# SFM3505-300, SFM3505-300-X datasheet

**High performance digital mass flow meter**


## Highlights

- High accuracy
- Low noise
- Low pressure drop
- Reduced dependency to inlet conditions
- Compact dimensions

The SFM3505 series are compact digital gas flow sensors that successfully combine ultra low noise, high accuracy and low pressure drop, all in a compact form factor. Succeeding the proven SFM3119 and SFM3100, the SFM3505 feature a completely re-engineered architecture to deliver best-in-class performance at a minimal pressure drop. The sensor is offered in two performance tiers, SFM3505-300 with standard and SFM3505-300-X with high accuracy.

Built on Sensirion's latest 5th-generation CMOSens® Technology, the SFM3505 integrates the sensor element and advanced signal processing on a single microchip. This enables fast, stable, and fully calibrated digital output via a standard $I^2C$ interface. Designed to be integrated in long-lived devices, the sensor does not need any additional calibration in production nor recalibration in the field due to the excellent long-term stability of CMOSens® chips.

It is calibrated for air and oxygen and incorporates on-chip temperature compensation, ensuring precise measurements under varying conditions. This is the ideal sensor for inspiratory flow measurements in applications such as mechanical ventilation, anesthesia, and gas mixing systems.

## Applications

- Ventilation
- Anesthesia
- High accuracy and high flows applications

## Device Overview

| Product | Details |
|---|---|
| SFM3505-300 | Inspiratory gas flow sensor |
| SFM3505-300-X | High accuracy gas flow sensor |

**See full product references on page 15.**

# Contents

# 1 Specifications

## 1.1 Flow specifications for SFM3505-300 [1]

| Parameter | Condition | Value | | Unit |
|---|---|---|---|---|
| Flow range | air, $O_2$ | -150 to 300 | | slm [2] |
| Sensor output | | 1: air flow, 2: $O_2$ flow | | |
| | | Typical | Maximal | |
| Accuracy [3,4] | Span | ±2.3 | ±3 | % m.v. [5] |
| | Offset | ±0.04 | ±0.05 | slm |
| Noise [6,7] | Span | 0.5 | 1 | % m.v. |
| | Offset | 0.002 | 0.01 | slm |
| Accuracy derating with temperature [8] | -20 to +85°C | ±(0.03 slm or 0.5%) | | … per 10°C from 25°C |
| Pressure dependence [9] | 525 hPa (abs.) | -1.5 | - | % |
| | 750 hPa (abs.) | -0.5 | - | % |
| | 1400 hPa (abs.) | +0.7 | - | % |
| | 1650 hPa (abs.) | +1.0 | - | % |
| Pressure drop [10] | 60 slm | 57 | 85 | Pa |
| | 100 slm | 140 | 200 | Pa |
| | 200 slm | 540 | 750 | Pa |
| Flow step response time ($\tau_{63}$) [11] | Default filter settings (adjustable) | 3 | | ms |
| Resolution (24 bit) | | 0.00004 | | slm |

[1] Unless otherwise noted, all sensor specifications are valid in calibration conditions: dry air, at T=25 °C, absolute pressure = 966 hPa, horizontal flow direction and $V_{DD}$ = 3.3V.
[2] slm: mass flow measured in liters per minute at standard conditions (T = 20 °C, p = 1013.25 hPa)
[3] Total accuracy is a sum of offset and span accuracy levels. For "Typical" a CpK of 0.67 is targeted (95% of sensors within the typical limit). For "Maximal" no sensor measured outside these limits will be shipped and a CpK of 1.33 is targeted.
[4] Measurements in 100% oxygen showed an additional accuracy deviation of up to 0.5%m.v.
[5] % m.v. = % measured value = % of reading
[6] Noise Level is defined as standard deviation of individual sensor readings, measured at default settings. Default settings are: flow signal filter set to a response time of 3ms (see section 2.2), fixed N averaging set to N=2 (see section 2.3).
[7] Total noise is the sum of the offset and span noise levels. "Typical": average value. For "Maximal", a CpK of 1.33 is targeted.
[8] Accuracy derating with temperature defined as additional uncertainty to the calibration accuracy when the temperature deviates from 25 °C.
[9] Pressure dependence given as the average shift in sensor's output measured in the flow range 100 to 200 slm. The absolute pressure is the pressure inside the sensor.
[10] Pressure drop measured in air in calibration conditions. "Typical": average value. For "Maximal", a CpK of 1.33 is targeted.
[11] With default filter settings. The response time can be tuned by adjusting the chip low pass filter, see section 2.2.

## 1.2 Flow specifications for SFM3505-300-X [12]

| Parameter | Condition | Value | | Unit |
|---|---|---|---|---|
| Flow range | air, $O_2$ | -150 to 300 | | slm |
| Sensor output | | 1: air flow, 2: $O_2$ flow | | |
| | | Typical | Maximal | |
| Accuracy [13,14] | Span | ±1.5 | ±2 | % m.v. |
| | Offset | ±0.04 | ±0.05 | slm |
| Noise | see 1.1 | | | |
| Accuracy derating with temperature | | | | |
| Pressure dependence | | | | |
| Pressure drop | | | | |
| Flow step response time ($\tau_{63}$) | | | | |
| Resolution (24 bit) | | | | |

[12] Unless otherwise noted, all sensor specifications are valid in calibration conditions: dry air, at T=25 °C, absolute pressure = 966hPa, horizontal flow direction and $V_{DD}$ = 3.3V.
[13] For "Typical" a CpK of 0.67 is targeted (95% of sensors within the typical limit) and total accuracy is the sum of offset and span accuracy levels. For "Maximal" no sensor measured outside of these limits will be shipped, a CpK of 1.33 is targeted and total accuracy is the offset or span accuracy level, whichever is greater.
[14] Measurements in 100% oxygen showed an additional accuracy deviation of up to 0.5%m.v.

## 1.3 Electrical specifications

| Parameter | Symbol | Condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Supply Voltage | VDD | working voltage | 3.2 | 3.3 | 3.4 | V |
| | | absolute min and max ratings | -0.3 | | 5.5 | V |
| Power-up level | VPOR_H | | | | 2.5 | V |
| Power-down level | VPOR_L | | 1.5 | | | V |
| Max Voltage on pins (SDA, SCL, DRDY) | | absolute min and max ratings | -0.3 | | VDD+0.3 | V |
| Supply current | IDD | measuring | | 3.8 | 10 | mA |
| | | idle state | | 0.05 | 0.6 | mA |
| SCL and SDA sink current capability | | | 3 | | | mA |
| DRDY driving strength | | | | | 0.05 | mA |
| DRDY internal resistance | | | | 4 | | kΩ |

## 1.4 Timing specifications

| Parameter | Symbol | Comment | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Power-up time | $t_{PU}$ | Time to sensor ready | | | 2 | ms |
| Soft reset time | $t_{SR}$ | Time between soft reset command and sensor ready | | | 2 | ms |
| Time for first flow output available | $t_{1st}$ | Time between measurement command and first flow measurement available | | | 4 [15] | ms |
| Warm-up time | $t_w$ | Time to reach accuracy spec after measurement command | | | 50 | ms |
| $I^2C$ SCL frequency | $f_{I2C}$ | | | 400 | 1000 [16] | kHz |
| Internal flow sampling rate | $f_S$ | | 3880 | 4000 | 4120 | Hz |
| Output rate of the flow value | | Adjustable, see section 2.3 | | $f_S/2$ | $f_S$ | Hz |

[15] Valid for the default settings. This time depends on the configured number of samples to be averaged (N), see section 2.3.
[16] The choice of pull-up resistors and designed bus capacitance need to allow for fast enough signal transition. As an example, for 1000 kHz SCL frequency pull-up resistors of 1.5 kOhm combined with a bus capacitance of less than 90 pF achieve the transition time and respect the product's capability on SCL and SDA sink current.

## 1.5 Conditions of use

| Parameter | Comment | Min. | Max. | Unit |
|---|---|---|---|---|
| Operating overpressure | at 25°C<br>Pressure dependence: see 1.1 | | 650 | hPa gauge |
| Allowed overpressure | Tested for 1000 min at 40°C | | 650 | hPa gauge |
| Burst overpressure[17] | Tested for 5 min at 40°C | | 1250 | hPa gauge |
| Operating temperature [18] | Accuracy derating: see 1.1 | -20 | 85 | °C |
| Storage temperature | Tested for 48h | -20 | 85 | °C |
| Operating humidity [18] | | non-condensing | | |
| ESD HBM | Human body model tested on IC chip level | | 2 | kV |

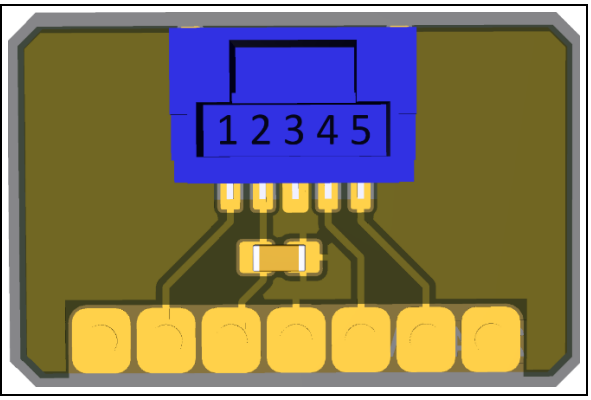
## 1.6 Media compatibility

| Parameter | Value |
|---|---|
| Compatible gases | Air, $N_2$, $O_2$, other non-aggressive gases (non-condensing) |
| Wetted materials | PPE+PS blend, Si, glass (Si3N4, SiOx), epoxy, FKM<br>typically non wetted: gold, FR4, lead-free solder |
| RoHS, REACH | RoHS and REACH compliant |

## 1.7 Pin assignment

The pin assignment of SFM3505 can be found in the table below. The connector on the sensor is a 5-pin, 1mm pitch JST socket (part number: BM05B-NSHSS-TBT(LF)(SN)) which fits to the corresponding JST connector plug (part number: NSHR-05V-S).

| Connector Pin | Name | Description |
|---|---|---|
| 1 | SDA | Bidirectional Serial Data ($I^2C$ Interface) |
| 2 | VDD | $V_{DD}$ Supply |
| 3 | GND | Connect to ground |
| 4 | SCL | Serial Clock ($I^2C$ Interface) |
| 5 | DRDY | Data ready signal |




[17] No burst means that the PCB remains in the sensor housing and leakage rate is below 5sccm at 300hPa overpressure.
[18] Long term exposure to high temperature and high humidity or high concentrations of $O_2$ can reduce the product lifetime.

# 2 Measurement Mode

After the sensor receives a "start continuous measurement" command (for more details see section 3.3.1) it enters the measurement mode and continuously provides measurement readings with the update rate of the flow output (see section 2.3). A single reading consists of two flow values: a 24-bit flow value for gas air and a 24-bit flow value for gas oxygen.

## 2.1 Data Ready Signal (DRDY)

The DRDY signal indicates whether new measurement results are available. The polarity is active low, meaning that when the signal is low there is new measurement data available and if the signal is high there is no new measurement data available. The DRDY will automatically clear to high when a measurement value is read out. The DRDY pin will also be set to low after initial power up, or after any hard- or soft-reset, until a measurement command, read device identifier command or fixed-N averaging configuration command is sent.

If the DRDY signal is not used, the pin should stay unconnected.

## 2.2 Flow Signal Filter

The response time and the noise level of the flow signal are both affected by the internal signal processing of SFM3505. A central element in this signal processing is a third order low pass filter with a default setting to achieve a $\tau_{63}$ 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 SFM3505 it is possible to reconfigure the low pass filter setting by sending a "start continuous measurement" command with an additional command argument (see section 3.3.1). 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: $\tau_{63}$ | Command argument: $a_{filter}$ |
|---|---|
| 1 ms | 33601 |
| 3 ms | 50961 (default) |
| 5 ms | 56105 |
| 10 ms | 60527 |

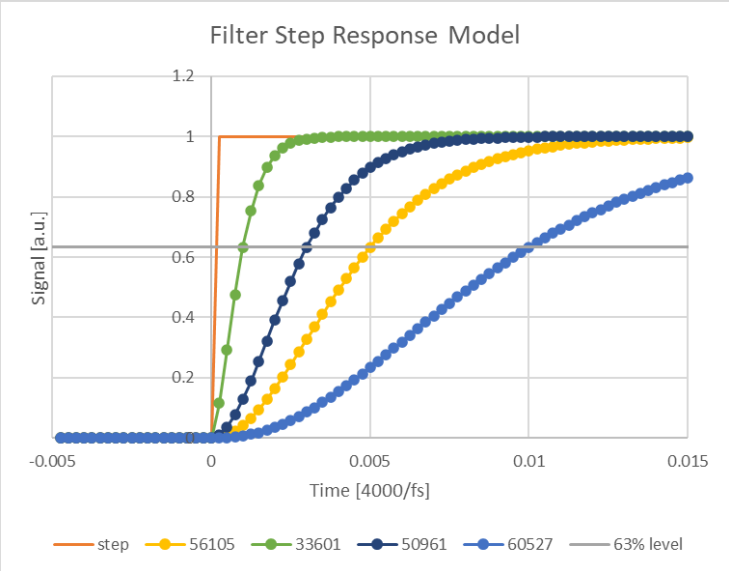



**Figure 1**: Model of the flow signal output for a step change of flow with different settings of the low pass filter. Remark: the time unit 4000/fs approximately corresponds to seconds.

## 2.3 Averaging of Flow Value

A fixed-N averaging mode for on-sensor averaging of the flow signal is implemented, in which every reading is the average of a fixed number (*N*) of measured flow values. Upon startup, a fixed averaging with *N* = 2 is set by default.

Averaging may be set to any fixed number $1 \leq N \leq 128$ of measurements to be averaged (c.f. section 3.3.3). If fixed-N averaging is chosen, the update time for new readings is $N \times 1/f_S$ accordingly. Averaging has the benefit that users can reduce the sensor output rate to their 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.

## 2.4 Sensor Start-Up and Warm-Up Behavior

The typical time for system power-up (until the sensor responds to communication requests) is $t_{PU}$. The typical time from a soft reset until the sensor responds to communication requests is $t_{SR}$ (see section 1.4).
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 3.3.1). The very first measurement after *Start Continuous Measurement* is ready after $t_{1st}$.
Due to the thermal measurement principle, a total warm-up time under default settings of typically $t_w$ is necessary for an accurate measurement. This includes $t_{1st}$ needed for measurement initialization.

# 3 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" (https://www.nxp.com/docs/en/user-guide/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 pull-up resistors to the bus voltage of the system.

## 3.1 I²C Address

The I²C address for SFM3505 is:

| Product Version | I2C address (hex) | I2C address (binary) |
|---|---|---|
| SFM3505 | 0x2E | 0b010'1110 |

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

## 3.2 I²C 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:

### 3.2.1 Write Command without Argument

The commands have a length of 16 bits:

I²C master sends the write header and writes a 16-bit command:

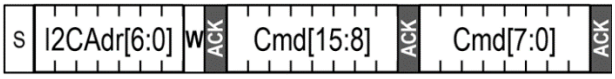



**Figure 2**: I²C sequences to send a command without an argument to the sensor.

### 3.2.2 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.

### 3.2.3 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.

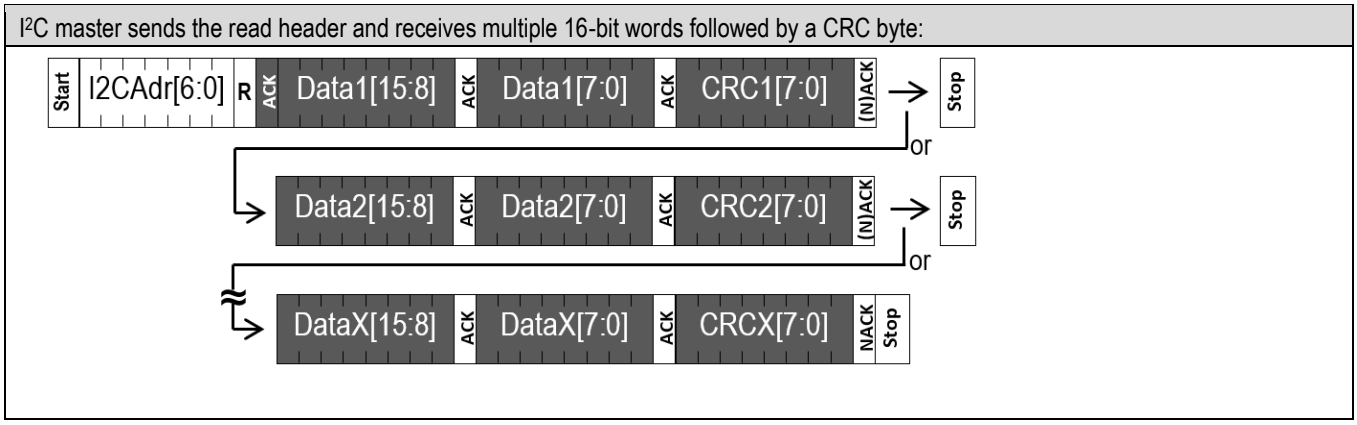



**Figure 4:** I²C sequences to read results from the sensor. Dark areas with white text indicate that the sensor controls the SDA (Data) line**.**

## 3.3 I²C Commands

The I²C command set consists of the following commands:

- Start Continuous Measurement
- Stop Continuous Measurement
- Configuration of Averaging
- Soft Reset
- Read Device Identifier

### 3.3.1 Start Continuous Measurement and Read Results

The command code for starting the continuous measurement is 0x3603. If sent without an argument (see Figure 2) the measurement starts in default mode and returns the flow value for air with the default filter response setting. 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 2.2.

| Command code (Hex) | Command argument | Output values | Filter response time | Comment |
|---|---|---|---|---|
| 0x3603 | None | Output pair: Air & $O_2$ | default, see 2.2 | Call without argument |
| 0x3603 | $a_{filter}$ | Output pair: Air & $O_2$ | According to sec. 2.2 | Customize signal filter setting |

After the command has been sent, the chip continuously measures and updates the measurement results. New data 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 3.3.2 for more details.**

After the start measurement command is sent:

- the first measurement result will be available after $t_{1st}$ (see timing specifications, section 1.4)
- accuracy deviations can occur during the first $t_w$ (including $t_{1st}$)

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 0x3603 | Byte1: Flow Air [23:16]<br>Byte2: Flow Air [15:8]<br>Byte3: CRC<br>Byte4: Flow Air [7:0]<br>Byte5: Flow O2 [23:16]<br>Byte6: CRC<br>Byte7: Flow O2 [15:8]<br>Byte8: Flow O2 [7:0]<br>Byte9: CRC | After a start continuous measurement command, the measurement results can be read out.<br>The read sequence can be aborted by a NACK and a STOP condition. |

The flow values are 24bit unsigned integers. For conversion into physical units refer to section 3.5.

### 3.3.2 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 0.5 ms to power down the heater, enter idle mode and be receptive for a new command. |

**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 3.3.4). In idle mode the sensor will consume less power.

### 3.3.3 Configuration of Averaging

| Command | Command code (Hex) | Command argument | Description |
|---|---|---|---|
| Configure averaging | 0x364D | *N* | This command configures the sensor's averaging mode: $1 \leq N \leq 128$ (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 2.3).<br>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.<br>If no averaging is desired, set *N* to 1. |

### 3.3.4 Soft Reset

| Command | $I^2C$ 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.<br>Note that the $I^2C$ address is 0x00, which is the general call address, and that the command is 8 bits long. The reset is implemented according to the $I^2C$ specification. |

After the reset command the sensor will maximally take $t_{SR}$ to reset. During this time, the sensor will not acknowledge its address nor accept commands.

### 3.3.5 Hard Reset

In order to hard reset the sensor, all pins need to be pulled to 0V: Vdd but also the communication lines.

### 3.3.6 Read Device 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. Please note that it takes maximally 60 us until the values can be read from the sensor (the sensor can be polled and the data availability is also indicated by the DRDY pin).

| Command | Command code (Hex) | Consecutive read | Description |
|---|---|---|---|
| Read device identifier | 0x365B | Byte1: Product identifier [31:24]<br>Byte2: Product identifier [23:16]<br>Byte3: CRC<br>Byte4: Product identifier [15:8]<br>Byte5: Product identifier [7:0]<br>Byte6: CRC<br>Byte7: Serial number [63:56]<br>Byte8: Serial number [55:48]<br>Byte9: CRC<br>Byte10: Serial number [47:40]<br>Byte11: Serial number [39:32]<br>Byte12: CRC<br>Byte13: Serial number [31:24]<br>Byte14: Serial number [23:16]<br>Byte15: CRC<br>Byte16: Serial number [15:8]<br>Byte17: Serial number [7:0]<br>Byte18: CRC | The command returns:<br>- 32-bit unique product and revision identifier. The identifier is listed in section 3.3.7 below.<br>*Note that the last 8 bits are the revision number and are subject to change during development.*<br>- 64-bit unique serial number in the format of an unsigned long integer.<br>The serial number can be converted from binary into decimal, whereby in decimal it has the following format:<br>*yywwxxxxxx*, where:<br>• *yy*: last 2 digits of year of manufacturing<br>• *ww*: calendar week of manufacturing<br>• *xxxxxx*: unique 6-digit number |

### 3.3.7 Product Identifier Values

| Material description | Product identifier | Comment |
|---|---|---|
| SFM3505-300 | 0x040602xx | meaning of the last byte: product revision |
| SFM3505-300-X | 0x040601xx | |

## 3.4 Checksum Calculation

The 8-bit CRC checksum transmitted after each data word is generated by a CRC algorithm. Its properties are listed in the table below. 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 |

## 3.5 Number Format and Conversion to Flow Physical Value

The digital calibrated gas flow signals read from the sensor are 24-bit unsigned integer number. The integer values are converted to physical values by subtracting an offset and dividing by a scale factor:

$$\text{Gas flow in slm } Q = \frac{sensor\ output - offset}{scale\ factor}$$

The scale factor and offset for SFM3505 are given in the table below:

| Signal | Scale Factor | Offset |
|---|---|---|
| Air / $O_2$ flow | 25’600 LSB24 / slm<br>0x6400 LSB24 / slm | 8'388'608 LSB24<br>0x80’0000 LSB24 |

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 Mechanical specifications

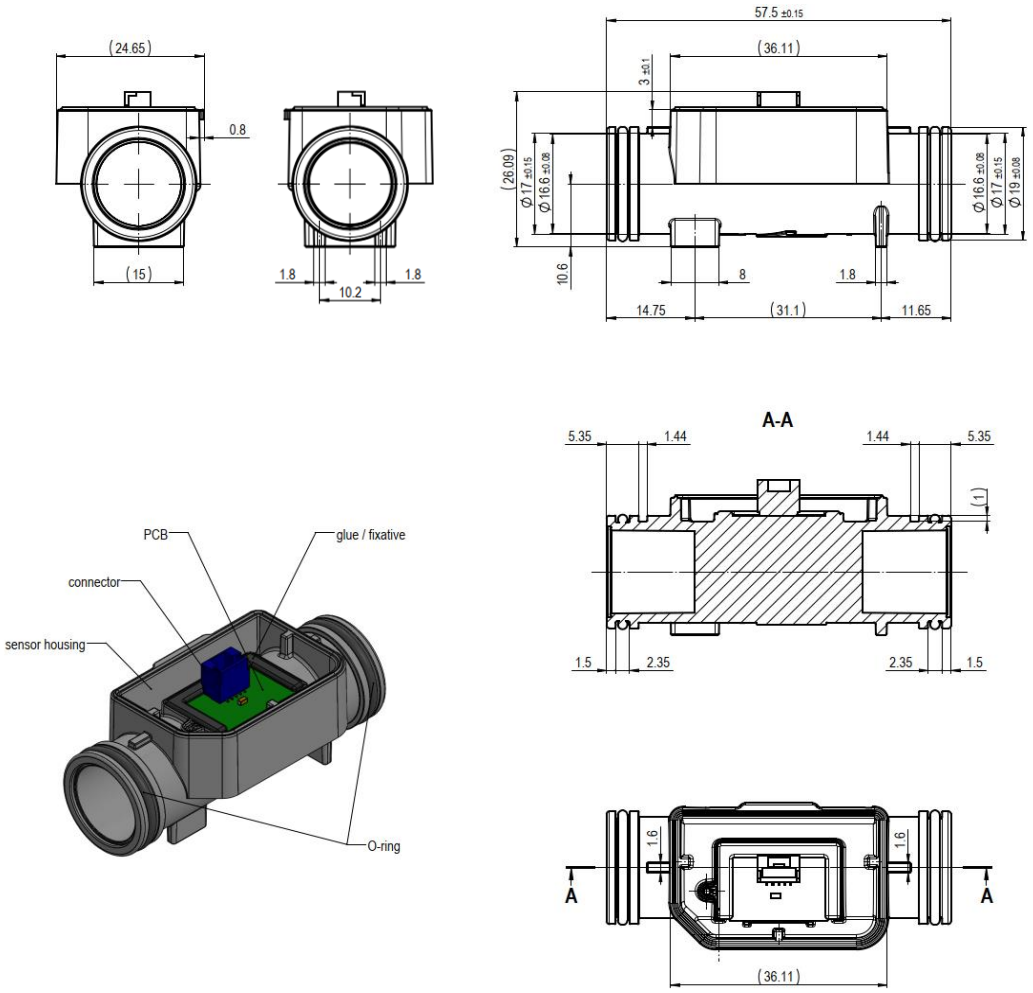



**Figure 5:** Drawing of SFM3505 with dimensions in mm. Extracted from drawing number 176937, revision 00.

## 4.1 O-rings

The white O-rings on the SFM3505 are produced according to ISO3601 class B and have the following dimensions:

| Dimension | Inner diameter | Wire diameter | Unit |
|---|---|---|---|
| Value | 16.1 | 1.6 | mm |

## 4.2 Flow path

The inner inlet diameter of the flow path is 14.0 mm. For optimal design-in, we recommend matching this inner diameter.

### 4.3 Label on sensor body

The sensor has a label on its body containing the following information in human readable text and in a GS1 data matrix:

| Description | GS1 matrix application identifier | Comment |
|---|---|---|
| Material description | - | Only in human readable text, see section 5 |
| Material number | 240 | See section 5 |
| Serial number | 21 | See section 3.3.6. Preceded by the mention "SN" for the human readable text. |

## 5 Ordering information

Use the material numbers shown in the following table when ordering the SFM3505. For the latest product information and local distributors, visit www.sensirion.com.

| Material description | Details | Material number |
|---|---|---|
| SFM3505-300 | Inspiratory gas flow meter | 3.001.246 |
| SFM3505-300-X | High accuracy inspiratory gas flow meter | 3.001.273 |

Packaging unit = minimal order quantity = 120 sensors (4 trays).

## 6 Revision History

| Date | Version | Pages | Changes |
|---|---|---|---|
| 2025/10 | 1.0 | all | first released version |

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