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Sensors and Power

Model PFLOW2001 Series

MEMS Mass Flow Sensors

(VA 1.1)

$C\mkern-4mu\epsilon$

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MEMS Mass Flow Sensor

Description

The PFLOW2001 series of mass flow sensors are made with micromachined (MEMS) sensing elements that offer an innovative thermal sensing principle with excellent linearity and removal of gas sensitivity of some common gases.

This PFLOW2001 Series mass flow sensor series offer a fully customizable flow dynamic range of 100:1 with the full-scale flowrate from 30 sccm to 5000 sccm. The sensors are opted with digital and analog interface, bi-directional sensing capability with an operational temperature range of -25 to 85 °C (-13 to 185 °F).

Features

- Wide supply voltage 8 … 15V and 2.7 … 5.5V for low power version
- Linear output 1…5V, low power version 0.2 … 2V
- Digital I2C bus output
- Fast response time (2ms typ.)
- 3-pin version with analog output for retrofit and as a replacement for older designs
- RoHS and REACH compliant

Experts on Design-In

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Contents

Revision History

Rev. No.	Change	Date	Author
1.0	Initial revision	10.04.2022	OSWO
1.1	Update of the I2C communication	20.06.2022	OSWO

References

Ref. No.	Document	Date	Author
1	PFLOW2001 I2C Application Note	10.06.2022	APSP
2	Step model of the sensor		APSP

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SPECIFICATIONS

Absolute maximum ratings [1]

Item	Condition	Rating			Unit
		Min.	Typ.	Max.	
Supply voltage, VDDmax		8		15	VDC
	Low voltage version	2.7		5.5	
I2C bus voltage, VDDIOmax	Normal and low voltage version	3.0		5.5	VDC
I2C frequency, f_{I2Cmax}		10		400	kHz
Maximum common mode pressure, Pmax				50 (3.5)	psi (bar)
Maximum overflow, Qmax	of full scale flowrate			10 x	sccm [2]
Maximum flowrate change	of full scale flowrate			2.5 x	sccm/sec
Operating temperature range, Top		-25		85	°C
Storage temperature, Tstg		-40		90	°C
Humidity, RHa	no condensation	0		100	%RH
Mechanical shock	MIL-STD-883			100	g

Notes:
1. Absolute Maximum Ratings indicate limits beyond which damage to the device may occur.
2. sccm denotes standard cubic centimeters per minute.
   Standard conditions: 20°C, 101.325kPa, dry and clean air

Performance characteristics

(Test conditions: V_{DD} = 8-15VDC, Ta = 20°C, RHa = 30…70%, unless otherwise stated)

Parameter	Value	Unit
Flow range, full scale	30, 50, 100, 200, 500, 1000, 2000, 3000, 4000, 5000 [1]	sccm
Dynamic range	100:1	n.a.
Accuracy [2]	± (1.5%RD + 0.15%FS)	%
Temperature error coefficient [3]	0.03	%RD/°C
Compensated temperature range	0 – 60	°C
Gas compatibility	Non-corrosive/non-explosive	n.a.
Compliance	RoHS, REACH, CE: IEC 6100-4-2;4;8	n.a.
Wetted materials	Polycarbonate, silicon nitride, FR4 and epoxy	n.a.

Notes:
1. Because of the channel size, for the 5000 sccm version there can be expected effects of installation related errors, or the flow conditioning is not as good as the other flow ranges.
2. Accuracy is the combined error from offset and span calibration, linearity, hysteresis, and repeatability over the entire calibrated flow range. For bi-directional sensors accuracy is defined for total absolute range, i.e. ±200 sccm sensor has absolute range of 400sccm.
3. For compensated temperature range.

Electrical Characteristics

(Test conditions: V_{DD} = 8-15VDC, Ta = 20°C, RHa = 30…70%, unless otherwise stated)

Item	Condition	Rating			Unit
		Min.	Typ.	Max.	
Supply voltage, V_{DD}		8		15	VDC
	Low voltage version	2.7		5.5	
Supply current		10	15	50	mA
	Low voltage version	5	7	10	
Warmup time [1]			500		msec
Response time, t_{90} [2]	Digital and analog output		2.0		msec
Minimum output load	analog & digital output		5		kΩ
Analog output (rated), Vout [3]		1		5	VDC
	Low voltage version	0.2		2	VDC
Analog null voltage - unidirectional		0.98	1.0	1.02	VDC
	Low voltage version	0.18		0.22	VDC
Analog null voltage - bidirectional		2.98	3.0	3.02	VDC
	Low voltage version	1.08	1.1	1.12	VDC
Analog null drift			0.05		%FSS/ year [4]
Analog maximum output [5]	1.2x of FSS		5.8		VDC
	Low voltage version		2.36		VDC
Digital maximum output [5]	I2C		1.2		FS
I2C bus voltage [6]	Normal and low voltage version	3.0		5.5	VDC
I2C frequency		10		400	kHz
Resolution digital output			15		bit
Digital null offset [7]			0		%FSS
Digital null drift [8]				0.05	%FSS/year

Notes**:**
1. Warm-up time is the time from power on to the first stable reading. It is recommended to warm up the sensor for up to 2 seconds before acquiring the data.
2. The time required for the response of the flow sensor to mass flow change from 10% to 90% of its final value. May be affected by the pneumatic interface.
3. Output is not ratio metric (internal voltage regulator provides stable sensor supply).
4. Full Scale Span (FSS) is the algebraic difference between the output signal for the highest and lowest specified flow.
5. Refer to Typical Output chapter for details.
6. Maximum I2C bus supply voltage is 5.5VDC. Provide separated supply for the sensor and I2C-bus, especially for normal sensor versions, which are rated 8-15V. Connecting bus supply to the sensor supply over 5.5VDC will damage the sensor.
7. Digital offset is zeroed during factory calibration process
8. The offset caused by null drift can be digitally zeroed using I2C command (see chapter: Digital I^2C Communication)

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Pressure drop characteristics

| Part no.	Flow Range	Pressure drop
PFLOW2001-30U PFLOW2001-30B	0…30 -30…30	<10 Pascal @ 30sccm
PFLOW2001-50U PFLOW2001-50B	0…50 -50…50	<20 Pascal @ 50sccm
PFLOW2001-100U PFLOW2001-100B	0…100 -100…100	<20 Pascal @ 100sccm
PFLOW2001-200U PFLOW2001-200B	0…200 -200…200	<30 Pascal @ 200sccm
PFLOW2001-500U PFLOW2001-500B	0…500 -500…500	40±10 Pascal @ 500sccm
PFLOW2001-1000U PFLOW2001-1000B	0…1000 -1000…1000	70±10 Pascal @ 1000sccm
PFLOW2001-2000U PFLOW2001-2000B	0…2000 -2000…2000	160±10 Pascal @ 2000sccm
PFLOW2001-3000U PFLOW2001-3000B	0…3000 -3000…3000	100±10 Pascal @ 3000sccm
PFLOW2001-4000U PFLOW2001-4000B	0…4000 -4000…4000	150±10 Pascal @ 4000sccm
PFLOW2001-5000U PFLOW2001-5000B	0…5000 -5000…5000	200±10 Pascal @ 5000sccm

MECHANICAL DIMENSIONS
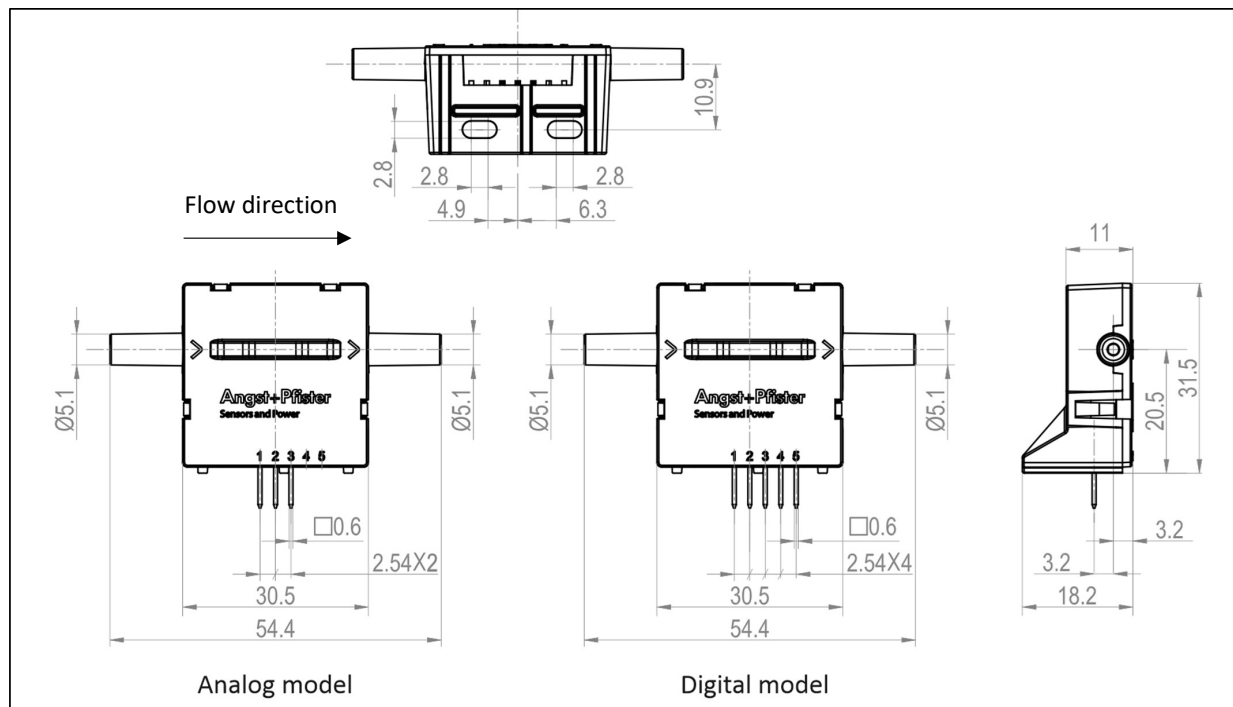
Figure 1 PFLOW2001. All units are in mm

Flow direction from left to right for uni-directional sensors.
Please refer to the step model of the sensor for details.

ELECTRICAL INTERFACE

Digital and analog version pinout

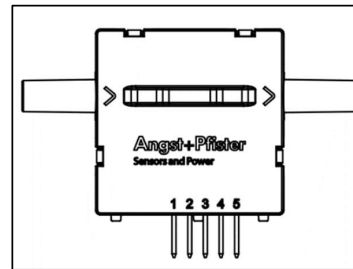| Pin#	Definition	Notes
1	Vout	Analog voltage output
2	V_{DD}	Supply
3	Vss	GND
4	SDA	I²C data
5	SCL	I²C clock

Figure 2 Digital and analog version (VI2C) pin assignment

Analog only version pinout

The only analog 3-pin version is as a replacement for

retrofit and older designs, where only analog output is required.

Pin#	Definition	Notes
1	Vout	Analog voltage output
2	V_{DD}	Supply
3	Vss	GND
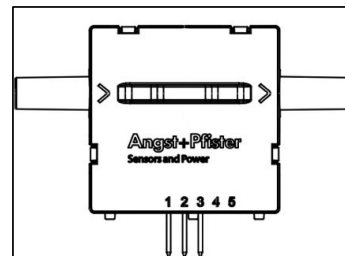
Figure 3 Analog only 3-pin version

GAS CORRECTION FACTORS

Gas type	Correction factor
Air	1.0
Oxygen (O2)	1.0
Nitrogen (N2)	1.0
Argon (Ar)	1.0
Hydrogen (H2)	*
Carbon dioxide (CO2)	0.545

*For Hydrogen applications please contact the manufacturer. The custom factory calibration with H2 needs to be performed, to provide specified measurement accuracy.

To obtain the real flow rates in a specific gas, multiply the readings from the sensor by the gas correction factor in the table. The factors are approximate and should be used as guidelines only. Sensor performance strongly depends on gas dynamics and must be evaluated in the respective application.

TYPICAL ANALOG OUTPUT

Table 1: PFLOW2001-U, typical analog output.

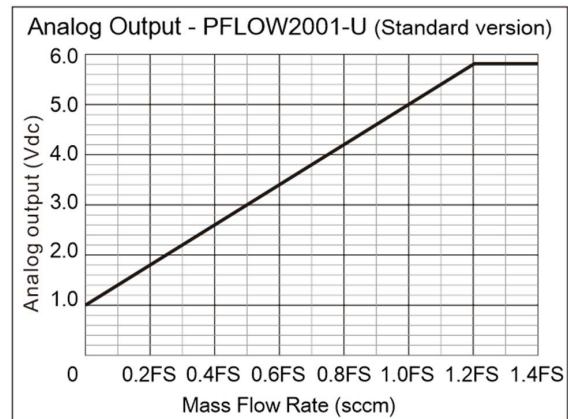| Flow Rate (sccm)	Typical Analog Output (Vdc)
0	1.0
0.2FS	1.8
0.4FS	2.6
0.6FS	3.4
0.8FS	4.2
1.0FS	5.0
1.2FS	5.8
1.4FS	5.8

Figure 1: typical analog output curve of PFLOW2001-U.

Table 2: PFLOW2001-B, typical analog output.

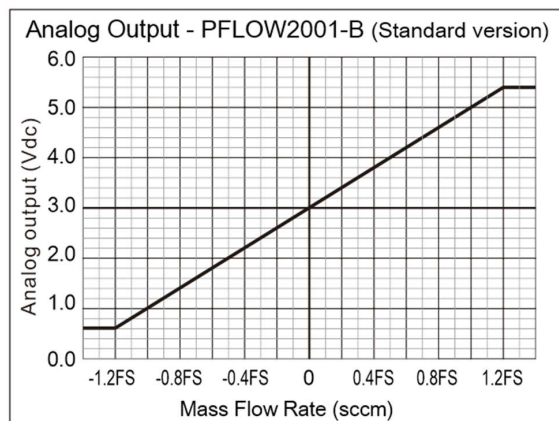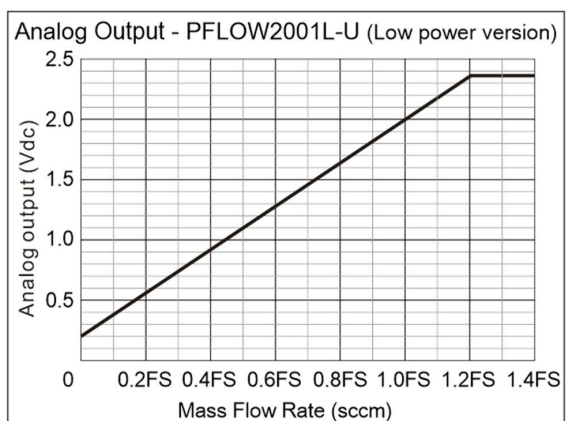| Flow Rate (sccm)	Typical Analog Output (Vdc)
-1.4FS	0.6
-1.2FS	0.6
-1.0FS	1.0
-0.8FS	1.4
-0.4FS	2.2
0	3.0
0.4FS	3.8
0.8FS	4.4
1.0FS	5.0
1.2FS	5.4
1.4FS	5.4

Figure 2: typical analog output curve of PFLOW2001-B.

Table 3: PFLOW2001L-U, typical analog output.

Flow Rate (sccm)	Typical Analog Output (Vdc)
0	0.20
0.2FS	0.56
0.4FS	0.92
0.6FS	1.28
0.8FS	1.64
1.0FS	2.00
1.2FS	2.36
1.4FS	2.36

Figure 3: typical analog output curve of PFLOW2001L-U.

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Table 4: PFLOW2001L-B, typical analog output.

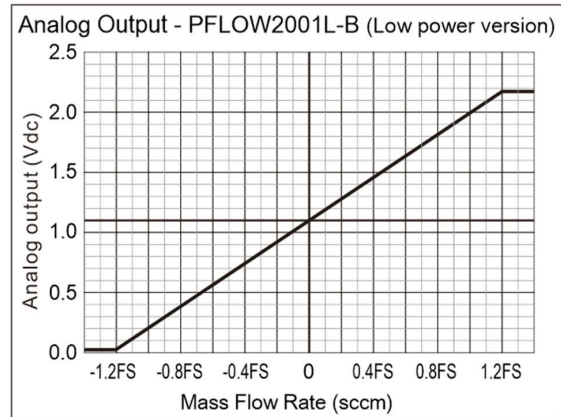| Flow Rate (sccm)	Typical Analog Output (Vdc)
-1.4FS	0.02
-1.2FS	0.02
-1.0FS	0.20
-0.8FS	0.38
-0.4FS	0.74
0	1.10
0.4FS	1.46
0.8FS	1.82
1.0FS	2.00
1.2FS	2.18
1.4FS	2.18

Figure 4: typical analog output curve of PFLOW2001L-B.

TYPICAL DIGITAL OUTPUT

Table 5: PFLOW2001(L)-U, typical digital output.

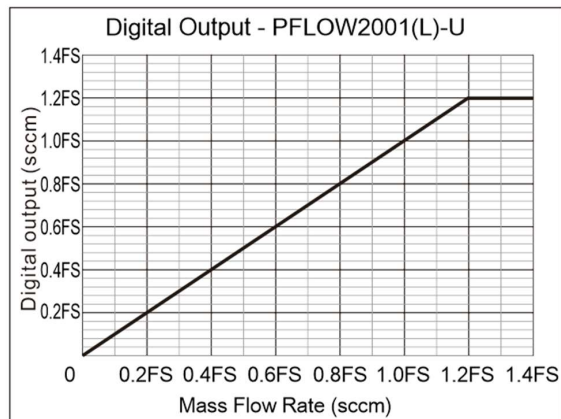| Flow Rate (sccm)	Typical Digital Output (sccm)
0	0
0.2FS	0.2FS
0.4FS	0.4FS
0.6FS	0.6FS
0.8FS	0.8FS
1.0FS	1.0FS
1.2FS	1.2FS
1.4FS	1.2FS

Figure 5: typical digital output curve of PFLOW2001(L)-U.

Table 6: PFLOW2001(L)-B, typical digital output.

Flow Rate (sccm)	Typical Digital Output (sccm)
-1.4FS	-1.2FS
-1.2FS	-1.2FS
-1.0FS	-1.0FS
-0.8FS	-0.8FS
-0.4FS	-0.4FS
0	0
0.4FS	0.4FS
0.8FS	0.8FS
1.0FS	1.0FS
1.2FS	1.2FS
1.4FS	1.2FS
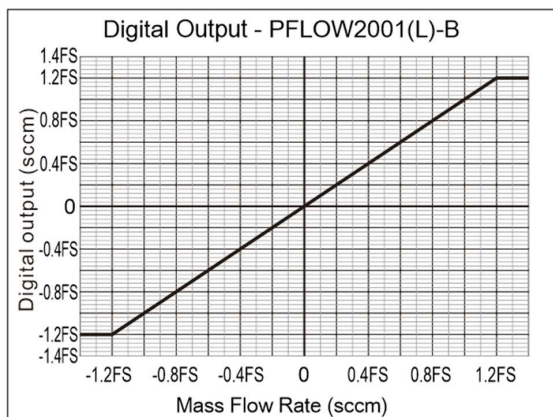
Figure 6: typical digital output curve of PFLOW2001(L)-B.

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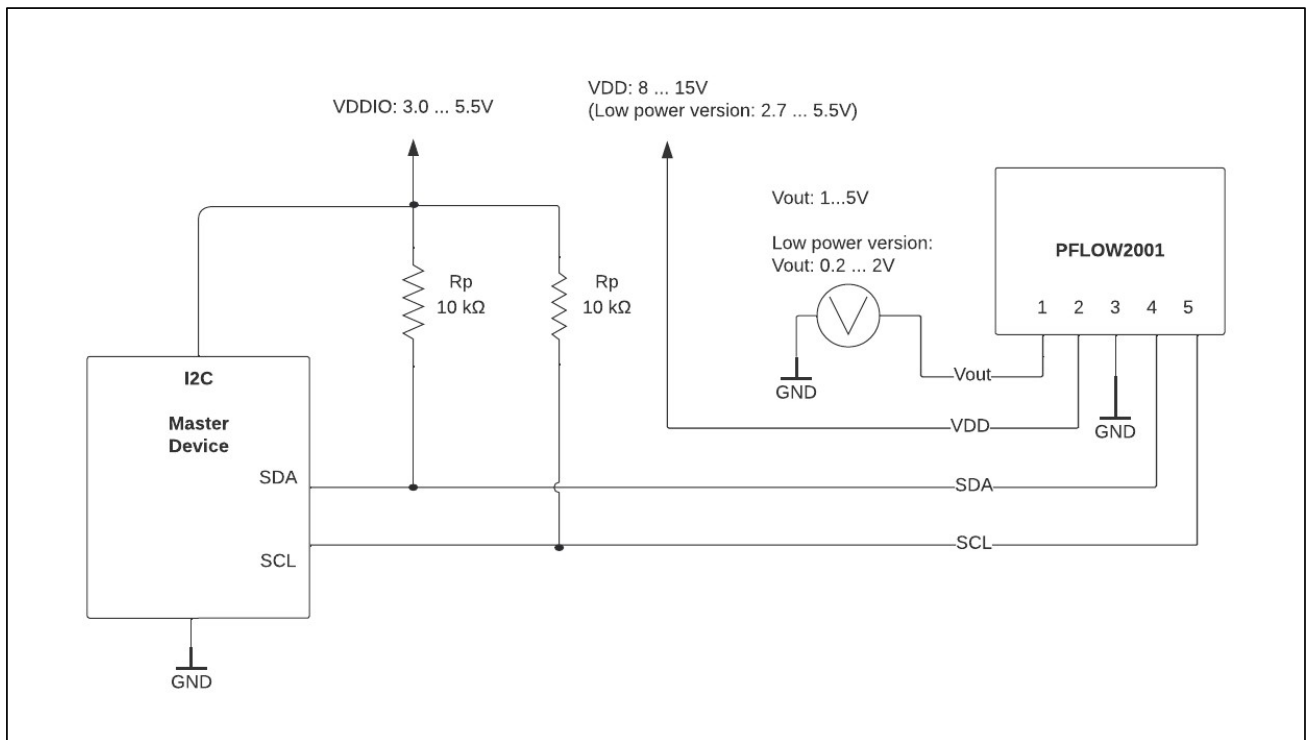
PFLOW2001 connection diagram

Figure 7. Analog and I2C interface connection diagram

When not using the analog output, the pin 1 shall be left unconnected (floating). Shortening Pin 1 to GND will cause malfunction of the sensor.

When not using the digital I2C output, the pin 4 and pin 5 shall be left unconnected (floating). Shortening Pin 4 and/ or 5 to GND will cause malfunction of the sensor.

Only for low power version of the sensor the VDD and VDDIO can be connected together.

DIGITAL I2C COMMUNICATION

I2C interface command description

The default I2C address of the sensor is 0x50.

Command Name	Command (2 Bytes)	Read/Write	Width (Byte)	Notes
Change I^{2}C address	0x00A4	Write	2	Write the new address in 8-bit format It will be transformed to 7-bit (shifted right) i.e.: 0x0A (8-bit) -> 0x05 (7-bit) Send new address in 2 Bytes + CRC i.e.: new I2C address is 0x05 (7-bit), then send 3 Bytes: 0x00, 0x0A, 0x36 Please refer to Application note for details and code sample
Flowrate offset reset	0x00F0	Write	2	Write to the sensor 2-bytes of any fixed value (will be ignored). Ensure no-flow conditions
Serial number	0x0030	Read	18	HEX, ASCII code 18-Bytes in sequence: 2-Bytes Data, 1 Byte CRC, 2-Bytes data, 1-Byte CRC,… Convert to ASCII to get serial number Serial number is always predeceased and followed by two stars "* *" (2A 2A in ASCII)
Flow rate	0x003A	Read	6	HEX, 6 Bytes in sequence: 2-Bytes Data, 1 Byte CRC, 2-Bytes data, 1-Byte CRC Measured value [sccm] = = Data (4-Byte, DEC) / 1000 **e.g.** If data = 0x0012D687, the flow rate will be 1234567 (DEC) / 1000 = 1234.567 sccm

Notes:

1. Recommended I2C pull-up resistors values 10kΩ

2. All commands are 2-Bytes long.

3. The highest significant byte is transmitted first; the lowest significant byte is transmitted last by the sensor.

4. When reading from the sensor, after the transmission from master to slave is finished, the bus shall be kept active, by sending only a restart condition.
   Sending a stop bit and releasing the bus will cause a communication error for the next communication and invalid response from the sensor (see Fig. 4 for details).
   Please be aware that the most I2C communication libraries for common master drivers, per default send the stop bit after the communication, which is incorrect for the sensor.

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5. All the data from the sensor are transmitted in following sequence: 2-Bytes Data, 1 Byte CRC, 2-Bytes data, 1-Byte CRC.
    i.e: Serial number:
    <u>2A 2A</u> FA <u>42 31</u> E6 <u>52 33</u> BF <u>31 33</u> 75 <u>34 33</u> 34 <u>2A 2A</u> FA
    ➜ without CRC: 2A 2A 42 31 52 33 31 33 34 33 2A 2A
    ➜ in ASCII: **B1R31343**

6. All data written to the sensor shall be in 2-Byte format followed by 1 Byte CRC.
    i.e.: reset flow rate offset:
    Send to the sensor the command to reset offset: 0x00, 0xF0
    Write to the sensor any 2-Byte fixed value i.e. 0xAA, 0x55
    Follow it by CRC-8: 0x36

7. Refer to the PFLOW 2001 I2C Application Note for details [1]

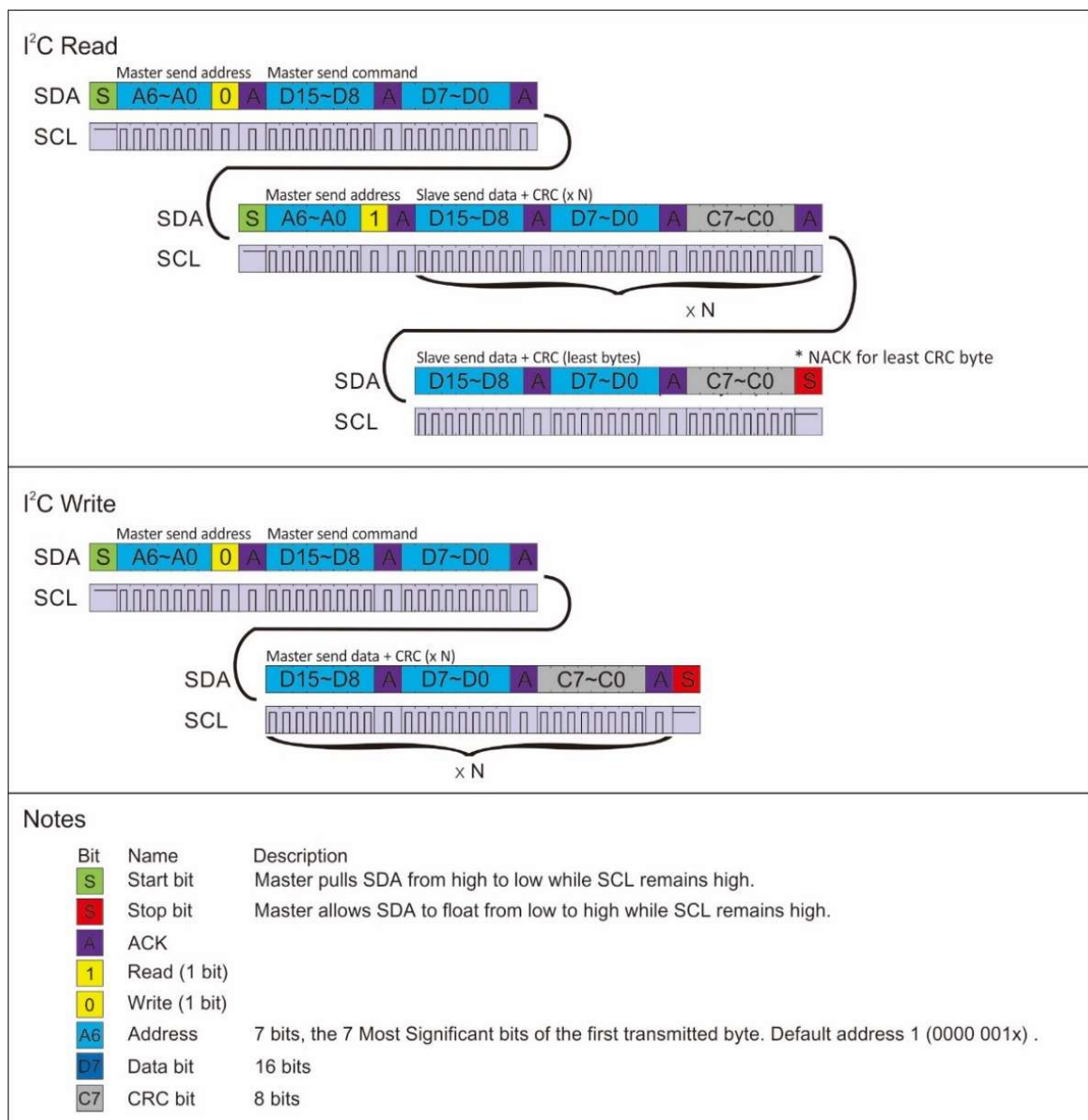## I2C interface read/write sequences

Figure 8 I2C interface read/ write sequence. Please no stop bit after master command
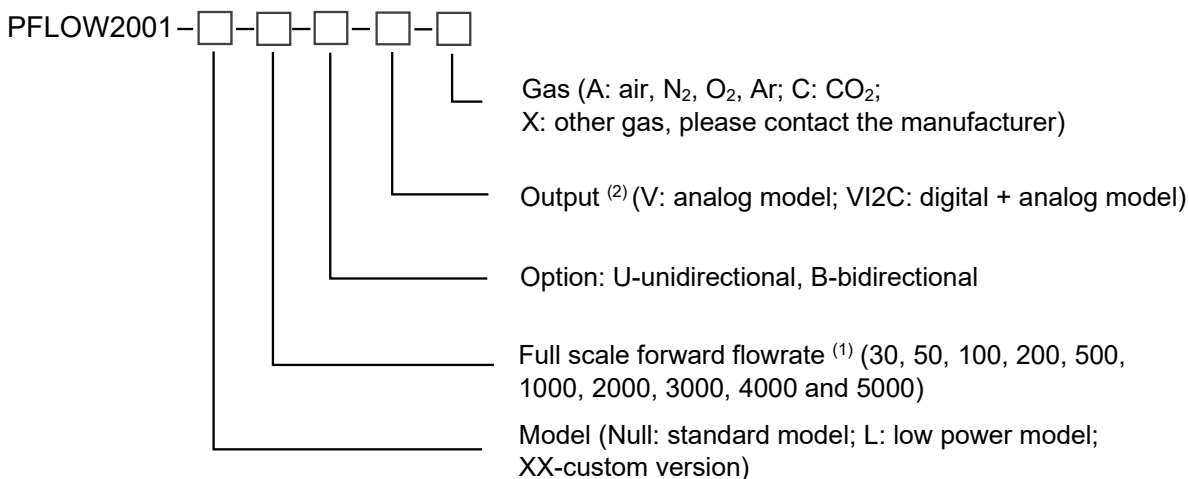
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CRC checksum calculation

The 8-bit CRC checksum transmitted after each two data bytes (int 16) is generated by a CRC algorithm. Its properties are listed in the following table. To calculate the checksum, only these two previously transmitted data bytes are used.

Property	Value
Name	CRC-8
Protected data	I^2C read and write
Width	8 bits
Polynomial	0x07 ($x8 + x2 + x + 1$)
Initialization	0x00
Reflect input	False
Reflect output	False
Final XOR	0x00
Example	CRC (0x4E20) = 0x6D

ORDERING INFORMATION

The product part number is composed of the product model number and suffix indicating the full-scale flow rate, mechanical connection, output format as well as the applicable gas. Refer to the following for the product order:

PFLOW2001 – ☐ – ☐ – ☐ – ☐ – ☐

Gas (A: air, N_2, O_2, Ar; C: CO_2;
X: other gas, please contact the manufacturer)

Output [2] (V: analog model; VI2C: digital + analog model)

Option: U-unidirectional, B-bidirectional

Full scale forward flowrate [1] (30, 50, 100, 200, 500, 1000, 2000, 3000, 4000 and 5000)

Model (Null: standard model; L: low power model; XX-custom version)

Note:
1. Full scale flowrate default unit is sccm. For bidirectional model i.e. 100-B means ±100 sccm
2. VI2C model consist of both outputs digital and analog. The analog only model is to be used as a replacement for retrofit and older designs, where the only 3-pin, analog sensor is required.

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We are here for you. Addresses and Contacts.

Headquarter Switzerland:

Angst+Pfister Sensors and Power AG

Thurgauerstrasse 66
CH-8050 Zurich

Phone +41 44 877 35 00
sensorsandpower@angst-pfister.com

Office Germany:

Angst+Pfister Sensors and Power Deutschland GmbH

Edisonstraße 16
D-85716 Unterschleißheim

Phone +49 89 374 288 87 00
sensorsandpower.de@angst-pfister.com

Scan here and get an overview of personal contacts!

sensorsandpower.angst-pfister.com