

Preliminary Datasheet SFM3019 series

Digital Mass Flow Meter



Product Summary

SFM3019 is Sensirion's solution on providing high volumes of flow meters for medical ventilators in order to support the global pandemic situation due to the Corona virus outbreak. It relies on a modular approach of assembling approved parts with good availability to Sensirion and a high-volume through-put manufacturing.

The housing geometry is based on the SFM3000 flow meter, hence it remains mechanically compatible to the SFM3000.

A flow range from -10slm to +240slm and one directional flow supports high flow applications while still allowing to detect back flows. To minimize pressure-drop the SFM3019 is equipped with one mesh at the inlet.

Disclaimer: The product is not fully qualified but the risk is deemed low as the processes and materials are already used in other products currently in production.

Benefits of Sensirion's CMOSens® Technology

- Scalability
- High reliability and long-term stability
- Best signal-to-noise ratio
- Industry-proven technology with a track record of more than 15 years
- Designed for mass production
- High process capability

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1. Ordering Information

Use the part names and item numbers shown in the following table when ordering the SFM3019. For the latest product information and local distributors, visit www.sensirion.com.

| Part name | Description | Product number |
|---------------|-------------------------------|----------------|
| SFM3019-240-C | -10 to 240slm range, with cap | 3.000.400 |

2. Specifications

2.1 Flow Specification¹

| Parameter | Condition | SFM3019 | | Units |
|--|-------------------|---|-------------|-------------------------|
| Measurement range ² | | Air/O ₂ : -10 to 240 | | slm ³ |
| | | Max. | Typ | |
| Accuracy ⁵ | span (0...240slm) | ±3% | ±2% | m.v. ⁴ |
| | span (-10...0slm) | ±5% | ±3% | m.v. |
| | Zero point | 0.1 (max.) | 0.05 (typ.) | slm |
| Repeatability ⁵ | span | ±1% | | m.v. |
| | Zero point | 0.05 | | slm |
| Noise Level ⁵ | span | ±1% | ±0.5% | m.v. |
| | Zero point | 0.06 | | slm |
| Span shift due to temperature variation | | < 0.5% of reading per 10°C | | |
| Flow step response time (τ ₆₃) | | < 3ms | | |
| Resolution | | 16 bit | | |
| Calibrated for | | O ₂ , Air | | |
| Media compatibility | | Air, N ₂ , O ₂ , non-condensing | | |
| Pressure Drop @60slm @200slm | | One mesh version <80 / 0.32 <500 / 2.0 | | Pa / inH ₂ O |

¹ Unless otherwise noted, all sensor specifications are valid at 25°C with VDD = 3.3 V and absolute pressure = 966 mbar.

² For other ranges contact Sensirion

³ In standard liter per minute at 20°C and 1013 mbar

⁴ Measured value

⁵ Span or offset value, whichever is larger

2.2 Temperature Specification¹

| Parameter | Value |
|-------------------|--|
| Measurement range | -20 °C to +85 °C |
| Resolution | 16 bit |
| Accuracy | 2 °C (-10 °C to +60 °C) 3 °C (-20 °C to +85 °C) |
| Repeatability | 0.1°C |

2.3 Electrical Specifications

| Parameter | Symbol | Condition | Min. | Typ. | Max | Units | Comments |
|---------------------|------------------|------------|------|------|-----|-------|-----------------------------|
| Supply Voltage | V _{DD} | | 2.7 | 3.3 | 5.5 | V | Recommended: 3.3V +/- 5% |
| Power-up/down level | V _{POR} | | 2.3 | 2.5 | 2.7 | V | |
| Supply current | I _{DD} | Measuring | | 3.8 | 5.5 | mA | VDD 3.3V |
| | | Idle state | | | 1.1 | mA | |
| | | Sleep mode | | | 1 | uA | |

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 | | 30 | | ms | To reach accuracy spec after first measurement command |
| I ² C SCL frequency | f _{I2C} | | 400 | 1000 | kHz | |
| Update rate flow value | | 1800 | 2000 | 2200 | Hz | |
| Update rate temperature value | | 112.5 | | | Hz | Temperature value is updated at least every 16 flow values |

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. Using the signal to measure solely the gas temperature will need special precautions, such as isolating the sensor from external temperate influences.

2.5 Mechanical Specifications

| Parameter | Symbol | Min. | Typ. | Max. | Units | Condition/Comment |
|--------------------------|-------------|------|------|------|-------|-------------------|
| Operating pressure range | | 0.7 | | 1.3 | bar | absolute |
| Allowable overpressure | P_{max} | -0.2 | | 0.2 | bar | gauge |
| Rated burst pressure | P_{burst} | | | >1 | bar | gauge |
| Weight | W | | | 14.6 | g | |

2.6 Materials

| Parameter | |
|------------------|---|
| Wetted materials | PPE+PS blend, Si, glass (Si_3N_4 , SiO_x), gold, FR4, copper alloy, lead-free solder, epoxy, polyurethane, stainless steel (annealed) |
| REACH, RoHS | REACH and RoHS compliant |

2.7 Absolute Minimum and Maximum Ratings

| Parameter | Rating | Units |
|--|----------------------|-------|
| Supply Voltage V_{DD} | -0.3 to 5.5 | V |
| Max Voltage on pins (SDA, SCL) | -0.3 to $V_{DD}+0.3$ | V |
| Input current on any pin | ± 70 | mA |
| Operating temperature range ¹ | 0 to +60 | °C |
| Storage temperature range | -20 to +70 | °C |
| Max. humidity for long term exposure | 40°C dew point | |
| ESD HBM (human body model) | 2 | kV |

2.8 Pin Assignment

The pin assignments of the SFM3019 series can be found in Table 1. The cap of the SFM3019 is compatible with DuraClik™ Wire-to-Board Receptacle Housing, Single Row, 4 Circuits. (Molex product number: 502351-0400).

| Pin no. | Name | Description |
|---------|------|--|
| 1 | SCL | Serial Clock (I ² C Interface) |
| 2 | VDD | VDD Supply |
| 3 | GND | Connect to ground |
| 4 | SDA | Bidirectional Serial Data (I ² C Interface) |

digital:

Table 1: SFM3019 series pin assignment.

¹ For Air and N₂. Long term exposure to (high concentrations of) O₂ at high temperatures can reduce the product lifetime

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 every ~0.5ms. Therefore, a new reading can be obtained every 0.5ms. A single reading consists of three measurement values: flow, temperature, and one value for a status word (for more details see Section 4.3.1).

3.1 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. This averaging mode is the default mode selected upon startup and after a reset.
- 2) Fixed-N averaging: in this mode, every reading is the average of a fixed number (N) of measured flow values.

3.1.1 Average-Until-Read

If the ‘average till read’ option is chosen, the sensor averages all values x_i prior to the 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 64ms of averaging, the averaged value is obtained as the arithmetic mean:

$$\bar{x} = \sum_{i=1}^M \frac{x_i}{M} \quad \text{for } t < 64 \text{ ms}$$

If the period between readouts is longer than 64ms, the sensor will continue to average, but using a different algorithm. In this algorithm, exponential smoothing is used with a smoothing factor $\alpha = 0.02$:

$S_k = \alpha \cdot x_k + (1 - \alpha) \cdot S_{k-1}$, $S_0 = \bar{x}$, for $t > 64 \text{ ms}$ Where S_0 is the arithmetic mean value after the first 64ms and the readout value for flow is S_k .

With an exponential smoothing factor of $\alpha = 0.02$, the value read out by the user is an average value of about the last 64ms. In order not to lose information, it is recommended to read out the sensor at least once every 64ms. Please refer to the relevant literature for more information about exponential smoothing.

Average-until-read is the default averaging mode after startup and after a reset. It can further 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).

3.1.2 Fixed-N Averaging

Averaging may also be set to a fixed number 1:N: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 $N \cdot 0.5\text{ms}$ 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, ~2kHz measurements x_i :

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

If no averaging is desired, set N to 1.

3.2 Sensor Start-Up and Warm-Up Behavior

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

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 12ms.

Due to the thermal measurement principle, a total warm-up time of typically 30ms is necessary for a reliable measurement. This includes the 12ms needed for measurement initialization.

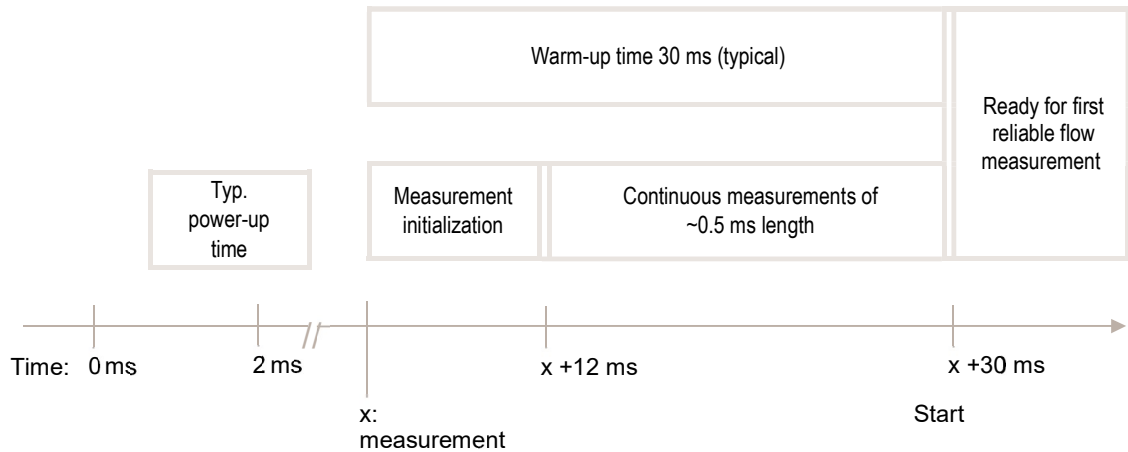


Figure 1: Timing

3.3 Status Word and further sensor checks

The gasflow sensor uses Sensirion's latest flow chip generation. This allows to return 3 data words simultaneously with every measurement (see Section 4.3.1). In order to provide to the user the possibility to query certain status and configuration information from the sensor, a status word is returned with every measurement. The sensor also features an automated CRC check of its entire memory and further possibilities for checks.

3.3.1 Status Word

The status word is returned along with every flow and temperature measurement. It contains the measurement command that is currently running, information on the currently selected averaging mode, and the measurement parameter of the current measurement command. This measurement parameter is a fixed value of 0x3FF if a measurement command for pure gases is running (commands 0x3603 or 0x3608). If a measurement command for binary gas mixtures is running (command 0x3632), the measurement parameter reflects the concentration of Gas 0 set by the user. The table below lists the values returned by the status word.

| Command Code of running measurement command | Bits <15:12>: currently running measurement command | Bit <11>: status of exponential smoothing | Bit <10>: averaging mode | Bits <9:0>: concentration |
|---|---|---|---|--|
| 0x3603 | 0b0000 | 0: Exponential smoothing is not active 1: Averaging mode has switched to exponential smoothing | 0: Fixed-N averaging is active 1: Average-Until-Read is active | Fixed value of 0b11111111 = 0x3FF = 1023 to indicate that a pure gas is being measured |
| 0x3608 | 0b0001 | | | |
| 0x3615 | 0b0010 | | | |
| 0x361E | 0b0011 | | | |
| 0x3624 | 0b0100 | | | |
| 0x362F | 0b0101 | | | |
| 0x3632 | 0b0110 | | | Volume fraction of Gas 0 (in ‰) |
| 0x3639 | 0b0111 | | | |
| 0x3646 | 0b1000 | | | |

Table 2: Values returned by the status word depending on the measurement command running. Rows, which are grayed out are reserved for future uses.

3.3.2 Sensor Checks

The gasflow sensor checks the integrity of its entire memory content (including all lookup tables for all gases and gasmixtures and the entire configuration) at start up automatically using a CRC check sum. In case the CRC check fails, the I²C-interface is deactivated.

The following command provides a further possibility for an integrity check: Read Product Information (command code 0x367C, see Section 4.3.8): Ideally suited to test if the sensor is connected correctly and if the sensor has been assigned the correct I²C-address upon startup.

4. Digital Interface Description

The sensor's digital interface is compatible with the I²C protocol. This chapter describes the available command set. For detailed information about the I²C protocol, please consult the document "NXP I²C-bus specification and user manual" (http://www.nxp.com/documents/user_manual/UM10204.pdf).

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

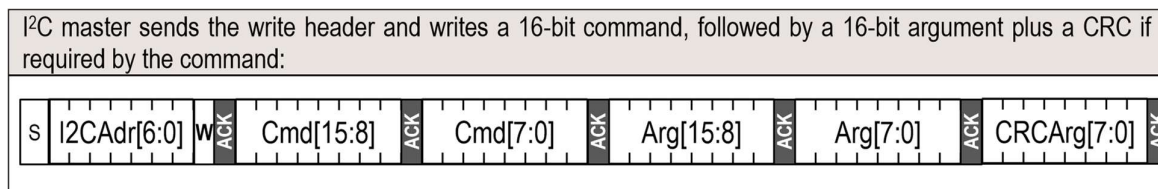
4.1 I²C Address

The I²C address for SFM3019 in Hex and binary is 0x2E and b 0101110.

In the I²C protocol, a read or write bit follows the I²C address.

4.2 I²C Sequences

The commands have a length of 16 bits. If commands require an argument, they are followed by a 16-bit argument plus an 8bit checksum:



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:

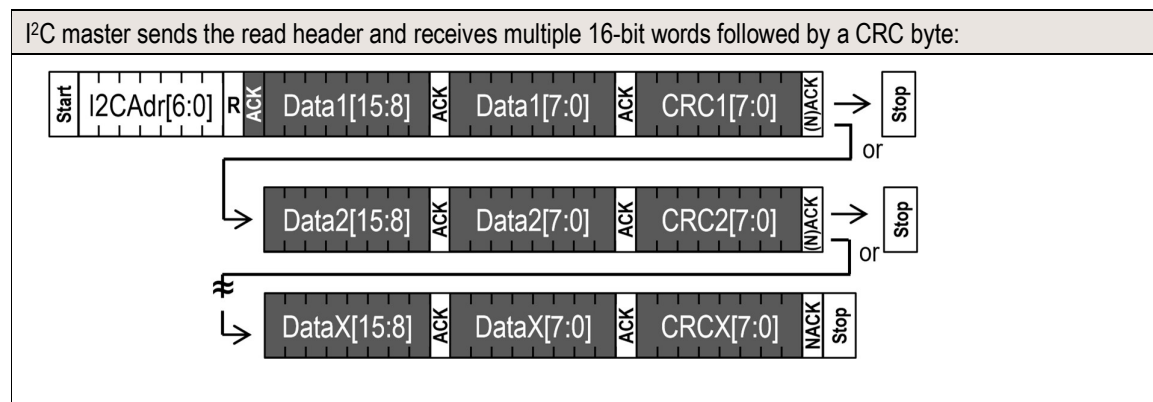


Figure 2: I²C sequences. Dark areas with white text indicate that the sensor controls the SDA (Data) line.

I²C sequences can be aborted with a NACK and STOP condition.

4.3 I²C Commands

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

- Various Start continuous measurement commands (one for each gas/gas mixture)
- Update concentration
- Stop continuous measurement command
- 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

The sensor measures both flow and temperature and 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 specific command code used for the start continuous measurement command selects the calibrated gas or binary gas mixture (lookup table) for the flow signal.

| Command code (Hex) | SFM3019 | Command argument | Averaging |
|--------------------|-----------------------------------|--|----------------------------|
| 0x3603 | Gas 0: O ₂ | N/A | According to Section.4.3.4 |
| 0x3608 | Gas 1: Air | N/A | |
| 0x3615 | Reserved for future use | N/A | |
| 0x361E | Reserved for future use | N/A | |
| 0x3624 | Reserved for future use | N/A | |
| 0x362F | Reserved for future use | N/A | |
| 0x3632 | Gas mixture 0: Air-O ₂ | Volume fraction of O ₂ (in ‰) | |

Table 4: I²C command to start continuous measurement

After the command has been sent, the chip continuously measures and updates the measurement results as described in Section 3. New results (flow, temperature, and sanity check) 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 12ms
- small accuracy deviations (few % of reading) can occur during the first 30ms (including the 12ms)

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.

| 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 don't 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. The flow value is a raw data value consisting of a 16bit signed integer. For conversion into physical units refer to sections 4.5, 4.5.1.

4.3.2 Update Concentration

To update the concentration of a binary gas mixture dynamically, i.e. without interrupting the running measurement mode (see 3.3.1), an I²C transmission sequence consisting of a set of two instructions (for details see Section 4.) is provided:

| Command | Command code (Hex) | Command argument | Description |
|--|--------------------|-------------------------------|--|
| Transmit concentration | 0xE17D | Volume fraction of Gas 0 in ‰ | This instruction transmits the concentration value to the flow sensor. |
| Reset I ² C address pointer | 0xE000 | None | This instruction resets the I ² C address pointer to the regular result output buffer such that the measurement data as described in Sections 4.2 and 4.3 are obtained upon a subsequent read header. |

Table 6: I²C commands to update the concentration for binary gas mixtures.

For further important details please refer to Sections 3.3, 4.3.1.

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 exceptions are the soft reset (see Section 4.3.6) command and the update concentration command (see Section 4.3.2).

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 | <i>N</i> | <p>This command configures the sensor's averaging mode:</p> <ol style="list-style-type: none"> 1) $N=0$ (default): average-until-read mode (c.f. Section 3.1) 2) $1 \leq N \leq 128$: 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 $N = \text{CmdArgument}$, c.f. Section 3.1). <p>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 average-until-read mode (i.e. N is set to 0). 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.</p> |

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). It further returns a checksum over the lookup tables used to convert the raw flow signals into flow readings. The scale factor and offset are specific to the calibrated gas / gas mixture and its corresponding lookup table used for the flow measurement. Therefore, the gas / gas mixture needs to be specified in the command argument by the command code of the corresponding start continuous measurement (see Section 4.3.1).

| Command | Command code (Hex) | Command argument (Hex) |
|--|--------------------|---|
| Read Scale Factor, Offset, and Flow Unit | 0x3661 | Command code of desired gas / gas mixture for scale factor, offset and flow unit (Section 4.3.1). |

| 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 | <p>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).</p> <p>The flow unit is a 16-bit identifier.</p> <p>The offset and the consecutive bytes don't need to be read out (every time). The read sequence can be aborted by a NACK and a STOP condition.</p> |

Table 9: Read Scale Factor, Offset, and Flow Unit

4.3.6 Soft Reset

| Command | I ² C 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. <u>Note that the I²C address is 0x00, which is the general call address, and that the command is 8 bits long.</u> The reset is implemented according to the I ² C 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 | NA | NA | The sensor exits the sleep mode and enters the idle mode when it receives the valid I²C address and a write bit ('0') . Note that the I ² C address is not acknowledged. It is necessary to poll the sensor to see whether the sensor has received the address and has woken up. This should take typically 16ms. |

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 mode can only be entered from the 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 | Note that the command need to be preceded with an I ² C write header (I ² C address + W). The command returns: <ul style="list-style-type: none"> - 32 bit unique product and revision number. The number is listed in Table 13 below. <i>Note that the last 8 bits are the revision number and are subject to change as long as the datasheet is preliminary.</i> - 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: <i>yywwxxxxxx</i> , where: <i>yy</i> : last to digits of calibration year, <i>ww</i> : calibration week, <i>xxxxxx</i> : unique 6-digit sequential number within the calibration week. |

Table 12: Read product identifier

| Product | Product number | Comment |
|---------|----------------|---|
| SFM3019 | 0x04020611 | Last two digits: 8x indicating a prototype 1x indicating finalized products, therefore last two bytes expected to change during development |

Table 13: Product number for SFM3019

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 ($x^8 + x^5 + x^4 + 1$) |
| 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, temperature, and sanity check 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 | SFM3019 | | Comment |
|--|-----------------------|--------|---|
| | Scale Factor | Offset | |
| Gas 0: | 170 slm ⁻¹ | -24576 | Can be read out using an I ² C-command (c.f. Sec. 4.3.5) |
| Gas 1: | 170 slm ⁻¹ | -24576 | |
| Gas 2-5: reserved for future use | tbd | tbd | |
| Gas mixture 0: Gas1 - Gas0 | 170 slm ⁻¹ | -24576 | |
| Gas mixture 1: reserved for future use | tbd | tbd | |
| Temperature | 200 °C ⁻¹ | 0 | |

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 / gas mixture / lookup table.

The flow unit slm signifies standard liters per minute with reference temperature equal to 20°C and reference pressure equal to 1013mbar.

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 °C = $\frac{Sensor\ Output - offset}{Scale\ factor}$).

4.5.4 Flow Unit

The flow unit is specific to every calibrated gas / gas mixture / lookup table and is specified in Section 4.5.1.. It can further be read out using an I²C-command (Section 4.3.5). 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 tables below:

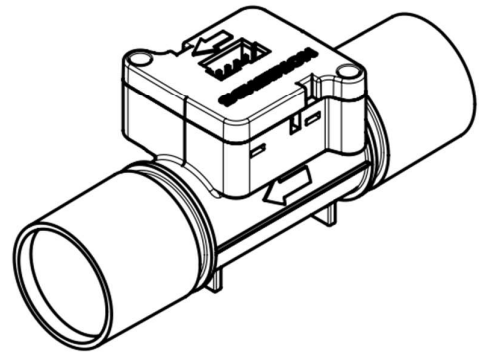
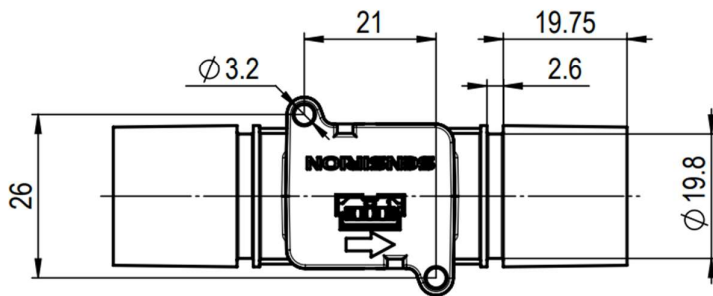
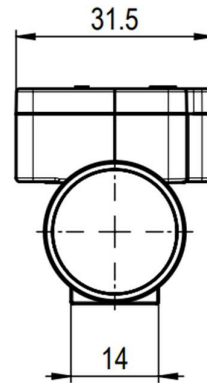
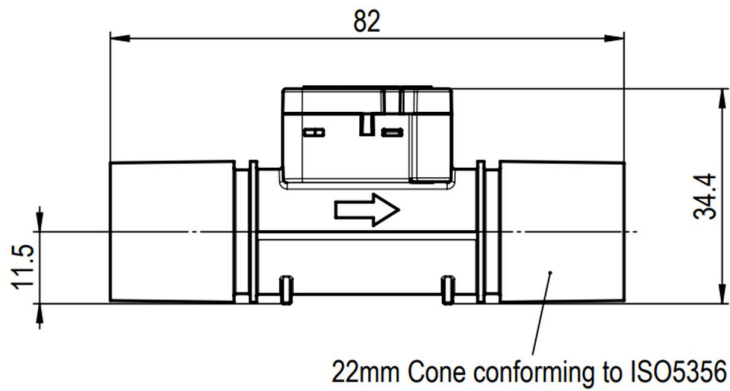
| Bits <3:0> | Unit Prefix | Multiplier |
|-------------|-------------|-----------------------|
| 0b0011 = 3 | n | 10 ⁻⁹ |
| 0b0100 = 4 | μ | 10 ⁻⁶ |
| 0b0101 = 5 | m | 10 ⁻³ |
| 0b0110 = 6 | c | 10 ⁻² |
| 0b0111 = 7 | d | 10 ⁻¹ |
| 0b1000 = 8 | N/A | 10 ⁰ = 1 |
| 0b1001 = 9 | da | 10 ¹ = 10 |
| 0b1010 = 10 | h | 10 ² = 100 |
| 0b1011 = 11 | k | 10 ³ |
| 0b1100 = 12 | M | 10 ⁶ |
| 0b1101 = 13 | G | 10 ⁹ |

| Bits <7:4> | Time Base |
|------------|-----------------|
| 0b0000 = 0 | none |
| 0b0001 = 1 | per microsecond |
| 0b0010 = 2 | per millisecond |
| 0b0011 = 3 | per second |
| 0b0100 = 4 | per minute |
| 0b0101 = 5 | per hour |
| 0b0110 = 6 | per day |

| Bits <12:8> | Unit |
|-------------|---|
| 0b00000 = 0 | norm liter (T ₀ =0°C, p ₀ =1013mbar) |
| 0b00001 = 1 | standard liter (T ₀ =20°C, p ₀ =1013mbar) |
| 0b00010 = 2 | standard liter (T ₀ =15°C, p ₀ =1013mbar) |
| 0b00011 = 3 | standard liter (T ₀ =25°C, p ₀ =1013mbar) |
| 0b01000 = 8 | liter |
| 0b01001 = 9 | gram |

Example: standard liter per minute (slm) with reference temperature equal to 20°C and reference pressure equal to 1013mbar is encoded as 0b 0000 0001 0100 1000 = 0x0148 = 328. Standard cubic centimeters per minute (sccm) with the same reference conditions is encoded as 0b 0000 0001 0100 0101 = 0x0145 = 325.

5. Package Outline¹



¹ To allow for a further capacity increase within the next months Sensirion recommends to plan an additional 6mm free space over the sensor cover. This will not affect the behavior of the sensor. Please contact Sensirion for further information.

6. Soldering

Standard wave soldering systems may be used for soldering SFMxxxx sensors. Reflow soldering is not feasible and may damage the sensor. Contact Sensirion for further information.

7. Shipping Package

Packing units: 20 items/tray

8. Revision History

| Date | Author | Version | Changes |
|------------|--------|---------|---|
| 29.03.2020 | JGOE | V0.7 | Major rework and re-release |
| 02.04.2020 | JGOE | V0.8 | Flow Specification straightened |
| 03.04.2020 | JGOE | V0.9 | Flow Specification straightened, Product Number updated |

9. 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.

See application note "Handling Instructions" 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 datasheet 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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