, even if the pressure of the entire system changes (**Figure 3**). A suitable sensor solution for such a case is an absolute pressure sensor.

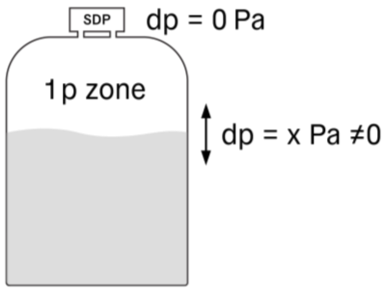


Figure 3. In a closed system (i.e. a tank), changes in pressure cannot be detected by any differential pressure sensor.

The properties of the system gas can influence the sensor measurement. The sensor is calibrated for air and N_2 at T = 25 °C and p = 966 mbar. If the properties of the system gas deviate from the properties of the calibration gas, a correction of the sensor reading may be applied. In general, the SDP sensor can measure differential pressure at varying absolute pressures. If the absolute pressure deviates from the calibrated pressure, the influence of absolute pressure on the signal can be corrected. For a detailed description of correction factors refer to the application note on Signal compensation.

3 Mass Air Flow

3.1 Definition

Mass flow rate is a measure of the gas mass that flows through a system per unit time. In a simplified physical interpretation, a mass flow rate describes the amount of flowing gas molecules per unit time. The SI-unit for mass flow rate is kg/s. The signal read-out of the SDP sensor is Pascal (Pa), the SI-unit for pressure. The mass flow through the gasflow system can be correlated to the pressure reading of the sensor.

3.1.1 Mass flow or standard volume flow

Standard volume flow refers to the volume flow at given standard conditions for temperature and pressure. Common units are "standard liters per minute [slm]", "standard cubic centimeters per minute [sccm]" or "norm liters per minute [ln/min]".
Because standard volume flow is referenced to a defined temperature, T, and pressure, p, the number of molecules, n, in the volume, V, can be calculated using the ideal gas law ($pV = nkT$). In other words, standard volume flow refers to the number of molecules per time and with it to the mass per time. For a given gas, a sensor measuring standard volume flow is a mass flow sensor.
Because of its thermal measurement principle, Sensirion's SDP sensors are ideally suited for massflow measurements.

3.2 SDP Integration

The SDP sensor is commonly used for massflow measurements. As such, it is installed in a bypass configuration (**Figure 4**): 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 gas flows through the mainpass, a small gas stream flows through the SDP sensor that acts as the bypass. The sensor detects a mass flow and measures a pressure difference. For a detailed description of this sensor integration refer to the SDP Engineering Guideline.

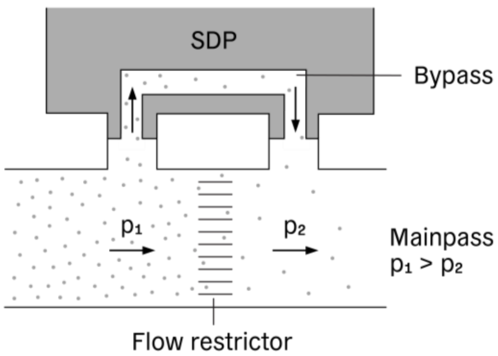


Figure 4. For mass flow measurements, the SDP sensor is installed in a bypass configuration. A flow restrictor in the mainpass creates a pressure difference that causes the gas to flow through the sensor.

Massflow Derivation from Differential Pressure

Massflow derivation from a differential pressure depends on many (design) parameters. Therefore, it is not possible to calculate the system mass flow from differential pressure through a simple mathematical formula. Instead, a thorough characterization of the flow system during the design-in process of the SDP sensor provides a correlation between differential pressure reading and mass flow. A description of such a system characterization is provided in the SDP Engineering Guide.

3.3 Advantages

The flow restrictor in the mainpass defines the flow *vs.* DP characteristic of the system. By using the SDP sensor with mass flow temperature compensation, the initial massflow-to-dp-correlation can be adopted to all devices

with the same flow system. It must not be repeated for every device separately. For details on massflow-to-dp-correlation, refer to the SDP Engineering Guide.
Massflow measurements with the SDP sensor do not require altitude correction.

3.4 Considerations

The properties of the system gas can influence the sensor measurement. The sensor is calibrated for air and N_2 at T = 25 °C = 77 °F and p = 966 mbar. If the properties of the system gas deviate from the properties of the calibration gas, a correction of the sensor reading may be applied. For a detailed description of correction factors refer to the application note on Signal Compensation.

4 Volume Air Flow

4.1 General Definition

Volume flow rate is a measure of the gas volume that flows through a system per unit time. The SI-unit for volume flow rate is m^3/s. The signal read-out of the SDP sensor is Pascal (Pa), the SI-unit for pressure. The volume flow rate can be derived from the mass flow rate which can be measured with the SDP sensor (Chapter 3).

4.2 SDP Integration

The volume flow rate is mathematically derived from the mass flow rate. Therefore, sensor integration for volume flow determination follows the integration of the SDP sensor for mass flow determination (Chapter 3.2).

Volume Flow Derivation from Mass Flow

The volume flow can be calculated from the mass flow of a gas flow system:

The volume flow rate, $\dot{V}$, of a gas is defined as
$$\dot{V} = \frac{V}{t} \quad (1)$$

The mass flow rate, $\dot{m}$, of a gas is defined as
$$\dot{m} = \frac{m}{t} \quad (2)$$

The density, ρ, of a gas is defined as
$$\rho = \frac{m}{V} = \frac{\dot{m}}{\dot{V}} \quad (3)$$

The ideal gas law is:
$$p\,V = n\,R\,T \quad (4)$$

The molar mass, M, of a substance is:
$$M = \frac{m}{n} \quad (5)$$

with
V = gas volume [m^3]
m = gas mass [kg]
t = unit time of the gas flow [s]
p = pressure [Pa]
T = temperature [K]
n = amount of substance [mol]
R = gas constant = 8.314 [J/mol K]

The volume flow rate can be derived from the above formulas as follows:

from 3:
$$\dot{V} = \dot{m}\,\frac{V}{m}$$

from 4: $$\dot{V} = \dot{m} \frac{n\,R\,T}{m\,p}$$

from 5: $$\dot{V} = \dot{m} \frac{R\,T}{M\,p} \tag{6}$$

Example Calculation Volume Flow from Mass Flow

Let's assume a measurement condition of T = 25 °C = 298.5 K, p = 1 atm = 101'325 Pa and the molar mass of dry air $M_{\text{dry air}}$ = 28.97 g/mol.
You measure a mass flow of $\dot{m}$ = 0.03 g/s in your system. Therefore, the volume flow under the given system settings is:

$$\dot{V} = 0.03 * \frac{8.314 * 298.5}{28.97 * 101'325} * 10^{-3} = 25 * 10^{-6} \frac{m^3}{s} \approx 25 \frac{mL}{s}$$

4.3 Advantages

The flow restrictor in the mainpass defines the flow *vs.* DP characteristic of the system. By using the SDP sensor with mass flow temperature compensation, the initial mass flow-to-dp-correlation can be adopted to all devices with the same flow system. It must not be repeated for every device separately. For details on mass flow-to-dp-correlation, refer to the SDP Engineering Guide.

4.4 Considerations

The properties of the system gas can influence the sensor measurement. The sensor is calibrated for air and N_2 at T = 25 °C and p = 966 mbar. If the properties of the system gas deviate from the properties of the calibration gas, a correction of the sensor reading may be applied. Volume flow is sensitive to absolute pressure. Volume flow measurements with SDP require altitude correction. For a detailed description of correction factors refer to the application note on Signal Compensation.

5 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)

6 Revision History

Date	Version	Pages	Changes
01 2024	0.1	all	Initial version
06 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.

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

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

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