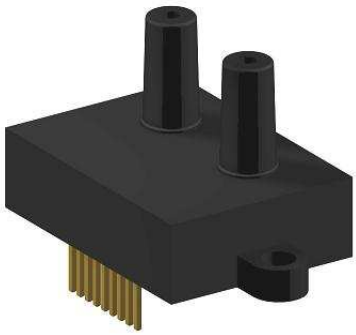
OIF4

Digital air flow sensor

General Description

OIF4 is a new digital airflow sensor with enhanced functions and performances. This system in package has been designed for demanding applications with high accuracy requirements over whole temperature and flow ranges. For this reason it is fully factory calibrated and provides a 10 bits linearized output between -200 and 200 sccm. The internal ASIC supports SPI standard communication up to 2MHz.
The sensor operates on the heat transfer principle to measure air flow, using MEMS sensing die, placed in a properly designed channel, that provides accurate and repeatable measurements. The sensor is designed to measure mass flow of air and non-corrosive gases with a fast response time (≈10ms).
Thanks to the internal ASIC, different full scale monodirectional or bidirectional ranges can be easily customized (i.e. ±500sccm).

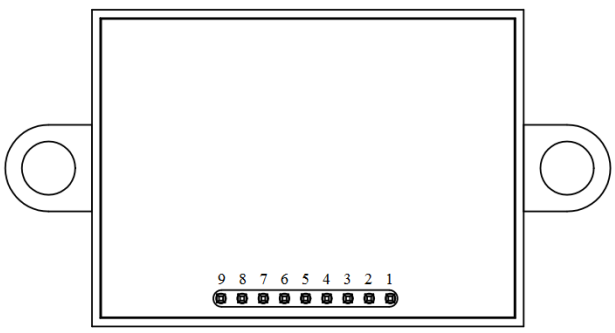


Applications

Home and building automation
Biomedical (respirators, ventilators, spirometers)
Environmental monitoring
Energy efficiency management
Industrial plants (Air to fuel ratio, HVAC filters)
Automotive (air/gasoline mixture, air conditioning)
Leak detection equipment
Meteorology

Features

- **Small size: sensing area w/o package of 3x3mm^2**
- **High sensitivity, accuracy and linearity, especially at low rates**
- **Low power consumption**
- **Fast response time**
- **Low pressure drop**
- **Bidirectional sensing capability**
- **Customization on end-user needs (packaging side and range of application)**
- **Output signal: analog (± 5V) and digital (SPI)**



Sensor pinout (bottom view)

Pin functions

No.	Name	Function
1	VCC	+4.5 to +5.5 V Digital Supply Voltage
2	GND	Digital Ground
3	$\overline{CS}$	SPI I/O, Chip Select active low
4	SCK	SPI I/O, Clock
5	MOSI	SPI I/O, Master Out Slave In
6	MISO	SPI I/O, Master In Slave Out
7	$\overline{ERR}$	Error Message Output active low
8	OUTP	Positive Analog Output
9	OUTN	Negative Analog Output

Ordering Information

OIF4	10 bit Digital Air Flow Sensor ±200sccm

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_S	Supply voltage		+4.5		+5.5	V
AFR_{MAX}	Maximum air flow range		-1000		1000	sccm
Ts	Storage temperature range		-40		+100	℃
$V_{PIN}()$	Voltage at all pins	Reference to GND	-0.3		+6	V
$I_{SPI}()$	Current in MISO, MOSI, NERR, SCK		-60		60	mA
$I_{PIN}()$	Current in all other pins		-20		20	mA

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.

AC ELECTRICAL CHARACTERISTICS

T_A = 25℃, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
AFR	Air Flow Range	-25℃ < T_A < 85℃	-200		200	sccm
V_S	Supply voltage	-25℃ < T_A < 85℃	4.5	5	5.5	V
I_s	Supply current			25		mA
τ	Response Time		10			ms
R	Resolution			10		bit
Ta	Operating ambient temperature range		-25		+85	℃
A	Total accuracy	-25℃ < T_A < 85℃	-1.0		+1.0	% FSS
A_Z	Null accuracy	-25℃ < T_A < 85℃	-0.1		+0.1	% FSS

ELECTRICAL CHARACTERISTICS: SPI INTERFACE

T_A = 25℃, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
t_{CC}	CS to SCLK Setup	@ t_{CLK} 2 MHz	26		31	µs
t_{DC}	Data to SCLK Setup	@ t_{CLK} 2 MHz		620		ns
t_{CDH}	SCLK to Data Hold	@ t_{CLK} 2 MHz		280		ns
t_R, t_F	SCLK rise and fall	@ t_{CLK} 2 MHz		20		ns
t_{CH}	SCLK High Time	@ t_{CLK} 2 MHz		240		ns
t_{CL}	SCLK Low Time	@ t_{CLK} 2 MHz		240		ns
t_{CDH}	SCLK to CS Hold	@ t_{CLK} 2 MHz	44		61	µs
t_{CLK}	SCLK frequency		DC		2.0	MHz

Detailed Description

Figure 1 reports the timing diagram that must be implemented for a correct SPI communication.

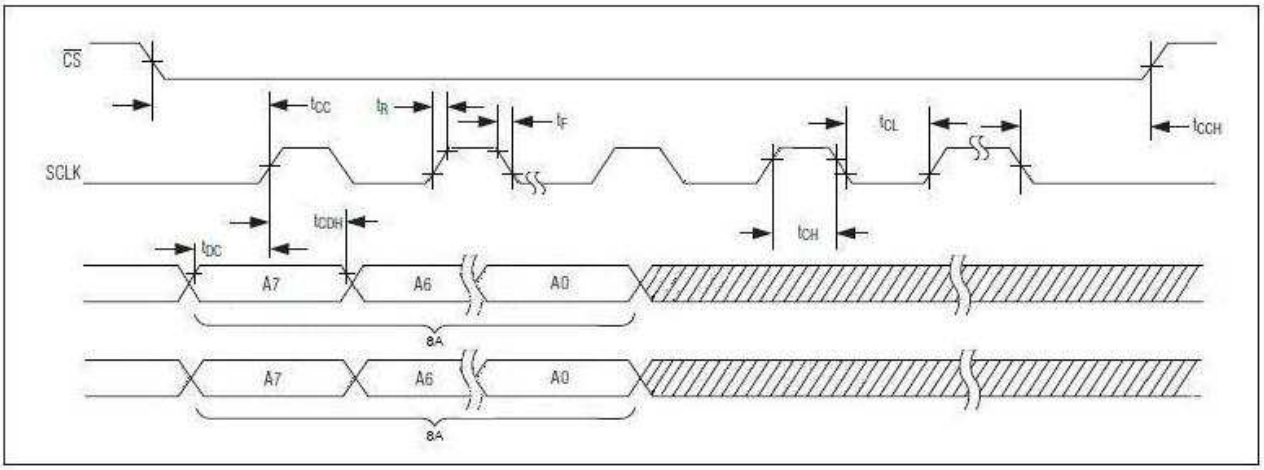


Figure 1 - Timing diagram, Reading example

Note 1: SPI mode employed is 00 (clock polarity = 0; clock phase = 0)

READ REGISTER PROCEDURE

The data reading procedure from internal registers is very simple, as the sensor (SPI slave) does not need any processing time and the registers can be read out in continuous mode. The master must transmit the **Read REGISTER** opcode (**0x8A**), the EEPROM register address and a number of 0x00 bytes equal to the data bytes that have to be read. The slave immediately outputs the opcode, the register address and the data bytes depending on the MOSI command length (see DATA1, DATA2, etc. in figure 2). The internal address counter is incremented following each data byte.
If an error occurs during register readout in continuous mode, the internal address counter is no longer incremented and the error bit FAIL is set in the communication status register.

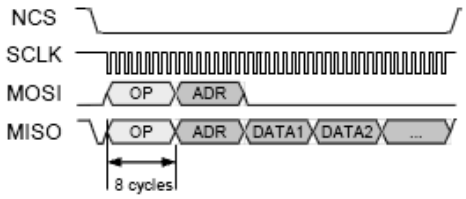


Figure 2 - Read Register

Below an example of the frame that must be transmitted on the MOSI line to get the ASIC identifier is reported (table 1):

0x8A	0x50	0x00	0x00	0x00	0x00	0x00
Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7

Table 1 – master frame request: ASIC ROM ID

This frame reads the ASIC identifier (ROM):

- the MSB (Byte 1) is the read register opcode;
- the second byte (Byte 2) indicates the first address that has to be read;
- the following bytes (Byte 3 to Byte 7) are equal to 0x00 and represent how many bytes have to be read (the example reports five registers).

The ASIC answers:

0x8A	0x50	0x48	0x4F	0x02	0x69	0x43
-	-	'H'	'O'	'Z'	'i'	'C'
Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7

Table 2 – slave answer

The frame reported above has the following meaning:

- the MSB (Byte 1) means that the operation is "read register";
- the second byte (Byte 2) indicates the first ASIC ROM address that has been read;
- the following 5 bytes (Byte 3 to 7) represent the read data (i.e. the ASIC identifier).

The parameters that can be read in the status register are:

Address	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x40	DSENS (7:0)							
0x41							DSENS(9:8)	
0x42			ERROR(5:0)					
0x43	DTEMP(7:0)							
0x44	THACT(7:0)							
0x45				THACT(12:8)				
0x46	TBACT(7:0)							
0x47						TBACT(10:8)		
0x48	OSACT(7:0)							
0x49							OSACT(9:8)	
0x4A	IHEATACT(7:0)							
0x4B					IHEATACT(11:8)			

Table 3 – EEPROM parameters

The values reported in table 3 refer to:

- DSENS: Output Sensor Data (10 bit), whose values are in the range [-512 ; +511].
- ERROR: Error Notification (6 bit)

ERROR	Addr. 0x42; bit 5:0	
Bit	Name	Meaning
0	EHEATBD	heater breakdown when high impedance is detected at heater pin.
1	EHEATSC	heater short-circuit when the PI-Controller is active. Otherwise EHEATSC is always off.
2	ESENSBD	Sensor or bulk resistor breakdown.
3	EADMAX	Sensor output above AD-MAX.
4	EADMIN	Sensor output below AD-MIN.
5	EEEPROM	EEPROM not present or invalid (CRC).

Table 4 – ERROR types

- DTEMP: Internal sensor temperature (8 bit)

DTEMP	Addr. 0x43; bit 7:0
Code	Temperature
0x00	-62°C
0x01	-61°C
...	...
0x3E	0°C
...	...
0xFF	193°C

Table 5 – Internal ASIC temperature

- THACT: Actual Heater Resistor Temperature (13 bit)

THACT(7:0) Addr. 0x44; bit 7:0 THACT(12:8) Addr. 0x45; bit 4:0	
Code	Temperature
0x0000	-62.000°C
0x0001	-61.875°C
...	...
0x1FFF	961.875°C

Table 6 – Sensor heater temperature

- TBACT: Actual Bulk Resistor Temperature (11 bit)

TBACT(7:0) Addr. 0x46; bit 7:0 TBACT(10:8) Addr. 0x47; bit 2:0	
Code	Temperature
0x000	-62.000°C
0x001	-61.875°C
...	...
0x7FF	193.875°C

Table 7 – Sensor bulk temperature

- OSACT: Actual Offset Correction Value (10 bit)

OSACT(7:0) Addr. 0x48; bit 7:0 OSACT(9:8) Addr. 0x49; bit 1:0	
0x000	|cOS|=0
0x001	|cOS|=0.0009
...	...
0x3FF	|cOS|=0.9990

Table 8 – Output data offset correction

- IHEATACT: Actual Heater Current Value (12 bit)

IHEATACT(7:0) Addr. 0x4A; bit 7:0 IHEATACT(11:8) Addr. 0x4B; bit 11:8	
Code	Temperature
0x000	0 µA
0x001	8.75 µA
...	...
0xFFF	35.83 µA

Table 9 – Airflow heater current

READ STATUS REGISTER COMMAND

All these parameters can be read together with the OP command **0x9C** that allows users to read the entire status register, instead of a specific address. In this case no register address needs to be specified.

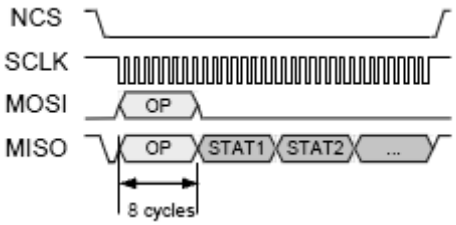


Figure 3 - Read Status Register command

Another useful function is the opcode **0xAD**, that allows an SPI STATUS check. This command can be used to request the status of the last data transmission. The SPISTATUS byte contains the following information:

SPISTATUS		
Bit	Name	Meaning
7	ERROR	Opcode not implemented
6..4	-	Reserved
3	DISMISS	Address refused
2	FAIL	Data request has failed
1	BUSY	Slave is busy with a request
0	VALID	DATA is valid
NB	Display logic: 1 = true, 0 = false	

Table 10 – SPISTATUS byte

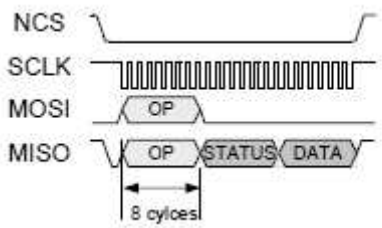


Figure 4 - REGISTER status/data

SENSOR RESPONSE

T_A = 25°C, unless otherwise noted.

The sensor outputs a digital linearized signal between -512 and +511 proportional to a flow range of [-200; +200] sccm.

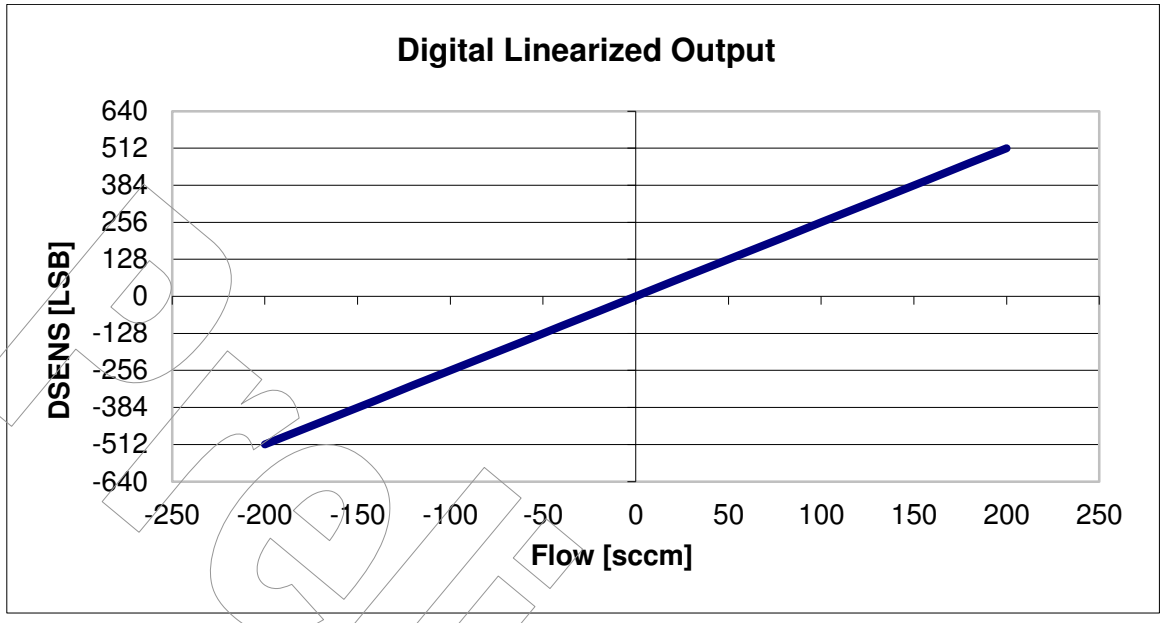


Figure 5 - Digital linearized output

OIF4 provides also an analog linearized output between pins OUTP and OUTN.

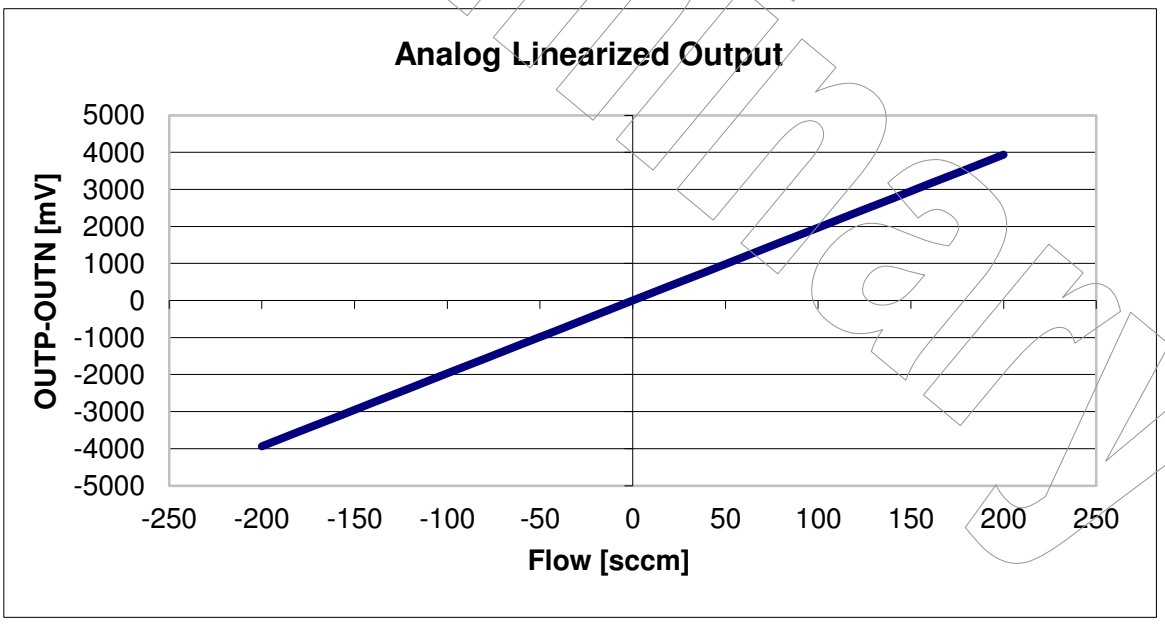


Figure 6 - Analog linearized output

Both analog and digital output are available also not linearized on specific request:

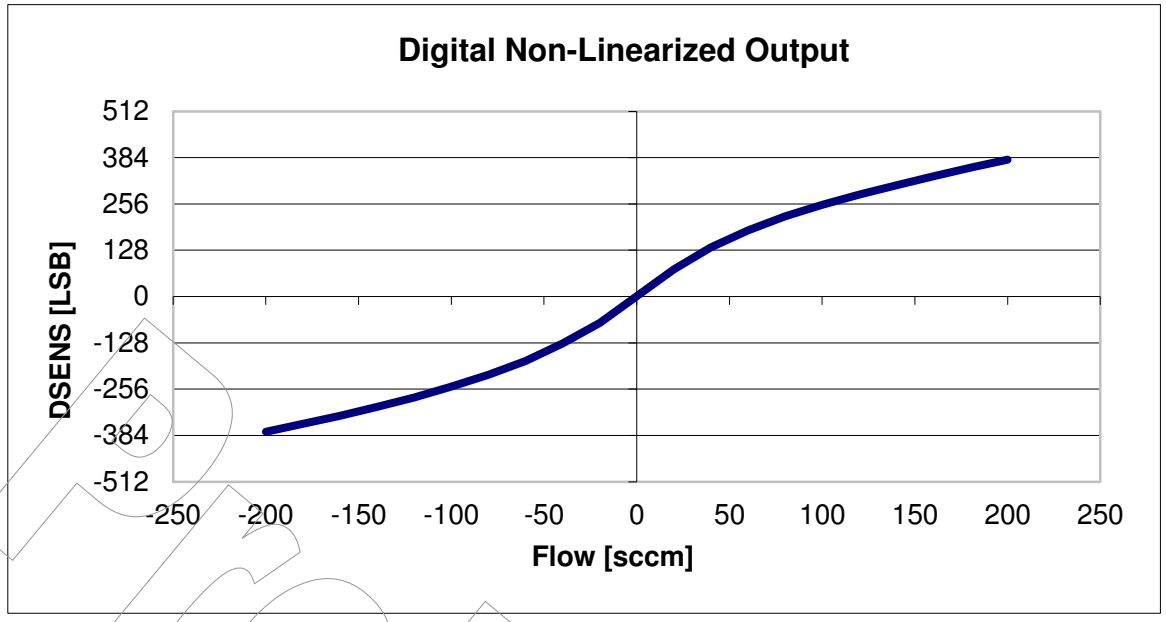


Figure 7 - Digital non-linearized output

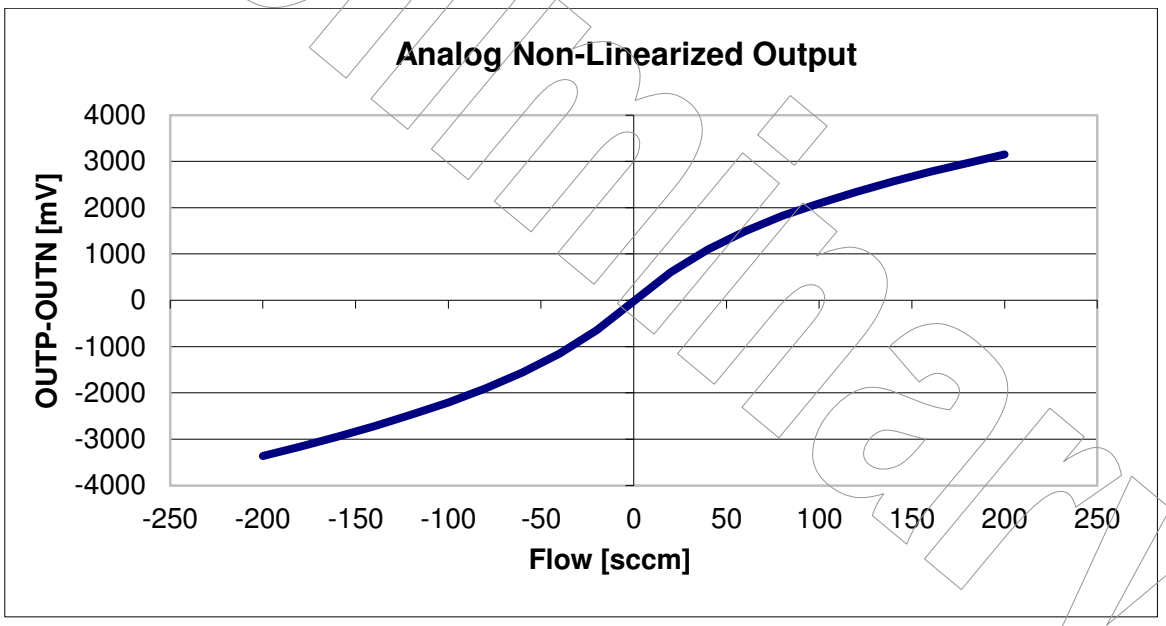


Figure 8 - Analog non-linearized output

MECHANICAL DIMENSIONS

The dimensions are expressed in mm, tolerance ±0.2mm.

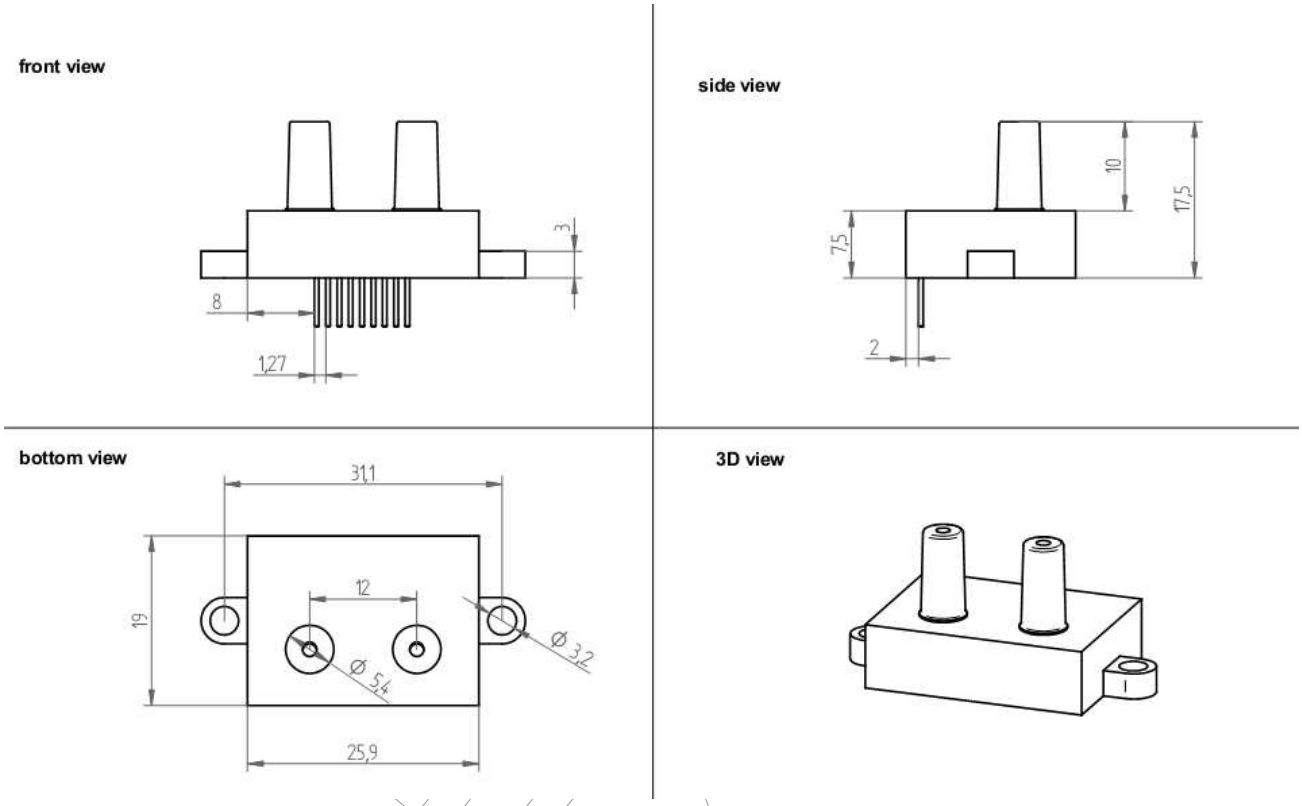


Figure 9 - Mechanical dimensions