Datasheet SFM3304-xxx-D

Digital Disposable Mass Flow Meter

Product Summary

Sensirion's SFM3304-xxx-D is a digital flow meter with particularly **small dead space** designed for **medical** applications.

It measures the flow of air and other non-aggressive gases up to 250 slm. The SFM3304-xxx-D is a **single-use** disposable sensor, with **medical cones** for pneumatic connection to standard breathing circuits and an easy-to-use and **reliable electrical connector**. The sensor element, signal processing and digital calibration are on a single microchip assuring very **fast signal processing time, best-in-class accuracy and superior robustness** to rough handling and adverse conditions.

Based on the SFM3300-250-D, the SFM3304-xxx-D offers similar specifications and additional features due to a newer chip generation including tunable response time, noise level and sampling rate. The SFM3304-xxx-D is offered in customized individual packaging, ready for use.

Key characteristics at a glance

- Flow range from -250 to 250 slm
- I²C interface
- Very small dead space
- Low pressure drop across the sensor
- No recalibration needed
- Individual and customized packaging

Benefits of Sensirion's CMOSens® Technology

- High reliability and long-term stability
- Best signal-to-noise ratio
- Industry-proven technology with a track record of several decades
- Designed for mass production
- High process capability
- Scalability

Content

1. Ordering Information

The part name and order number are customer specific because the sensor is delivered in an individual package with a customized label (see Section 6). Please contact your Sensirion representative for more information.

Part name	Description	Order number
SFM3304-xxx-D	-250 to 250 slm range, disposable sensor, with integrated heater	TBD

Minimal order quantity is 500 sensors (one box).

2. Specifications

2.1 Flow Sensor Specifications[1]

Parameter	Conditions	SFM3304-xxx-D		Units
Measurement range	Air	-250 to 250		slm [2]
		Typ. [3]	**Max.**[4]	
Accuracy [5]	| flow | < 100 slm	±3	±5	% m.v. [6]
	| flow | > 100 slm	±7	±10	% m.v. [6]
	offset	±0.1	±0.2	slm[2]
		Typ. [8]	**Max.**[4]	
Noise Level [5, 7, 10]	| flow | < 25 slm	0.5	2.5	% m.v. [6]
	| flow | > 25 slm	1.5	5	% m.v. [6]
	offset	0.03	0.2	slm [2]
Span shift due to temperature variation			0.5	% m.v. per 10°C
Flow step response time (τ_{63}) [9]	default settings [10]	3		ms
Resolution (16 bit)			0.01	slm
Pressure Drop [11]	60 slm	100 / 0.40	230 / 0.93	Pa / inH2O
	100 slm	280 / 1.13	550 / 2.21	Pa / inH2O
	200 slm	1150 / 4.62	1900 / 7.63	Pa / inH2O
Media compatibility		Air, N_2, O_2, non-agressive gases, non-condensing		

[1] Unless otherwise noted, all sensor specifications are valid at T = 25°C with VDD = 3.3 V, absolute pressure = 966 hPa and horizontal flow direction.
[2] Mass flow measured in slm: liters per minute at standard conditions (T = 20°C and p = 1013.25 hPa)
[3] “Typ”: a CpK of 0.67 is targeted (95% of sensors within the Typ limit)
[4] “Max”: no sensor measured outside of these limits will be shipped and a CpK of 1.33 is targeted
[5] Total value is the sum of offset and span value
[6] % m.v. = % measured value = % of reading
[7] Noise Level is defined as standard deviation of individual sensor readings, measured at default settings.
[8] “Typ.”: average value
[9] The response time can be tuned by adjusting the chip low pass filter, see Section 3.1.
[10] Default settings are: flow signal filter set to a response time of 3ms (see Section 3.1), fixed N averaging set to N=2 (see Section 3.2.2).
[11] Measured with air in calibration conditions, as described in footnote 1.

2.2 Temperature Sensor Specifications[1]

Parameter	Value
Measurement range	-20 °C to +85 °C
Resolution	16 bit
Accuracy	±2 °C for -10 < T < 50 °C ±3 °C otherwise

2.3 Electrical Specifications

Parameter	Symbol	Condition	Min.	Typ.	Max	Units	Comments
Supply Voltage	V_{DD}	working voltage	3.15	3.3	3.45	V	
		absolute min and max ratings	-0.3		5.5	V	
Power-up level	V_{POR_H}				1.7	V	
Power-down level	V_{POR_L}		1.0			V	
Max Voltage on pins (SDA, SCL)		absolute min and max ratings	-0.3		V_{DD}+0.3	V	
Supply current	I_{DD}	measuring		6.5	8.6	mA	
		idle state		0.045	0.6	mA	
		sleep mode			1.2	uA	
External heater resistance				51		Ω	
External heater power rating					0.5	W	Only apply sufficient power to avoid condensation or icing. See section 7.3
ESD test		RC parameters: 330 Ohm and 150 pF			8	kV	Discharge voltage applied on individual connector pins while the device is not grounded.

[1] 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 and self-heating.

2.4 Timing Specifications

Parameter	Symbol	Min.	Typ.	Max.	Units	Comments
Power-up time	t_{PU}		2		ms	Time to sensor ready
Soft reset time	t_{SR}			2	ms	Time between soft reset command or exit sleep mode and sensor ready
Warm-up time	t_w			50	ms	To reach accuracy spec after first measurement command
I^2C SCL frequency	f_{I2C}		400	1000	kHz	
Internal flow sampling rate	f_S	3600	4000	4400	Hz	
Default output rate of the flow value			$f_S/2$		Hz	Adjustable, see Section 3.2.2
Internal temperature sampling rate			$f_S/26$		Hz	Temperature value is updated every 13 flow values with the default averaging configuration for the flow output rate

2.5 Conditions of use

Parameter	Min.	Typ.	Max.	Units	Condition / Comment
Calibrated temperature range	+10		+50	°C	dry gas
Operating temperature range[1]	+5		+50	°C	10-95% rel. hum. (non cond.)
Extended operating range	-20		+5	°C	recommended to use on-sensor heater
Storage temperature	-40		70	°C	10-95% rel. hum. (non cond.), for <48h
Operating pressure range	540		1140	hPa	absolute pressure of gas inside of sensor
Operating overpressure			100	hPa	gauge
Rated burst overpressure			300	hPa	gauge
Allowable torsion			0.75	N.m	torsion applied between opposing pneumatic connectors
Shelf life		3		year	based on tests on SFM3300-D

2.6 Materials

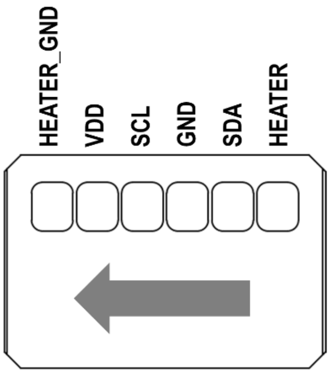
Parameter	
Wetted materials	Si, Si3N4, SiOx, Gold, Epoxy, MABS, silicone
REACH, RoHS	REACH and RoHS compliant

[1] For Air and N_2. Long term exposure to (high concentrations of) O_2 at high temperatures can reduce the product lifetime

2.7 Pin Assignment

The pin assignments of the SFM3304-xxx-D can be found in Table 1. The mechanical interface of the SFM3304-xxx-D's electrical connector is the same as for the SFM3300-D/AW and SFM3400-D/AW. Please visit sensirion.com for an evaluation kit cable compatible with our proximal sensor family: SFM3304-D, SFM3300-D/AW and SFM3400-D/AW (available in 2024).

Name	Description
HEATER_GND	Ground for the heater
VDD	VDD Supply
SCL	Serial Clock (I^2C Interface)
GND	Connect to ground
SDA	Bidirectional Serial Data (I^2C Interface)
HEATER	Supply voltage to the heater



Arrow indicating the positive flow direction

Table 1: SFM3304-xxx-D pin assignment and flow direction

3. Measurement Mode

After the sensor receives a "start continuous measurement" command (for more details see Section 4.3.1) it enters the corresponding measurement mode and continuously performs a measurement with the update rate of the flow output (see Section 2.4). A single reading consists of three measurement values: flow, temperature, and one value for a status word (for more details on status word see Section 4.3.2).

3.1 Flow Signal Filter

The response time and the noise level of the flow signal are both affected by the internal signal processing of the SFM3304. A central element in this signal processing is a third order low pass filter with a default setting to achieve a τ_{63} step response time of 3 ms.

However, for some applications it might be preferred to have either a faster signal response (at the cost of higher noise level), or oppositely a lower noise level (at the cost of slower signal response).

With the SFM3304 it is possible to reconfigure the low pass filter setting by sending a "start continuous measurement" command with an additional command argument (see Section 4.2.2). The custom low pass filter setting then stays active for as long as the continuous measurement mode stays active.

The command argument a_{filter} (unsigned 16-bit integer value) defines the low pass filter setting by:

Response Time: τ_{63}	Command argument: a_{filter}
1 ms	33601
3 ms	50961 (default)
5 ms	56105
10 ms	60527

Table 2: Arguments for the command "start continuous measurement" tuning the response time of the flow output.

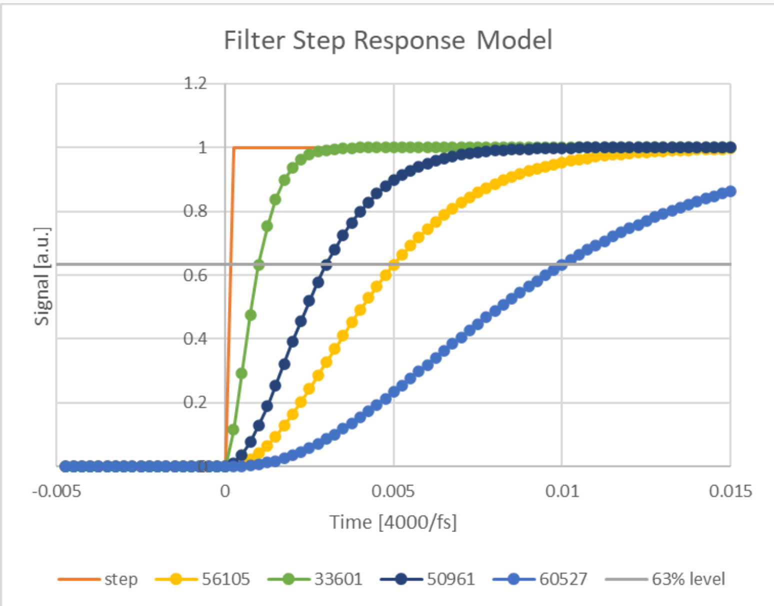


Figure 1: Model of the flow signal output for a step change of flow with different settings of the low pass filter. Remark: the time unit 4000/fs approximately corresponds to seconds.

3.2 Averaging of Flow Value

Two modes for on-sensor averaging of the flow signal are available:

1) Average-until-read: in this mode, the sensor averages all measured values prior to read out.
2) Fixed-N averaging: in this mode, every reading is the average of a fixed number (N) of measured flow values. This averaging mode is the default mode selected upon startup and after a reset, with N=2.

3.2.1 Average-Until-Read

If the 'average till read' option is chosen, the sensor averages all values x_i since the previous read out. This has the benefit that the user can read out the sensor at his own desired speed, without losing information and thus preventing aliasing. During the first $t_{AUR\_max} = 128/f_s$ of averaging (typical t_{AUR_max}= 32 ms), the averaged value is obtained as the arithmetic mean:

$$\bar{x} = \sum_{i=1}^{M} \frac{x_i}{M} \qquad \text{for } t < t_{AUR\_max}$$

If the period between readouts is longer than t_{AUR_max}, the sensor will continue to average, but using a different algorithm. In this algorithm, exponential smoothing is used with a smoothing factor α = 0.02:

$$S_k = \alpha \cdot x_k + (1 - \alpha) \cdot S_{k-1}, \qquad S_0 = \bar{x}, \qquad \text{for } t > t_{AUR\_max}$$

Where S_0 is the arithmetic mean value after the first t_{AUR_max} and the readout value for flow is S_k.

With an exponential smoothing factor of α = 0.02, the value read out by the user is an average value of about the last t_{AUR_max}. In order not to lose information, it is recommended to read out the sensor at least once every t_{AUR_max}. Please refer to the relevant literature for more information about exponential smoothing.

Average-until-read can be selected by the user by setting N=0 in the argument for the "Configuration of Averaging" command (for more details see Section 4.3.4).

3.2.2 Fixed-N Averaging

Averaging may also be set to a fixed number $1 \le N \le 128$ of measurements to be averaged (c.f. Section 4.3.4). This type of averaging is especially suited to avoid any averaging (N=1). If fixed-N averaging is chosen, the update time for new readings is $N \times 1/f_S$ accordingly. Averaging has the benefit that the user can read out the sensor at his own desired speed, without losing information and thus preventing aliasing. In this case, the averaged value $\bar{x}$ is the arithmetic mean of the individual measurements x_i:

$$\bar{x} = \sum_{i=1}^{N} \frac{x_i}{N}$$

If no averaging is desired, set N to 1. The default mode selected upon startup and after a reset is this fixed-N averaging with N=2.

3.3 Sensor Start-Up and Warm-Up Behavior

The typical time for system power-up (until the sensor responds to communication requests) is 2 ms. The typical time from a soft reset until the sensor responds to communication requests is also 2 ms.

After reset or start-up of the sensor, the sensor's internal heater is off and is automatically turned on by performing a *Start Continuous Measurement* command (see Section 4.3.1). The very first measurement after *Start Continuous Measurement* is ready after approximately 4 ms.

Due to the thermal measurement principle, a total warm-up time of typically 50 ms[1] is necessary for an accurate measurement. This includes the 4 ms needed for measurement initialization.

3.4 Sensor Check at Start-Up

The gas flow sensor checks the integrity of its entire memory content at start-up automatically using a CRC check sum. In case the CRC check fails, the I^{2}C-interface is deactivated.

The following command provides a further possibility for an integrity check: Read Product Identifier (command code 0xE102, see Section 4.3.8). Ideally suited to test if the sensor is connected correctly.

4. Digital Interface Description

The sensor's digital interface is compatible with the I^{2}C protocol. This chapter describes the available command set. For detailed information about the I^{2}C protocol, please consult the document "NXP I^{2}C-bus specification and user manual" (I2C-bus specification and user manual (nxp.com)).

The physical interface consists of two bus lines: a data line (SDA) and a clock line (SCL) which need to be connected via pull-up resistors to the bus voltage of the system.

4.1 I2C Address

The I^{2}C address for the SFM3304-xxx-D is:

Product Version	I2C address (hex)	I2C address (binary)
SFM3304-xxx-D	0x2E	0b010'1110

Table 3: I2C addresses of the SFM3304-xxx-D

In the I^{2}C protocol, a read or write bit follows the I^{2}C address.

4.2 I^{2}C Sequences

An I2C sequence typically consists of a command sent by the master to the slave (the sensor) and a subsequent readout of data by the master from the slave. It depends on the specific command if an argument to the command is needed and if data can be read out from the slave following the command. I2C read sequences can be aborted with a NACK and STOP condition. The following sections provide I2C sequences for the specific tasks. Dark areas with white text indicate that the sensor controls the SDA (Data) line:

4.2.1 Write Command without Argument

The commands have a length of 16 bits:

I^{2}C master sends the write header and writes a 16-bit command:

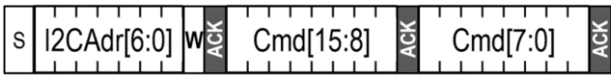


Figure 2: I^{2}C sequences to send a command without an argument to the sensor.

[1] Warm-up time under default settings.

4.2.2 Write Command with Argument

Commands have a length of 16 bits and are followed by a 16-bit argument plus an 8-bit checksum:

I²C master sends the write header and writes a 16-bit command, followed by a 16-bit argument plus a CRC byte:

Figure 3: I²C sequences to send a command with an argument to the sensor.

4.2.3 Read data from the Slave

After that, data is read from the sensor in multiples of 16-bit words, each followed by an 8-bit checksum to ensure communication reliability. I²C sequences can be aborted with a NACK and STOP condition as indicated below.

I²C master sends the read header and receives multiple 16-bit words followed by a CRC byte:

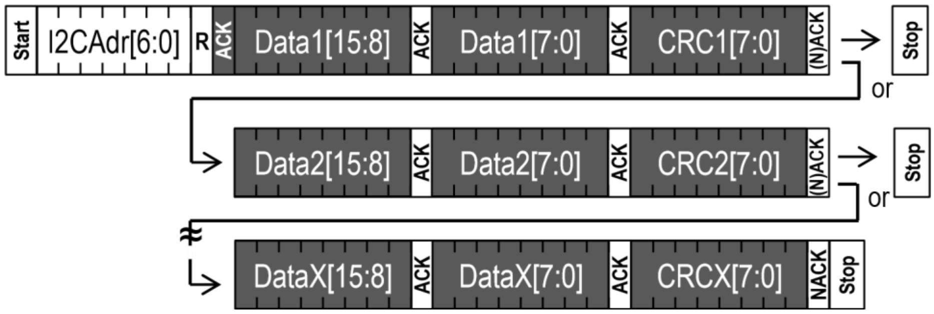


Figure 4: I²C sequences to read results from the sensor. Dark areas with white text indicate that the sensor controls the SDA (Data) line

4.3 I²C Commands

The command set consists of a set of various commands, which are described in the following sections:

- Start Continuous Measurement
- Stop Continuous Measurement
- Configuration of Averaging
- Read Scale Factor, Offset, and Flow Unit
- Soft Reset
- Entering and Exiting Sleep Mode
- Read Product Identifier

4.3.1 Start Continuous Measurement and Read Results

The sensor measures both flow and temperature and provides in a third data buffer a status word. All three measurement results can be read out through one single I²C read header when the continuous measurement is running.

The command code for starting the continuous measurement is 0x3603. If sent without an argument (see Figure 2) the measurement starts in default mode. For custom filter settings the command can be sent with an argument (see Figure 3), where the argument configures the flow signal filter as described in section 3.1.

Command code (Hex)	Gas	Command argument	Response Time
0x3603	Gas 0: Air	NA (call without argument)	3 ms
0x3603	Gas 0: Air	Flow signal filter setting (call with argument)	According to Sec. 3.1

Table 4: I²C commands to start continuous measurement

After the command has been sent, the chip continuously measures and updates the measurement results. New results (flow, temperature, and status word) can be read continuously with a single I²C read header for each measurement.

Further commands must not be sent until the stop measurement command has been sent. Consult section 4.3.3 for more details.

After the start measurement command is sent:

- the first measurement result will be available after 4 ms
- accuracy deviations can occur during the first 50 ms (including the 4 ms)

If an I²C read header (I²C address + read bit) is sent to the sensor when no measurement data is available, the sensor will respond with a NACK condition. Otherwise, the sensor will respond with the following output:

Preceding command	Consecutive read	Description
Continuous measurement	Byte1: Flow 8msb Byte2: Flow 8lsb Byte3: CRC Byte4: Temp 8msb Byte5: Temp 8lsb Byte6: CRC Byte7: Status Word 8msb Byte8: Status Word 8lsb Byte9: CRC	After a start continuous measurement command, the measurement results can be read out. The temperature and the consecutive bytes do not need to be read out (every time). The read sequence can be aborted by a NACK and a STOP condition.

Table 5: Consecutive reads after I²C command to start continuous measurement (see Section 4.2.3). The flow and temperature values are 16bit signed integers. For conversion into physical units refer to Section 4.5.

4.3.2 Status Word

The status word is returned along with every flow and temperature measurement. It contains an identifier representing the measurement command that is currently running, information on the currently selected averaging mode and the filter setting configuration. The table below lists the values returned by the status word.

Measurement Mode	**Status Word (bits 15:0)**				
Command Code of running measurement command	Bits <15:12>: identifier for the currently running measurement command	Bit <11>: status of exponential smoothing	Bit <10>: averaging mode	Bit <9>: command argument reception	Bits <8:0>: configured number of averages
0x3603	0b0000	0: Exponential smoothing is not active 1: Averaging mode has switched to exponential smoothing	0: Average-Until-Read is active 1: Fixed-N averaging is active	0: No command argument received; default filter settings applied 1: command argument has been received; signal filter is configured accordingly	Configured number of averages. (0 for average until read mode)

Table 6: Values returned by the status word.

4.3.3 Stop Continuous Measurement

Command	Command code (Hex)	Description
Stop continuous measurement	0x3FF9	This command stops the continuous measurement and puts the sensor in idle mode. After it receives the stop command, the sensor needs up to 0.5ms to power down the heater, enter idle mode and be receptive for a new command.

Table 7: I²C command to stop continuous measurement.

When the sensor is in continuous measurement mode, the sensor must be stopped before it can accept another command. The only exception is the soft reset command (see Section 4.3.6). In idle mode the sensor will consume less power but consider the sleep mode for most effective energy saving results.

4.3.4 Configuration of Averaging

Command	Command code (Hex)	Command argument	Description
Configure averaging	0x366A	*N*	This command configures the sensor's averaging mode: 1) *N*=0: average-until-read mode (c.f. Section 3.2) 2) 1≤*N*≤128 (default N=2): fixed-*N* averaging mode. *N* is the number of internal measurements that are averaged for one returned measurement value (i.e. the average over *N* flow samples, where *N* = CmdArgument, c.f. Section 3.2). The configured averaging mode will be used for flow measurements until a reset or re-execution of this command is performed. After a reset, averaging is set to fixed-N averaging mode with N = 2. The highest averaging number allowed is 128. If a higher number is used in the command argument, it will be overruled by the maximal value of 128 samples to average. If no averaging is desired, set *N* to 1.

Table 8: I²C command to configure averaging.

4.3.5 Read Scale Factor, Offset, and Flow Unit

This command provides the scale factor and offset to convert flow readings into physical units (see Section 4.5). The scale factor and offset are specific to the calibrated gas and its corresponding lookup table used for the flow measurement. Therefore, the gas needs to be specified in the command argument by the command code of the corresponding start continuous measurement (see Section 4.3.1).

For the SFM3304-xxx-D, the flow unit is a fixed value 0x0148 and corresponds to slm: standard liter per minute at 20°C and 1013.25 hPa pressure.

Command	Command code (Hex)	Command argument (Hex)
Read Scale Factor, Offset, and Flow Unit	0x3661	Command code of desired gas for scale factor, offset and flow unit (Section 4.3.1). The command argument needs to be followed by the correct CRC (Section 4.2). For the SFM3304-xxx-D the only calibrated gas is air, according to Table 4 the command argument is 0x3603 with the corresponding CRC 0x3A.

Preceding command	Consecutive read	Description
Read Scale Factor, Offset, and Flow Unit	Byte1: Scale factor 8msb Byte2: Scale factor 8lsb Byte3: CRC Byte4: Offset 8msb Byte5: Offset 8lsb Byte6: CRC Byte7: Flow Unit 8msb Byte8: Flow Unit 8lsb Byte9: CRC	After a "Read Scale Factor, Offset, and Flow Unit" command, the corresponding results can be read out. The scale factor and offset are a 16-bit signed integer number represented by a two's complement (ranging from -32'768 to 32'767). The flow unit is a 16-bit identifier.

Table 9: I²C command to read the scale factor, offset, and flow unit. Result of this command.

4.3.6 Soft Reset

Command	I²C address + W bit + command code (Hex)	Consecutive read	Description
General call reset	0x0006	NA	This sequence resets the sensor with a separate reset block, which is as much as possible detached from the rest of the system on chip. Note that the I²C address is 0x00, which is the general call address, and that the command is 8 bits long. The reset is implemented according to the I²C specification.

Table 10: Reset command

After the reset command the sensor will typically take 2ms to reset. During this time, the sensor will not acknowledge its address nor accept commands.

4.3.7 Entering and Exiting Sleep Mode

In sleep mode the sensor uses a minimum amount of power. The mode can only be entered from idle mode, i.e. when the sensor is not performing measurements.

This mode is particularly useful for battery operated devices. To minimize the current in this mode, the complexity of the sleep mode circuit has been reduced as much as possible, which is mainly reflected by the way the sensor exits the sleep mode. In sleep mode the sensor cannot be soft reset.

Command	Command code (Hex)	Consecutive read	Description
Enter Sleep mode	0x3677	NA	The sleep command can be sent after a stop continuous measurement command has been issued and the sensor is in idle mode.
Exit Sleep mode	0x00	NA	The sensor exits the sleep mode and enters the idle mode when it receives an I2C write header (i.e. the valid I2C address and a write bit ('0')) plus one byte of data (i.e. the command is only 8 bits). The sensor should wake up within 2ms. Note that the I²C address is **not** acknowledged. It is necessary to poll the sensor to see whether the sensor has received the command sequence to exit the sleep mode and has woken up. Polling with a write header (I2C address and a write bit) can be used to check whether the sensor has woken up.

Table 11: Sleep mode commands

4.3.8 Read Product Identifier

The product identifier and the serial number can be read out by sending the command below. The command can only be issued in idle mode, i.e. when the sensor is not performing measurements

Command	Command code (Hex)	Consecutive read	Description
Read product identifier	0xE102	Byte1: Product number [31:24] Byte2: Product number [23:16] Byte3: CRC Byte4: Product number [15:8] Byte5: Product number [7:0] Byte6: CRC Byte7: Serial number [63:56] Byte8: Serial number [55:48] Byte9: CRC Byte10: Serial number [47:40] Byte11: Serial number [39:32] Byte12: CRC Byte13: Serial number [31:24] Byte14: Serial number [23:16] Byte15: CRC Byte16: Serial number [15:8] Byte17: Serial number [7:0] Byte18: CRC	The command returns: - 32-bit unique product and revision number. The number is listed in Table 13 below. *Note that the last 8 bits are the revision number and are subject to change as long as the datasheet is preliminary.* - 64-bit unique serial number in the format of an unsigned long integer. The serial number can be converted from binary into decimal, whereby in decimal it has the following format: *yywwxxxxxx*, where: *yy*: last 2 digits of calibration year, *ww*: calibration week, *xxxxxx*: unique 6-digit sequential number within the calibration week.

Table 12: Read product identifier command

Product	Product number
SFM3304-xxx-D	0x0405010x

Table 13: Product number for SFM3304-xxx-D

4.4 Checksum Calculation

The 8-bit CRC checksum transmitted after each data word is generated by a CRC algorithm. Its properties are listed in Table 14. The CRC covers the contents of the two previously transmitted data bytes. To calculate the checksum, only these two previously transmitted data bytes are used.

Property	Value
Name	CRC-8
Protected data	read data
Width	8 bit
Polynomial	0x31 (x8 + x5 + x4 + 1)
Initialization	0xFF
Reflect input	False
Reflect output	False
Final XOR	0x00
Example	CRC (0xBEEF) = 0x92

Table 14: Checksum definition

4.5 Number Format and Conversion to Physical Values

The number format of the flow and temperature signals and the conversion to a physical value with a scale factor and an offset where applicable is explained below:

4.5.1 Scale Factors and Offsets

Signal	SFM3304-xxx-D		Comment
	Scale Factor	Offset	
Gas 0: Air	120 LSB16 / slm	0 LSB16	Can be read out using an I²C-command (c.f. Sec. 4.3.5)
Temperature	200 LSB16 / °C	0 LSB16	

Table 15: Scale factors and offsets

4.5.2 Flow

The digital calibrated gas flow signal read from the sensor is a 16-bit signed integer number represented by a two's complement (ranging from -32'768 to 32'767). The integer value can be converted to the physical value by subtracting the offset and dividing it by the scale factor (gas flow in $slm = \frac{sensor\ output - offset}{scale\ factor}$). The scale factor and offset are specific to every calibrated gas.

The flow unit slm signifies standard liters per minute with reference temperature equal to 20°C and reference pressure equal to 1013.25 hPa.

4.5.3 Temperature

The digital calibrated temperature signal read from the sensor is a 16-bit signed integer number represented by a two's complement (ranging from -32'768 to 32'767). The integer value can be converted to the physical value by subtracting the offset and dividing it by the scale factor (temperature in $°\mathrm{C} = \frac{Sensor\ Output - offset}{Scale\ factor}$).

4.5.4 Flow Unit

The flow unit is specific to every calibrated gas and is specified in Section 4.5.1**.** It can further be read out using an I²C-command (Section4.3.5). The flow unit is given by a 16-bit unsigned word, where the information about the unit is encoded in the first 13 bits as follows:

1. Bits <3:0>: unit prefix (multiplier)
2. Bits <7:4>: time base (e.g. per minute)
3. Bits <12:8>: unit (e.g. standard liter)

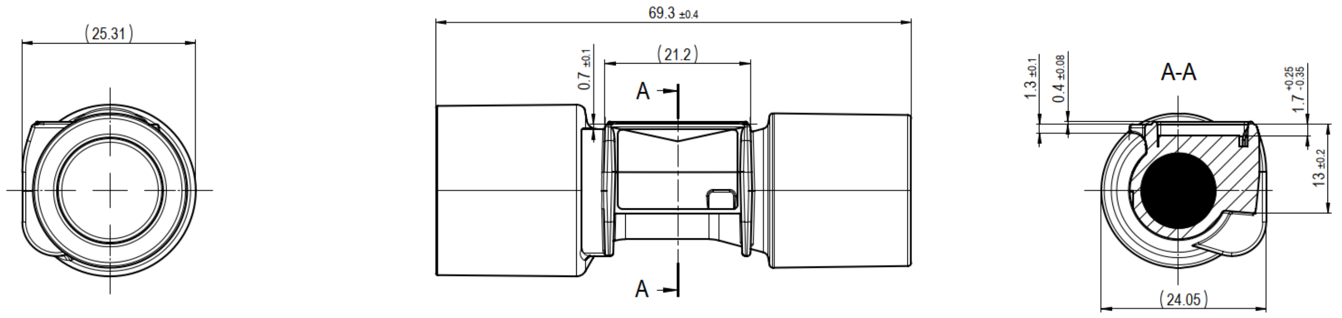
The allowed values for the 3 unit constituents are given in the table below:

Bits <12:8>	Signification: Unit	Bits <7:4>	Signification: Time Base	Bits <3:0>	Signification: Unit Prefix	overall code (16 bits)	Signification: flow unit
0b00001 = 1	standard liter (T_0=20°C, p_0=1013.25 hPa)	0b0100 = 4	per minute	0b1000 = 8	10^{-0} = 1	0b 0000 0001 0100 1000 = 0x0148 = 328	standard liter per minute (slm) with reference temperature =20°C and reference pressure =1013.25 hPa

Table 16: Possible result(s) for the flow unit

5. Product Dimensions

All dimensions are in millimeters.



Pneumatic connectors of the SFM3304-xxx-D are ISO5356-1:2015 compatible medical cones. Details about this type of connection can be found in the description of the standard.

Dimension	Condition	Value	Unit
Length		69.3	mm
Proximal large pneumatic connector	cone	22	mm
Proximal small pneumatic connector	socket	15	mm
Distal large pneumatic connector	socket	22	mm
Distal small pneumatic connector	cone	15	mm
Dead space		<10	ml
Weight		<20	g

6. Packaging

6.1 Individual Packaging

Each sensor is placed in a blister-type single unit packaging, composed of printable paper (permeable to ethylene oxide) and thermoformed plastic sealed together.

Individual packaging	
Physical dimensions	105 x 53 x 30 mm
Printable area	79 x 37 mm
Printable paper (bottom of packaging)	Wipak Gas Paper 60
Thermoformable plastic (top of packaging)	Wipak Fitform 150

6.2 Label artwork

The label is defined in collaboration with the customer. Once the label is approved by the customer, the part name and the order number of the SFM3304-xxx-D are also defined in an addendum of the datasheet.

6.3 Higher level of packaging

The individually packaged sensors are shipped in a box containing 500 sensors, which is the minimal order quantity. Optional service of smaller boxing (10 sensors per box) can be agreed upon, please reach out to your Sensirion contact for further information.

Shipping box	
Number of sensors in a box	100 perforated bands of 5 single packaged sensors = 500 sensors
Box dimensions	59 x 39 x 33 cm
Box weight	9 to 10 kg

7. Instructions for use

7.1 Flow direction

Positive flow direction is from the distal to proximal side, so that inspiratory flows are positive and expiratory flows negative. The flow direction is also indicated by an arrow on the sensor PCB.

7.2 Inlet flow conditions

The SFM3304 is sensitive to jetting inlet conditions. To prevent large signal noise and measurement errors do not directly connect adapters with inner diameter less than 10 mm to the SFM3304. In case small inner diameter cannot be avoided, inserting a filter or an angle piece between the jet and the SFM3304 will improve the inlet conditions. Early testing of the customer specific inlet conditions is recommended.

7.3 Heater operation

The sensor has an external heater for cases where the gas flowing through the sensor contains high humidity and is warmer than the ambient temperature, and therefore than the sensor housing. In such cases, heating the sensor can help to avoid condensation or icing. Sufficient power should be provided for this purpose, but excessive power must be avoided for two reasons:

1) to stay within the operating temperature range,
2) to maintain the best accuracy.

Reading out the chip temperature can be used as feedback on the current sensor temperature.

8. Revision History

Date	Author	Version	Changes
10.2023	PSIM	v1.0	first released datasheet

9. Important Notices

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.

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