Application Note for SDP600 and SDP1000 Series

Measuring Differential Pressure and Air Volume with Sensirion's CMOSens® technology

Summary

The increasing customer requirements for comfort and safety and the optimal utilization of energy ask for high quality yet cost effective transducers in automatic building control systems. Besides measuring relative humidity, temperature and mass flow, Sensirion AG is providing a new generation of differential pressure sensors for air handling in building automation. These transducers provide a revolutionary step as far as accuracy, reproducibility and resolution is concerned. Since they are based on the cost effective CMOSens® technology they can be offered at a very attractive price. The goal of this report is to compare conventional differential pressure sensors with the product line of Sensirion and to give a short introduction to Sensirion's proprietary CMOSens® technology.

Traditional static differential pressure sensors for air are based on stress sensitive membrane structures. These devices however, are limited by a large offset drift, a restricted measurement range and a low accuracy and reproducibility at small pressure ranges. These disadvantages either have to be tolerated at the sacrifice of system performance or have to be overcome by an expensive system complexity (i.e. periodical offset adjustment using valves).

As a cost effective alternative, dynamic sensors are commonly used in HVAC applications. These devices are based on a thermal principle (e.g. hot wires). However, since an air flow is required to detect a pressure difference they sometimes suffer from a bad reputation concerning long term stability and staining. In addition, the pressure drop in the connecting tube when applying such a dynamic sensor affects the measurement accuracy substantially.

Differential pressure sensors based on CMOSens® technology largely overcome above limitations. Combined with the very attractive price they are a favorable alternative to measure differential pressure and air volumes in HVAC applications.

1. CMOSens® Technology Unifies Sensor with Readout Circuitry

CMOSens® denotes the fusion of the sensing element with the readout circuitry on a single CMOS chip. CMOS (Complementary Metal Oxide Semiconductor) is the prevalent technology for integrated circuits applied for e.g. Intel microprocessors and solid state memories (Flash, DRAM). By combining the sensor element and the readout electronics the weak sensor signals are seamlessly amplified, digitized and conditioned. This leads to an substantial advantage with respect to technical performance. CMOS technology is perfectly suited for low cost production at large quantities.

CMOSens® sensors from Sensirion also contain a temperature sensor which is used for precise temperature compensation. In conjunction with a built-in self test and the digital linearization the chip represents a powerful microsystem (shown in Figure 1). This system matches the requirements for differential pressure measurements.

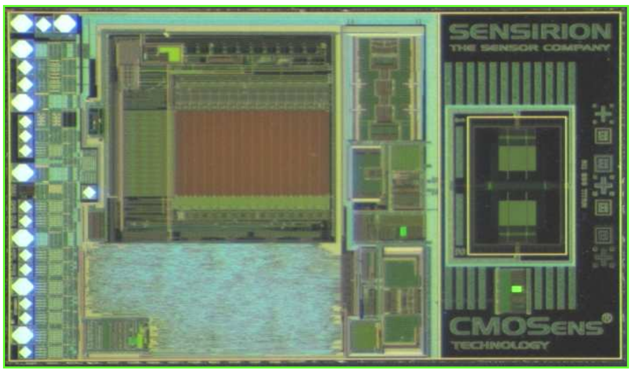


Figure 1: Photograph of the CMOSens® differential pressure sensor chip. Besides the sensing element (right) the chip contains integrated circuits for amplification, analog-to-digital conversion, digital signal conditioning and an EEPROM memory cell.

Besides the optimized readout electronics the sensor element is of major importance. Similar to conventional dynamic sensors the sensor principle is based on a heater. There are two approaches to integrate this thermal principle on a silicon chip: old sensor generations use a silicon bridge which is etched from the front. This bridge contains a heater and the temperature sensor. Although simple in production this approach has the disadvantage that dust tends to accumulate at the bridge and pressure peaks can destroy the tiny microstructure. In order to overcome these problems Sensirion has chosen a more robust approach:

A glass passivated membrane structure is etched from the back of the chip (see Figure 2). The flat surface prevents particles from being trapped at the sensor site. In addition and due to the low-noise on-chip interface circuit, the required amount of air to detect the applied pressure difference can substantially be reduced. This leads to a quasi static measurement. Extensive field test in harsh environments (e.g. air with dust, chlorine, smoke, humid air, ammonia) confirm the great robustness of the CMOSens® based differential pressure sensors against any kind of contamination and staining.

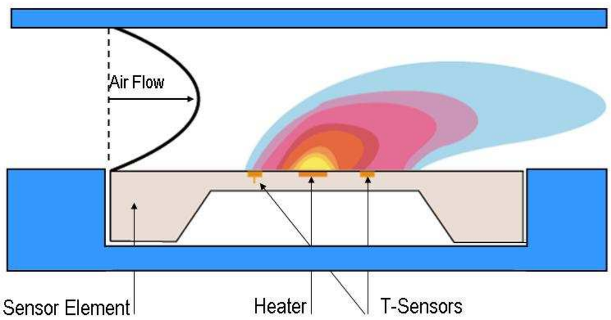


Figure 2: Thermal measurement principle: a heater generates a temperature profile on a membrane. The applied pressure difference ΔP enforces an air flow. This air flow destroys the symmetry of the temperature profile which is detected by the two temperature sensors. The temperature difference is a direct function of the applied pressure difference.

2. CMOSens® Leads to Unsurpassed Technical Performance

A heater is placed in the middle of the membrane and two temperature sensors are placed on either side (see Figure 2). The heater generates a temperature profile. Due to the symmetry of the structure and foremost thanks to the highly precise CMOS fabrication with nanometer tolerances the offset of such a differential sensor becomes negligible.

Even the lightest air movement leads to an asymmetry of the temperature distribution on the membrane. This is measured by the two temperature sensors and amplified by the subsequent low-noise amplifier. The following analog-to-digital conversion and a digital signal processing unit corrects for the sensor non-linearity and compensates for the temperature effects by taking into account the data from the on-chip temperature sensor. In this way the sensor chip provides a highly accurate and temperature compensated output. A block diagram of the CMOSens® chip is shown in Figure 3.

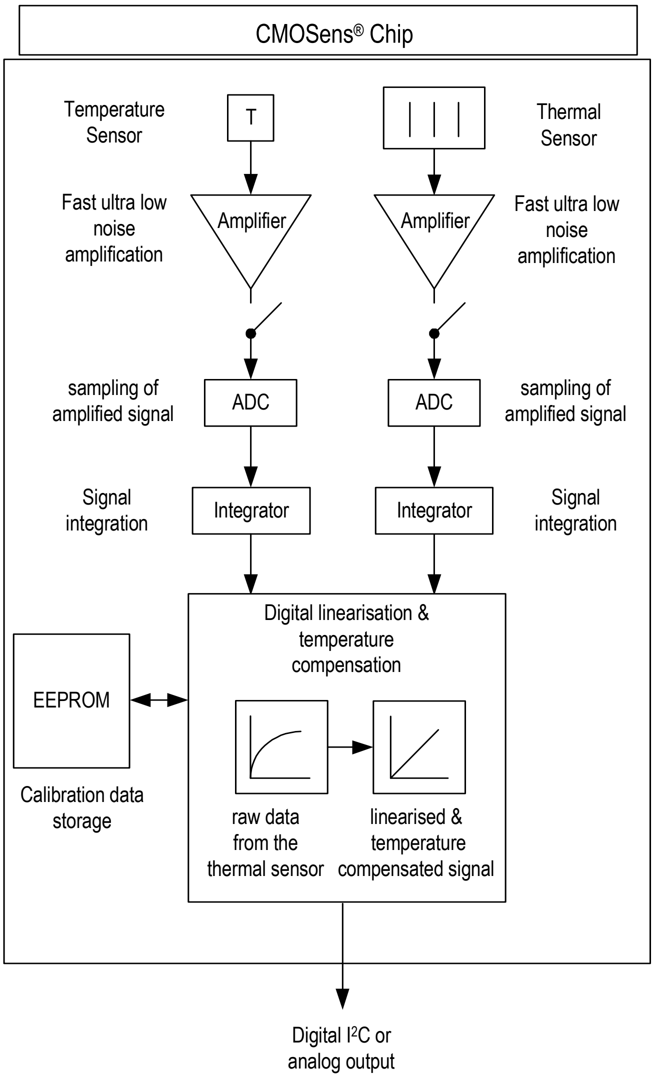


Figure 3: Block diagram of the CMOSens® differential pressure sensor chip. The on-chip signal conditioning includes low-noise amplification, temperature compensation and linearization.

3. CMOSens® Sensors Compared to Conventional Differential Pressure Sensors

Compared to traditional static and dynamic sensors for differential pressure measurement in HVAC applications, CMOSens® based sensors offer great advantages with respect to offset stability, accuracy and resolution. In addition, with CMOSens® sensors the measurement range is three to ten times larger compared to conventional sensors. Hence, without sacrificing performance a 0…500 Pa full scale CMOSens® sensor replaces three traditional differential pressure sensors each of which covering only a fraction of this range (e.g. 0…100 Pa, 0…300 Pa, 0…500 Pa). A reproducibility of 0.1 Pa is typical for CMOSens® sensors even in the range below 10 Pa. No sensitivity to the mounting orientation is observed.

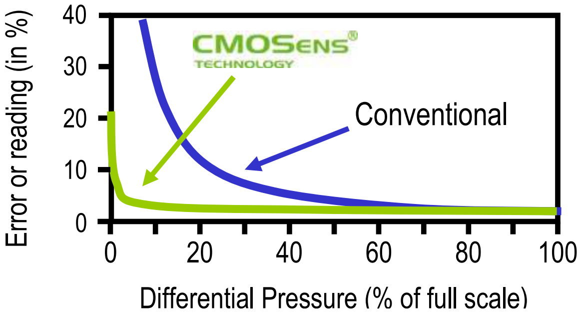


Figure 4: Specified error tolerances of a traditional transmitter and the guaranteed specifications of the SDP differential pressure transmitter of Sensirion. The given error tolerances include a temperature variation of ±10°C around room temperature.

The disadvantage of conventional dynamic sensors caused by the required air flow (such as parasitic pressure drop in the connecting tubes or the degradation due to staining) are eliminated since the air flow is reduced by a factor of 10 to 50 compared to traditional dynamic differential pressure sensors.

The subsequent table provides a comprehensive overview of static and dynamic sensors and compares their performance with CMOSens® based differential pressure sensors.

Table 1: Comparison of differential pressure sensors for HVAC applications:

	Static Sensors (Membranes)	CMOSens® Sensors (thermal)
Offset	Large intrinsic offset. Large offset drift for low cost silicon based sensors. A periodical compensation is often required.	Smaller than 0.5 Pa, drift below resolution
Measurement range	1:10 of full scale	1:50 up to 1:500 of full scale
Air flow and staining	No flow. Minimal staining effects.	The very small air flow leads to a quasi-static measurement and reduces staining effects drastically.
Resolution	Max. 0.1 Pa if large membranes are used.	Up to 0.008 Pa possible
Reproducibility	Limited to a couple of Pa due to offset drift and low sensitivity.	Typically better than 0.1 Pa
Sensitivity to the mounting orientation	Mounting orientation has influence on offset and sensitivity. Needs often to be trimmed manually after installation.	Can be mounted anywhere without restrictions.
Temperature dependence	Has to be compensated for.	Temperature compensated
Influence of connecting tube.	No influence	(influence smaller than 0.04% of measurement range)
Reproducibility below 10 Pa	Strongly limited by offset drift, mounting orientation and limited resolution.	

4. CMOSens Sensor Components and Transducers from Sensirion

Sensirion offers an increasing number of CMOSens® based sensor components (for OEM applications) and transducers. Most air handling tasks in HVAC can be covered. The heart of all these products is the sensor chip, shown in Figure 1. The difference between the products is solely the adaptation and calibration for the pressure range, the external power supply and the interface for the measurement data.

Below, the current product line of Sensirion is briefly introduced. Additional, detailed information such as data sheets and application notes can be found on Sensirion's web page www.sensirion.com.

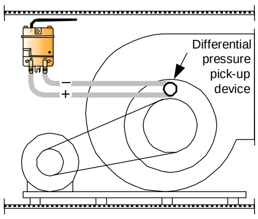
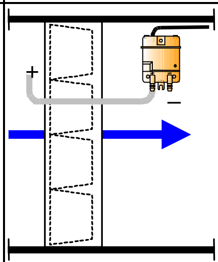
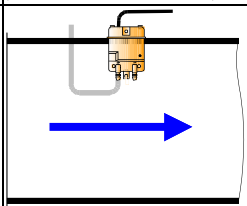
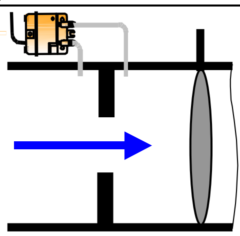
Table 2: Summary of CMOSens® products for differential pressure measurement provided by Sensirion AG.

Product	Picture	Interface	Range	Accuracy	Notes
SDP500 / SDP510		I^2C (digital)	0 … 500 Pa	0.2 Pa + 4.5 % m.v.	3.3 V power supply
SDP600 / SDP610		I^2C (digital)	-500 … 500 Pa	0.2 Pa + 3 % m.v.	3.3 V power supply Bi-directional
SDP1000-L / SDP2000-L		0.25 ... 4 V (1)	-62 … 62 Pa -5 … 125 Pa 0 ... 500 Pa 0 … 3500 Pa	0.2 Pa +1.5 % m.v.	5 V power supply Linear output
SDP1000-R		0.25 ... 4 V (1)	0 ... 500 Pa	1 Pa +1.5 % m.v.	5 V power supply Square root output
SDP1108-R		0.25 ... 4 V (1)	0 ... 500 Pa	0.06 Pa +0.4 % m.v.	5 V power supply Square root output 8 ms response time
ASP1400		RS232 (digital)	0 ... 100 Pa	0.4 Pa +1.5 % m.v.	0.001 Pa maximal resolution 0.05 % full scale accuracy.

5. HVAC-Applications of CMOSens® Differential Pressure Sensors

Thanks to the excellent technical performance of CMOSens® differential pressures sensors the application range is broad. The following table summarizes some major HVAC-applications and denotes the corresponding customer benefit.

Table 3: Major applications and customer benefits.

Application	Example	Customer Benefit
OEM applications e.g.: Compact VAV controller Frequency Converter Fan and Burner control		Cost effective solution for high volume OEM applications. Neither calibration nor offset trimming nor temperature compensation are required. Simplest system integration, exchangeable. Self heating of surrounding has no influence on accuracy due to temperature compensation on chip.
Control of fans and ventilators e.g. in air handling units		Highly accurate control of the air volume over a large range with just one sensor. Unique reproducibility and accuracy. No restrictions concerning the mounting orientation (transducer can be exposed to an air flow).
Filter control e.g. in air handling units		Accurate and reliable filter monitoring. By using the SDP6x0 product, the temperature of the air can be measured optionally.
Pressure control		Precise and reliable pressure control in air ducts and rooms even below 10 Pa. By using the SDP6x0 product, the temperature of the air can be measured optionally.
VAV control Control of dampers Measurement of the air volume and air velocity		Extremely accurate and cost effective air volume control even at pressure ranges below 10 Pa.

6. Summary

Compared to traditional static differential pressure sensors CMOSens® based differential pressures sensors provide an unsurpassed reproducibility, a larger measurement range, no offset drift, and no sensitivity to the mounting orientation.

Thanks to a much smaller air flow than in conventional dynamic pressure sensors the danger for contamination and the parasitic effects caused by the connecting tube are widely eliminated.

The technical advantages lead to a revolutionary precision for measuring and controlling pressure differences and air volumes in HVAC applications. Since also very attractive positioned with respect to their price, the CMOSens® based differential pressure sensor are a favorable alternative to traditional sensors used for air handling in building automation systems.

7. Revision history

Date	Version	Author	Changes
23.06.03	V1.0	AHA	Initial release
26.08.09	V1.1		Update
January 2010	V1.2		Layout update
April 2010	V1.3	DAT	Minor changes

Headquarter and Sales Offices

SENSIRION AG
Laubisruetistr. 50
CH-8712 Staefa ZH
Switzerland

Phone: + 41 (0)44 306 40 00
Fax: + 41 (0)44 306 40 30
info@sensirion.com
www.sensirion.com

SENSIRION Inc
Westlake Pl. Ctr. I, suite 204
2801 Townsgate Road
Westlake Village, CA 91361
USA

Phone: +1 805-409 4900
Fax: +1 805-435 0467
michael.karst@sensirion.com
www.sensirion.com

SENSIRION Japan
Sensirion Japan Co. Ltd.
Shinagawa Station Bldg. 7F
4-23-5 Takanawa
Minato-ku, Tokyo, Japan

phone: +81 3-3444-4940
fax: +81 3-3444-4939
info@sensirion.co.jp
www.sensirion.co.jp

SENSIRION Korea Co. Ltd.
#1414, Anyang Construction Tower B/D,
1112-1, Bisan-dong, Anyang-city,
Gyeonggi-Province, South Korea

Phone: +82-31-440-9925~27
Fax: +82-31-440-9927
info@sensirion.co.kr
www.sensirion.co.kr

SENSIRION China Co. Ltd.
Room 2411, Main Tower
Jin Zhong Huan Business Building,
Postal Code 518048
Futian District, Shenzhen, PR China

Phone: +86 755 8252 1501
Fax: +86 755 8252 1580
info@sensirion.com.cn/
www.sensirion.com.cn

Find your local representative at: http://www.sensirion.com/reps