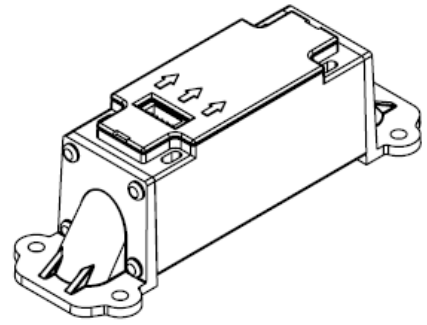


Datasheet SFM4200

Digital Flow Meter for Air and Oxygen

- Flow range: 0...160 slm
- Operating pressure up to 8 bar
- Very fast update time (0.5ms)



Product Summary

The SFM4200 sensor is Sensirion's digital flow meter designed for high-volume applications. It measures the flow rate of air, oxygen and other non-aggressive gases with high accuracy. The SFM4200 is designed for flows up to 160 slm and can be operated at pressures up to 8 bar and is resistant against burst pressure up to 13 bar. The SFM4200 operates from a 5 Volt supply voltage and features a digital 2-wire I2C interface. The measurement results are internally linearized and temperature compensated. The outstanding performance of this sensor is based on Sensirion's patented CMOSens® sensor technology, which combines the sensor element, signal processing and digital calibration on a single microchip. The flow rate of the gas is measured by a thermal sensor element which assures very fast signal processing time and bidirectional measurement with best-in-class accuracy. The well-proven CMOS technology is perfectly suited for high-quality mass production and is the ideal choice for demanding and cost-sensitive OEM applications.

Applications

- Medical
- Process automation
- Spectroscopy
- Environment monitoring
- Laboratory

1 Sensor Performance

1.1 Physical specifications¹

Specification	Condition	Value	Unit
Flow Range	Air/O2	0 ... 160	slm ²
Accuracy ^{3,4}	span < 80 slm	2.5	% m.v. ⁵
	span > 80 slm	5	% m.v. ⁵
	offset	0.04	slm
Noise Level ⁶	offset, typical	0.02	slm
	span < 80 slm, typical	0.5	% m.v.
	span > 80 slm, typical	1.2	% m.v.
Repeatability	10-100% FS	0.5	% m.v.
	<10% FS	0.02	% FS
Temperature Sensor ⁷	Calibrated range	0 ... 60	°C
	Accuracy	+/- 2	°C
Accuracy Shift Due to Temperature Variation ⁸	span	0.1	%m.v./°C
	offset	0.004	slm / °C
Pressure Coefficient	span < 80 slm, typical	0.3	% m.v. / bar
	span > 80 slm, typical	0.6	
Typical Pressure Drop	@ 60 slm	<2000	Pa
	@100 slm	<4000	
	@160 slm	<9000	

1.2 Ambient Conditions

Parameter	Condition	Value	Unit
Calibrated Temperature range	T(environment)=T(gas); 15% rel.hum.	0 ... +50	°C
Operating Temperature Range	10-95% rel. hum. (non cond.)	0 ...+50	°C
Storage Temperature	Max partial water pressure 50hPa (non-condensing)	-20 ... +70	°C
Operating Pressure Range	absolute	8	bar
Burst Pressure	gauge	13	bar
Orientation sensitivity		Use flow horizontally, electronic connector up	

¹ Unless otherwise noted, all sensor specifications are valid at: 23°C ±2°C, 966 mbar absolute pressure, with Vdd = 5V, calibration gas air, horizontal mounting position

² slm: mass flow measured in standard liters per minute using reference conditions of T= 20°C, p=1013 mbar

³ Including Offset, Non-Linearity, Hysteresis

⁴Total accuracy/noise level/resolution is a sum of offset and span accuracy/noise level/resolution.

⁵ In % of measured value (m.v.) = of rate = of reading

⁶ Noise level defined as standard deviation of individual sensor readings, measured at full sampling rate (typical: average of noise level)

⁷ The measured temperature is the temperature of the bulk silicon in the sensor. This temperature value is not only depending on the gas temperature, but also on the sensor's surroundings. Using the signal to measure solely the gas temperature will need special precautions, such as isolating the sensor from external temperature influences.

⁸ these effects need to be added to the initial values if applicable

1.3 Media compatibility

Parameter	Value
Calibration Gas	Air
Media Compatibility	Air (non-condensing), N2, O2, other non-aggressive gases
Wetted Materials	Si, Si ₃ N ₄ , SiO _x , Gold, Viton®, Epoxy, Glob Top, Polycarbonate, Stainless steel, Aluminum
RoHS and REACH	ROHS and REACH

2 Electrical Specifications

2.1 Electrical characteristics

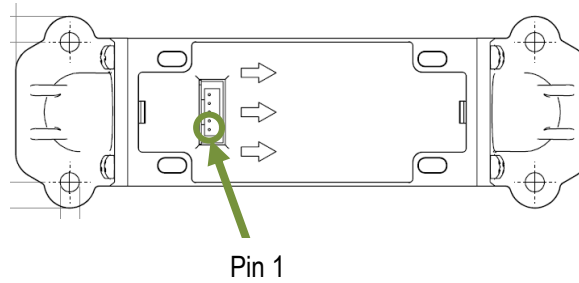
Electrical properties	Condition	Value		Unit
Interface		I ² C		
Default Sensor Address		64 (0x40)		
Update Time	14 bit	0.5		ms
Supply Voltage		5V +/-5%		Vdc
Communication Level	High Low	Min	Max	V
		2.5 GND	VDD 1.1	
Power Consumption	max	50		mW
Electrical Connector (male)		JST B5B-PH-SM4-TBT		
Output signal resolution		14		bit
Scale factor flow		256		1/slm
Offset flow		0		
Max. I ² C bus frequency		100		kHz

2.2 Pin Layout

Electrical Connector Male: JST B5B-PH-SM4-TBT

Pinout:

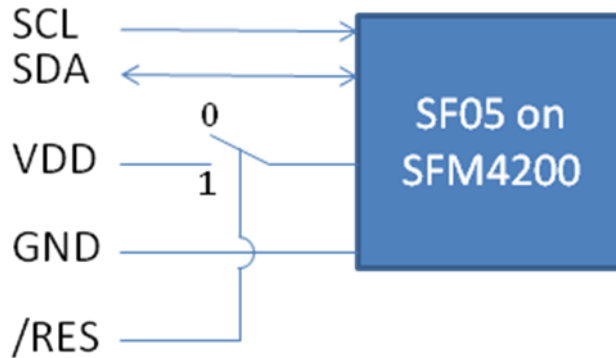
Pin	Function
1	SCK
2	VCC
3	GND
4	SDA
5	Reset Pin



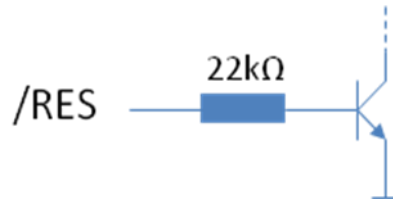
2.3 Reset Pin (/RES)

Active-low reset pin. Needs to be driven at both low and high levels (push/pull-output on customer's side).

Simplified block diagram:

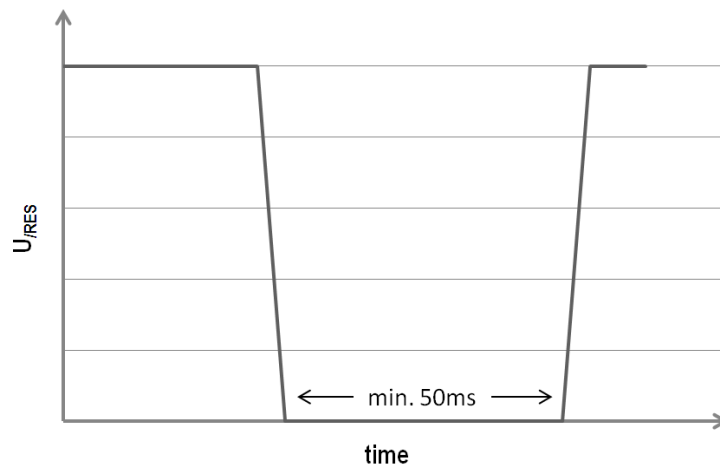


Input equivalent circuit:



Levels:	High-level (normal operation):	0.8V (min) to VDD (max)
	Low-level (reset state):	0V (min) to 0.35V (max)

Timing to trigger reset (condition: VDD supplied):

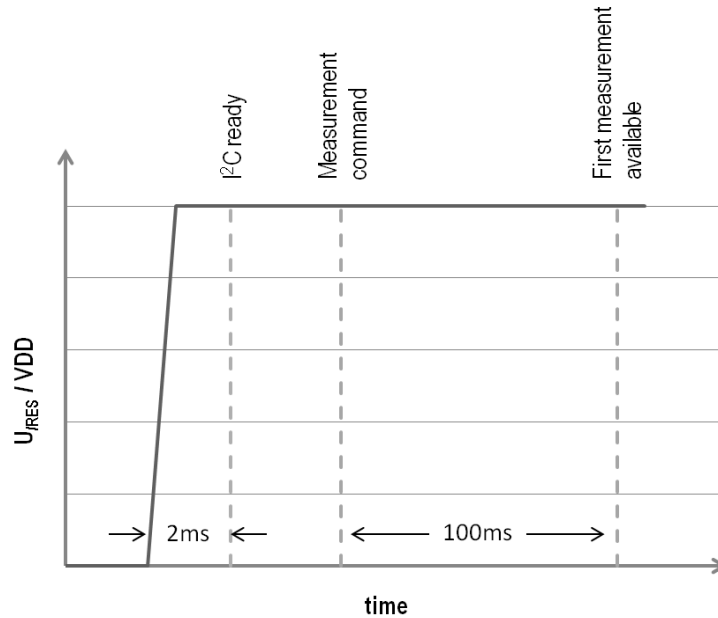


To ensure that the power to the SF05 flow chip is correctly interrupted during the reset, also pull down the SDA and SCL lines at the same time as pulling down the /RES line.

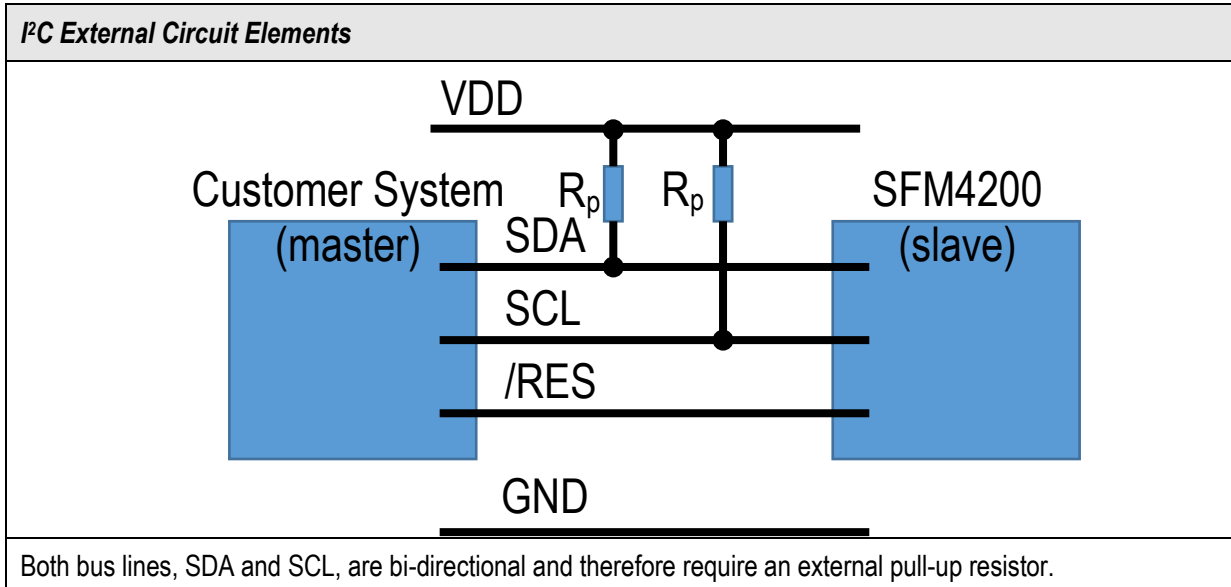
2.4 Startup Behavior

The start-up behavior after a reset is identical to the start-up behavior after normal power up:

After the rising edge on U_{RES} (condition: VDD supplied) or VDD (condition: /RES in high state) respectively, the I²C interface will be ready for communication after 2ms. Through a measurement command issued by the customer system, the sensor heater will be turned on. From then, it will take max. 100ms until the first measurement will be ready. Subsequently, measurement results may be read out via I²C with the maximum sampling frequency according to specification (100kHz).



2.5 Voltage Specification I²C



Communication between a master and the SF05 sensor system runs via the digital I²C-interface. For detailed specifications of the I²C protocol, please refer to the document "The I²C-Bus Specification, Version 2.1, January 2000" from NXP (http://www.nxp.com/products/interface_control/i2c).

Bi-directional bus lines are implemented by the devices (master and slave) using open-drain output stages and a pull-up resistor R_p connected to the supply voltage VDD.

The recommended pull-up resistor value R_p depends on the system setup (capacity of the circuit/cable, bus clock frequency). R_p must be $>1k\Omega$. In most cases, $R_p=10k\Omega$ is a reasonable choice. Optionally, the pull-up resistors may be connected to the master's supply line. Acceptable levels are 3.3Vdc to 5Vdc.

The capacitive loads on SDA and SCL line have to be the same. It is important to avoid asymmetric capacitive loads.

3 Mechanical Specifications

3.1 Housing

The CMOSens® SFM4200 Mass Flow Meter is mounted in chemically inert polycarbonate housing. The rugged package has been designed to withstand pressures of up to 8bar.

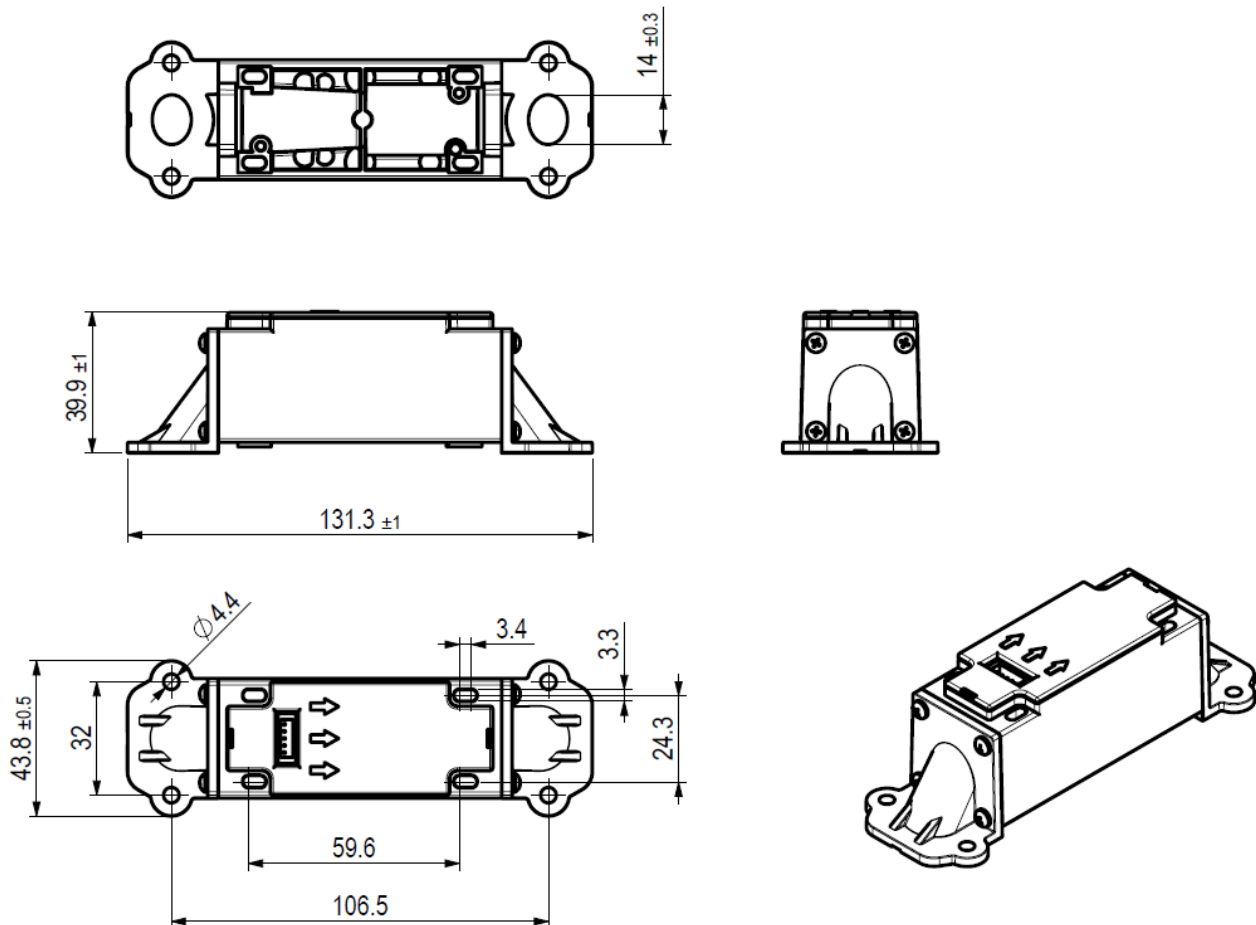


Figure 1: SFM4200. All units are in [mm].

3.2 Dimensions

Parameter	Condition	Value	Unit
Length		13.1	cm
Width		4.4	cm
Height		8.18	cm
Weight		95	g
Leak-Integrity	@ 2 bar gauge	< 1	sccm

4 Instructions for use

4.1 Calibration orientation

The sensors are calibrated horizontally with connector facing upwards.

4.2 ESD

The electronics of the SFM3000 sensor consist of a single automotive qualified chip. It complies with the following ESD norms:

- AEC Q 100 002 (4kV HBM)
- AEC Q 100 003 (200V MM)

Although the sensor complies with these norms, it does not mean the sensor is immune against ESD. The sensor is shipped in an antistatic tray to prevent electrostatic discharge. To avoid damage to the sensor, ground yourself using a grounding strap or by touching a grounded object before touching the sensor. Furthermore, store the parts in an antistatic package when not in use.

4.3 Safety Restrictions

The packaging method of the CMOSens[®] chip together with the inert housing and the sealing materials ensure a tight and highly resistant sealing of the device. Please be aware that aggressive and corrosive gases can influence the sensor element and may even destroy the Viton[®] sealing or the polycarbonate body.

Please also be careful with the use of explosive or toxic gases. Any leakage even outside the controller can be dangerous.

For the above reasons, Sensirion guarantees the safe use of the CMOSens[®] SFM4200 Mass Flow Meter for inert, in-explosive and non-toxic gases only.

4.4 Correction Formula for Oxygen Flow Measurement

Description of the correction formula for measuring oxygen flow with the SFM4200:

- $Q_{O_2}^{SFM}$ Flow indicated by air-calibrated SFM4200 in slm when O₂ is flowing through the SFM
- Q_{O_2} Real O₂ flow in slm
- ΔQ Correction function

$$Q_{O_2} = Q_{O_2}^{SFM} - \Delta Q$$

The correction ΔQ was measured by flowing O₂ through the air-calibrated SFM4200. From this measurement the following correction function was determined:

$$\Delta Q = 1.3 \times 10^{-2} \times Q_{O_2}^{SFM} + 1.2 \times 10^{-4} \times (Q_{O_2}^{SFM})^2$$

When a correction for FiO₂ other than 100% is needed, the correction ΔQ can be scaled proportional to the FiO₂. I.e. the correction formula for arbitrary FiO₂ is

$$Q_{O_2} = Q_{O_2}^{SFM} - \frac{FiO_2 - 21\%}{79\%} \times \Delta Q$$

5 I²C Interface Description

5.1 Bidirectional I²C Interface¹

The I²C protocol can be used to implement a bidirectional interface for SF05A register access. The I²C measurements use a fully standard I²C bus (refer to "The I²C -Bus Specification, Version 2.1, January 2000"). The I²C device address is set to h40 (=64) by default.

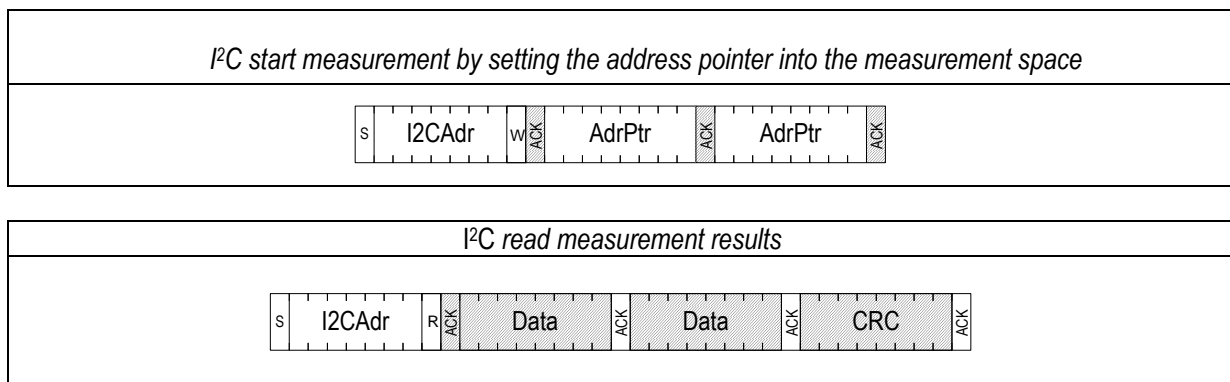
The following table describes the address pointers for the supported measurement registers:

Address Pointer [16 bit]	Type	Width [Byte]	Content / Command	Comment
h1000	RO	2	flow register	
h1001	RO	2	temperature register	
h1010	RO	2	status register	error flags
h7700	RO	2	ID register	silicon/revision ID

RO: Read Only Register

All registers are two bytes long. I²C measurements are started by setting the address pointer into the measurement space of the on-chip memory (addresses h1000 to h1FFF). The highest significant byte is set first; the lowest significant byte is set last. The measurement results are stored in the measurement registers.

Measurement result registers are continuously updated until measurement is stopped by setting the address pointer outside of the measurement space. The highest significant byte is transmitted first; the lowest significant byte is transmitted last. Measurement results are set to invalid after being read and only set to valid again when a new measurement result is available. If a result register is not valid, the chip does not acknowledge a read to it.



The CRC byte is calculated using the generator polynomial $G(x) = x^8 + x^5 + x^4 + 1$ (hex 0x31). The initial value is 0.

5.2 Serial Product Number, Scale Factors

Adress	#Bits	Description/Coding
0x31AE – 0x31AF	2 x <15:0>	Serial Product Number 0x31AE: Most significant word 0x31AF: Less significant word
0x30DE	<15:0>	Scale Factor Flow
0x30DF	<15:0>	Offset Flow
0x31AC	<15:0>	Scale Factor Temperature
0x31AD	<15:0>	Offset Temperature

¹ I²C is an onboard protocol. It is not intended for usage with cables. If customer is using the sensor connected via cables it is recommended to check the system carefully for electromagnetic disturbances.

5.3 Measurement Result Registers

Measurement results are stored in the measurement result registers which can be read via I²C bus. If a measurement is started the registers contain the latest measurement result. Bit 15 is always the most significant bit (MSB) and bit 0 is always the least significant bit (LSB). The following maps give more details on the content of the different registers:

5.3.1 Flow Register

Bit	#Bits	Description/Coding	Boot State default
15:0	16	flow path measurement	0

5.3.2 Temperature Register

Bit	#Bits	Description/Coding	Boot State default
15:0	16	temperature path measurement	0

5.3.3 Status Register

Bit	#Bits	Description/Coding	Boot State default
15:14	2	unused	0
13:0	14	measurement error occurred 00 0000 0000 0000: no error occurred else: error occurred	0

5.3.4 ID Register**

Bit	#Bits	Description/Coding	Boot State default
15:12	4	unused	0
11:0	12	revision ID	revision ID

** Please note that the revision ID register value will change in case of future chip revisions.

In order to obtain the measured flow in the predefined unit, the measured value read from the result register needs to be converted according to the following formula:

$$\text{flow in predefined unit} = (\text{measured value} - \text{offset flow}) / (\text{scale factor flow})$$

Offset Flow: 0 LSB
Scale Factor Flow: 256 LSB / slm

In case the sensor is also calibrated for temperature measurement, the value read out from the temperature result register needs to be converted according to the following formula:

$$\text{temperature in } ^\circ\text{C} = (\text{measured value} - \text{offset temperature}) / (\text{scale factor temperature})$$

Offset Temperature: 20'000 LSB
Scale Factor Temperature: 100 LSB / °C

Please note that the first measurement performed directly after chip initialization is not valid.

5.4 Control Register (Read/Write)

Various parts of the SF05 measurement process can be configured. One important parameter is the flow measurement resolution. The SF05 can be configured to measure in either 14-bit or 12-bit mode. **IMPORTANT:** After every reset of the sensor the flow resolution is set to 14 bit.

Bit 15 is always the most significant bit (MSB) and bit 0 is always the least significant bit (LSB). The following map gives more details on the content of the control register:

6 Ordering Information

Use the part names and product numbers shown in the table below when ordering SFM4200 sensors. For the latest product information and local distributors, visit Sensirion's website on <http://www.sensirion.com>

SENSOR NAME	ARTICLE NUMBER
SFM4200	1-101651-01

Packaging units: 45 sensors

Every sensor is traceable by a unique Serial Number.

Revision History

Date	Version	Author	Changes
09.06.2017	1.0	SAW, DAT	First Version, Updated parameters; Layout changed towards standard layout
04.10.2017	1.1	DAT	Corrected errors, updated mechanical drawing
14.08.2018	1.2	DAT	Released; removed "preliminary"

7 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 (including death). 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 datasheet 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.

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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REACH and RoHS Statement

The SFM4200 sensor complies with requirements of the following directives:

- EU Directive 1907/2006/EC concerning Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)
- EU Directive 2002/65/EC on the restriction of certain hazardous substances in electric and electronic equipment (RoHS), OJ01.01.2011

