OEM Mass Flow Controller VA.2

Model PFLOWC5001

Attention!

- Please carefully read this manual prior to operating this product.
- Do not open or modify any hardware which may lead to irrecoverable damage.
- Do not use this product if you suspect any malfunctions or defection.
- Do not use this product for corrosive media or in a strong vibration environment.
- Use this product according to the specified parameters.
- Only the trained or qualified personnel shall be allowed to perform product services.

Use with caution!

- Be cautious for electrical safety, and even it operates at a low voltage, any electrical shock might lead to some unexpected damages.
- The gas to be measured should be clean and free of particles, as particles may be accumulated inside the flow channel that may result in inaccuracy in metrology, clogging, or other irrecoverable damage.
- Do not apply for any unknown or non-specified gases that may damage the product.

Table of Contents

1. Overview

This manual provides essential information for the operation of the PFLOWC5001 series (OEM version) of gas mass flow controllers for general-purpose gas flow monitor and control applications. The products have a full-scale mass flow rate from 0.05 to 20 SLPM (higher flow models are available by request) and both analog and digital interfaces. The product performance, maintenance, troubleshooting, information for product orders, technical support, and repair are also included.

PFLOWC5001 products provide the standard or manifold configuration for the mechanical connections. Optionally it can also be offered with a manifold body with customized piping. It can be applied to instrumentation, medical and other applications. The series covers a wide dynamic flow range with a working pressure rating of up to 1.0 MPa (10 bar or 150 PSI) and a compensated temperature ranging from -5 to 50°C.

The sensing elements are manufactured with MEMS (micro-electro-mechanical systems) thermal mass flow sensing technologies that measure the flow medium's calorimetry and diffusivity. The sensor surface is passivated with silicon nitride ceramic materials and water/oilproof nanomaterials coating for performance and reliability. Compared to the conventional calorimetric flow sensing technology, this unique sensing approach offers better linearity, removes gas sensitivity for gases with similar thermal diffusivities, and improves temperature performance. It can also auto-recognize pre-programmed gases with significant differences in thermal diffusivity. It is the first in the industry that senses the mass flow with multiple gases without a manual gas conversion factor. As such, it facilitates and simplifies customer applications while ensuring high precision for gas measurements with cost-effective air calibration.

2. Receipt / unpack of the products

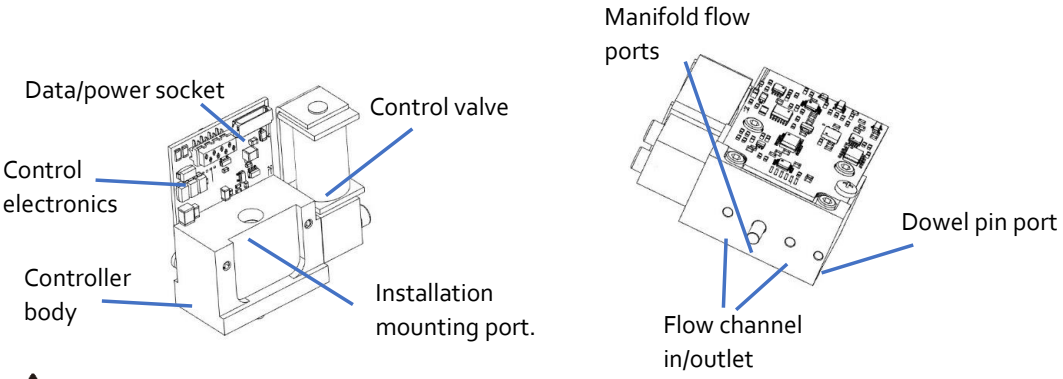
Upon receipt of the products, please check the packing box before dismantling the packing materials. Ensure no damages during shipping. If any abnormality is observed, please contact and notify the carrier who shipped the product and inform the distributors or sales representatives if the order is not placed directly with the manufacturer; otherwise, the manufacturer should be informed. Please refer to the return and repair section in this manual for any further actions.

If the packing box is intact, proceed to open the packing box, and you shall find the product (either the sensor formality per the actual order), together with the power and data cable if the order is included.

Please immediately check the integrity of the product and the power and data cable; if any abnormality is identified, please notify the distributor/sales representative or manufacturer as soon as possible. If any defects are confirmed, an exchange shall be arranged immediately via the original sales channel. This user manual shall also be included in the packing box or via an online link for an electronic version your sales agent should send. In most cases, this manual shall be made available to the customer before the actual order.

3. Knowing the products

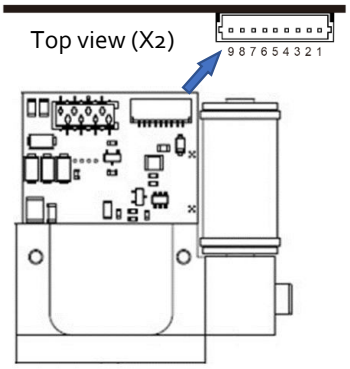
3.1 Product description



Note: The manifold base port size should not be smaller than those of the flow ports on the product.

Figure 3.1: PFLOW5001C parts description

3.2 Power and data pinout description



Pin	Definition
1	Power, 8~24Vdc
2	Power common /ground
3	RS232 TTL/EIA, RXD; RS485 A(+)
4	RS232 TTL/EIA, TxD; RS485 A(-)
5	Analog ground
6	TTL: PID 0...5Vdc; EIA/RS485: flow 0...5Vdc
7	TTL: flow 0...5Vdc; EIA/RS485: set point 0...5Vdc
8	TTL: set point 0...5Vdc; EIA/RS485: valve override
9	TTL: valve override

The electrical interface is a JST-SM09B-SRSS-TB connector (9 pole) for RS232 TTL digital + analog interface; while for RS232 EIA or RS485 + analog interface the connector is Micromatch 8 pole.

DO NOT connect or disconnect the cable when the external power is on!! It may damage the electronic chipsets of the product!

Note: 1. Power supply: The PFLOW5001C requires a power supply of 8 ~ 24 Vdc (max 26 Vdc). No particular requirements for the external power supply, but standard industrial power cautions should be applied.

2. The analog outputs 0 ~ 5 Vdc correspond to the specified full-scale flow range at the time of order. If the analog option is not selected, this pin output could be NULL.

3.3 Mechanical dimensions

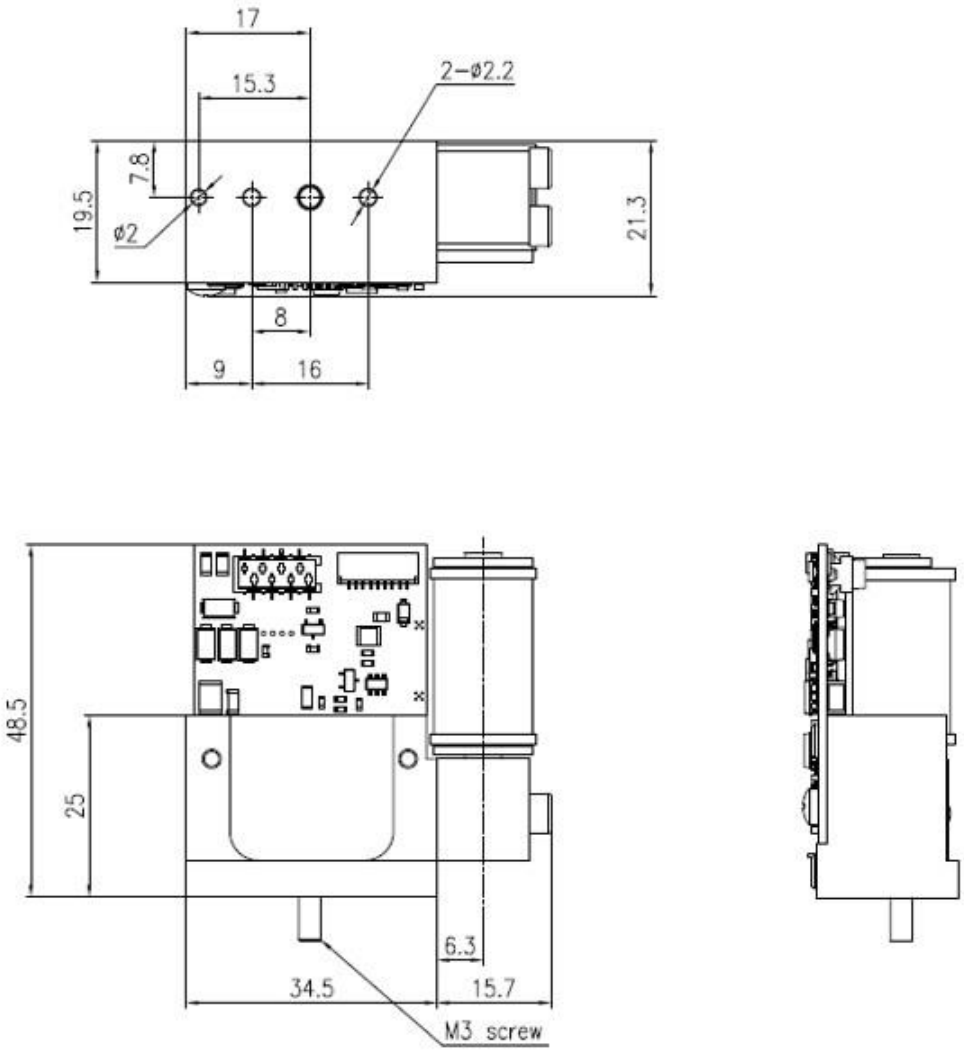


Figure 3.2: PFLOWC5001 manifold mechanical dimensions.

4. Installation

Do not open or alter any part of the product, which would lead to malfunction and irrecoverable damage. Please pay special attention to ESD and other electrical device handling precautions since this unit is an OEM version without external protection of the PCB etc. The system design should consider electromagnetic compatibility and related standards. Do not install this device for processes involving personal injury or other unsafe applications.

Ensure the connections leakage proof and all electrical precautions are applied for the installation. Please make sure the electrical cable is engaged correctly. It should be noted that the performance of a flow meter or controller will depend on system flow stability, although a flow conditioner is installed in the product. The system design would be necessary for flow stability and related flow noises.

To prevent over-forced installation, the mounding torque applied should be within 0.35±0.03 N·m. Sealing O-ring is recommended to be the ones that comply with ISO 3601/1; the mounting screw is specified for M3x20mm by ISO 14583; the dowel pin dimension is specified in the mechanical dimension section.

Please properly align the products with your gas manifold block, and no excessive force should be applied during installation. If the product is not calibrated for bi-directional operation, please follow the flow direction arrow and ensure the flow direction is correct.

5. Basic operation

5.1 RS232 communication protocol

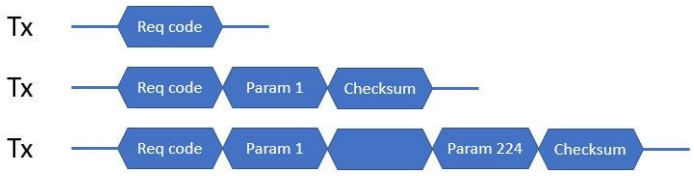
5.1.1 Serial port settings

	RTU
Baud rate (Bits per second)	57600 bps
Data bits	8
Stop bits	1
Parity	Odd
Flow control	No handshake
Level	TTL / EIA 232

Note: The maximum data writing rate is 100 Bytes/sec. Do not write when the device is active.

5.1.2 Command format

A one-character code is required at the beginning of any request. If the request is more than one byte, a checksum that sums all the preceding bytes values, truncated to the last 8 bits of the results, must be added at the end of the request.



5.1.3 Response format

The response must repeat the requested code, followed by data, ending with a checksum. The STOP request has no response.

5.1.4 Command to read/write variables

Please note: Channels 1 and 2 are reserved and not available. All read/write variables coded with 1 byte are MSB first. Continuous writing to persistent variables is not recommended, as it may impact the memory's lifetime.

Hex	Command	Parameter	Access	Note
0x61	Read_VAR_INT16	Variable ID		
0x62	Write_VAR_INT16	Variable ID+ Value of 2 bytes (higher first)		
0x63	Read_VAR_CHAR	Variable ID		
0x64	Write_VAR_CHAR	Variable ID+ Value of 1 byte (higher first)		

5.1.5 Read flow rate

Hex	Command	Parameter	Access	Note
0x31	Send_ONE_DATA	None	R/W	Single request, 1 flow value
0x32	Send_N_DATA	Nx 1byte	R/W	N flow value
0x33	Send_CONTINOUS	None, terminate with stop		Flow values (each 3.5 msec)
0x34	STOP	None	R/W	No response

The digital flow measure range (forward only) is (0...10000) = (0x0000...0x2710) = (0...100 %) F.S.

The maximum reading value is 11000 = 0x2AF8 = 110 % F.S.

Real_flow = digital_flow / 10000 * max_flow

Example:

Data direction	Hex data	Flow	Remark
Rx	31 32 02 34 33 34	Depends on the flow	Select desired input for set point, oHex = digital input, 1Hex= analog input
Tx	31 XX XX YY 32 HH LL YY 32 HH LL YY 33 XX XX YY None	Depends on the flow	YY = Checksum. Translate the Hex value in the Dec value and apply the decoding formula to get the actual flow measure 0x33 returns measured flow continuously each 3.5 ms STOP the continuous reading

5.1.6 Read serial number

Hex	Command	Parameter	Access	Note
0x68	Read_Serial_Number	None	R	Serial number

5.1.7 Select input mode

Hex	Command	Data type	Access	Note
0x1F	Select input mode	UINT8	R/W	Select input mode for set point, 0 = digital input, 1= analog input

Example 1: Check the input mode

Data direction	Hex data	Flow	Remark
Rx	63 1F 82	-	request – variable ID – checksum
Tx	63	-	The device sends back the request

Example 2: Change the input mode

Data direction	Hex data	Flow	Remark
Rx	64 1F 00 83 64 1F 01 84	Last value independent of the previous mode Set point according to analog value present at the input pin	Set the digital input mode Set the analog input mode
Tx	64 64	The device sends back the request	Tx

5.1.8 Setpoint

Hex	Command	Parameter	Access	Note
0x14	CtrlNominal	None	R/W	Set point mass flow

The digital set point range is (0...65535) = (0x0000...0xFFFF) = (0%...100%) F.S.

Example:

Data direction	Hex data	Flow	Remark
Rx	62 14 00 00 76 62 14 02 90 08 62 14 80 00 F6 62 14 FF FF 74	0 % F.S. 1 % F.S. 50 % F.S. 100 % F.S.	Zero flow Cut off limit value if present (on request) Flow set at 50 % of the F.S. Flow set at 100 % of the F.S.
Tx	62	The device sends back the request	The device sends back the request

Example with a 250 sccm F.S. device and a set point of 110 sccm:

set point = 110 [sccm] / 250 [sccm] * 65535 = 28835 = 0x70A3

5.1.9 Exhaust value

Hex	Command	Data type	Access	Note
0x1E	Exhaust value	UINT16	R/W	Exhaust value for open-loop control

Exhaust value is type uint16, the two bytes full range are (0…65535)= (0x0000…0xFFFF)

A value range between (0…4,095) allows direct control of the valve position from 0 corresponding to a closed valve to 4,095 corresponding to a fully open valve. Any value in between corresponds to a valve position, the resulting flow will be a nonlinear function of this value and a consistent offset is necessary to obtain a flow.

Setting the value to 32,768 (0x8000) enables PID control using either a digital or analog setpoint according to the selected mode.

Other values are not used.

5.1.10 Offset calibration

Hex	Command	Data type	Access	Note
0x03	Offset_zero	UINT8	R/W	Read: 0 – completed; 3 – error. Write 0 – none; 2 – reset.

5.1.11 P Gain and D Gain

Hex	Command	Data type	Access	Note
0x17	P Gain	UINT16	R/W	Available valve: 0 ~ 9999. The default value is 15.
0x19	D Gain	UINT16	R/W	Available valve: 0 ~ 9999. The default value is 25.

5.1.12 Firmware version

Hex	Command	Data type	Access	Note
0x01	Firmware version	UINT16	R	2 bytes (e.g. 3012 = 30.12)

5.1.13 Filter depth

Hex	Command	Parameter	Access	Note
0X07	Filter depth	UINT8	R/W	0 ~ 9, corresponding to 2^0 ~ 2^9 data in the software filter. The default value is 3, corresponding to $2^3 = 8$ data in the software filter

5.2 RS485 Modbus communication protocol

The digital communication protocol is based on standard Modbus RTU Half-plex mode. A master (PC or PLC) can communicate with multiple slaves (the current product) for data exchange and communication parameter configuration. Refer to Table 3.2 for the cable connection.

5.2.1 Hardware connection

The RS485 hardware layer is TIA/EIA-485-A, as illustrated below. In this configuration, the product is a slave.

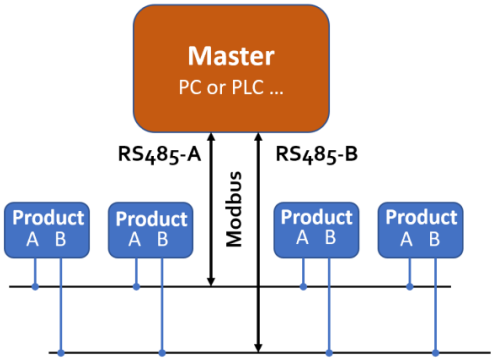


Figure 5.1: RS485 hardware

5.2.2 Communication parameters

The PC UART communication parameters are listed in table 5.1.

Table 5.1: PC UART communication parameters

Parameters	Protocol
	RTU
Baud rate (Bits per second)	38400 bps
Start bits	1
Data bits	8
Stop bits	1
Even/Odd parity	None
Bits period	104.2 µsec
Bytes period	1.1458 msec
Maximum data length	20
Maximum nodes	247

5.2.3 Frame

The frame function is based on the standard Modbus RTU framing:

Table 5.2: frame function

Start_bits	Address	Function codes	Data	CRC	Stop_bits
T1-T2-T3-T4	8 bit	8 bit	N 8 bit (20≥n≥0)	16 bit	T1-T2-T3-T4

Start_bits: 4 periods of a bit time for a new frame.

Address: The address can be set from 1 to 247 except for 157 (0x9d). 0 is the broadcast address.

Function codes: Define the product's functions/actions (slaves), either execution or response.

Data: The address of the register, length of data, and the data themselves.

CRC: CRC verification code. The low byte is followed by the high byte. For example, a 16-bit CRC is divided into BYTE_H and BYTE_L. The BYTE_L will come first in the framing, followed by the BYTE_H. The last one is the STOP signal.

Stop_bits: 4 periods of a bit time for ending the current frame.

5.2.4 Function codes

The Modbus function codes applied for the product are the sub-class of the standard Modbus function codes. These codes are used to set or read the registers of the product:

Table 5.3: function codes

Code	Name	Functions
0x03	Read register	Read register(s)
0x06	Set single register	Write one single 16-bit register
0x10	Set multiple registers	Write multiple registers

5.2.5 Registers

The product has multiple registers available for the assignment of the various functions. With these functions, the user can obtain the data from the products, such as *product address* and *flow rates* from the registers, or set the product functions by writing the corresponding parameters.

The currently available registers are listed in the following table, and the registers may be customized upon contacting the manufacturer. Where R: read; W: write-only; W/R: read and write.

Note: At the time of shipping, the write protection function is enabled except for address and baud rate. Once the user completes the register value change, the write protection will be automatically enabled again to prevent incidental data loss.

Table 5.4: Registers

Functions	Description	Register	Modbus
Address	Product address (R/W)	0x0081	40130 (0x0081)
Serial number	Serial number of the product (R)	0x0030	40049 (0x0030)
Flow rate	Current flow rate (R)	0x003A ~ 0x003B	40059 (0x003A)
Baud rate	Communication baud rate (R/W)	0x0082	40131 (0x0082)
GCF	Gas conversion factor (R/W)	0x008B	40140 (0x008B)
Digital filter depth	Response time or sampling time (R/W)	0x008C	40141 (0x008C)
Offset calibration	Offset reset or calibration (W)	0x00F0	40241 (0x00F0)
Write protection	Write protection of selected parameters (W)	0x00FF	40256 (0x00FF)

The detailed information of each register is described below: Y: enabled; N: disabled

Address	**0x0081**	**Write**	Y
		Read	Y
Description	Address of the product		
Value type	UINT 16		
Notes	Values from 1 to 247 except for 157 (0x9d). The broadcast address is not enabled, and the default address is 1.		

SN, Serial number	**0x0030**	**Write**	N
		Read	Y
Description	Series Number of the product, SN		
Value type	UINT 8 (12 bits)		
Notes	SN= value(0x0030), value(0x0031),….,value (0x0035); Receiving 12 bits as 2A 41 31 42 32 33 34 35 36 2A, the corresponding Serial Number is **A1B23456**.		

Flow rate	**0x003A ~ 0x003B**	**Write**	N
		Read	Y
Description	Current flow rate		
Value type	UINT 16		
Notes	Flow rate = [Value (0x003A) * 65536 + value (0x003B)] / 1000 e.g., When the user reads "0" from register 0x003A and "20340" from register 0x003B, the current flow rate = (0 * 65536 + 20340) / 1000 = 20.340 SLPM		

Baud rate	**0x0082**	**Write**	Y
		Read	Y
Description	Communication baud rate		
Value type	UINT 16		

Notes	0: baud rate=4800; 1: baud rate=9600; 2: baud rate=19200; 3 baud rate=38400. The default value is 3. e.g., When the user reads "3" from register 0x0082, the baud rate is 38400.		
GCF	**0x008B**	**Write**	Y
		Read	Y
Description	The gas conversion factor for applicable gas is different from the calibration gas		
Value type	UINT 16		
Notes	The GCF of air is 1000 (default), typically read from register 0x008B. **Note: The product will disable this function with write protection once the metering gas is confirmed with the proper GCF. For a specific GCF value, please contact the manufacturer.**		

Response time	**0x008C**	**Write**	Y
		Read	Y
Description	Digital filter depth setting		
Value type	UINT 16		
Notes	0 ~ 9 programmable, corresponding to 2^0 ~ 2^9 data sampling in the software filter. The default value is 3, corresponding to 2^3 = 8 data sampling.		

Offset calibration	**0x00F0**	**Write**	Y
		Read	N
Description	Reset or calibrate the offset		
Value type	UINT 16, Fixed value 0xAA55		
Notes	To reset or calibrate the offset, write 0xAA55 to register 0x00F0. **Note: When executing this function, ensure there is NO flow in the flow channel.**		

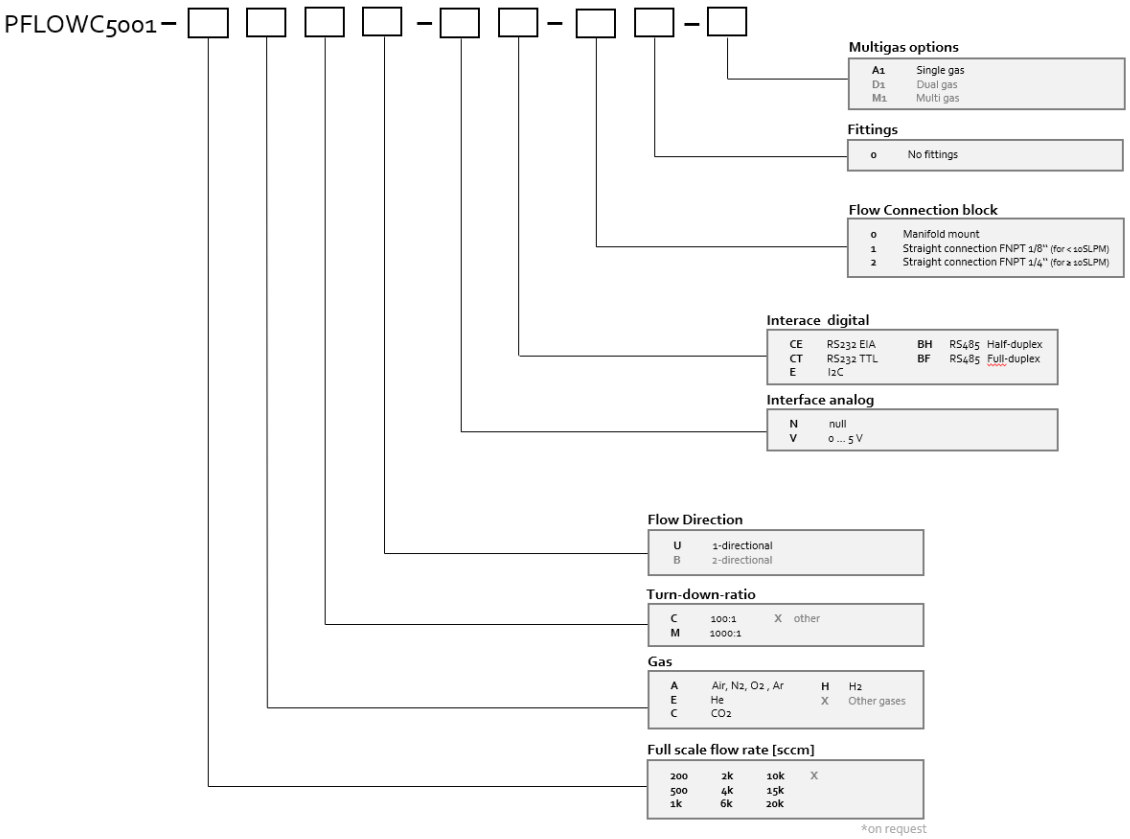
Write protection	**0x00FF**	**Write**	Y
		Read	N
Description	Write protection disabler for a set value to a specific register.		
Value type	UINT 16, Fixed value 0xAA55		
Notes	This function is enabled at the time of product shipment. To enable the write function of a specific parameter, such as GCF or offset, the user needs to send 0xAA55 to the register 0x00FF, and then the write function will be enabled (write protection is disabled). After the write execution is completed, the firmware will automatically re-enable the write protection.		

5.3 Analog output and control

The analog data outputs are fully linearized in both voltage and current output.

6. Product selection

The product part number comprises the product model number and suffixes, indicating each selectable parameter. Refer to the following for details.



Example

PFLOWC5001-200ACU-NCE-00-A1

Note: For CO_2, the full-scale flow is 60% of the specified ones.

7. Product performance

Unless otherwise noted, all specifications listed in the following table apply for calibration conditions at 20°C and 101.325 kPa absolute pressure with air.

	Value	Unit
Flow control range, full scale	50 / ... / 20000	sccm
Accuracy	±1 r.d. or ±0.2 f.s whichever is larger	%
Repeatability	0.20	%
Turn-down ratio	100:1, up to 1000:1	
Setting time	<150	msec
Temperature range	-5 ~ 50	°C
Maximum pressure	1.0 (150)	MPa (psi)
Humidity	<95, no condensation	%RH
Analog null shift	±30	mV
Power supply	8 ~ 24	Vdc
Working current	50	mA
Output	Linear, analog 0 ~ 5 Vdc / Rs485 Modbus / RS232	
Maximum overflow	3000 (3SLPM) (<1000 models); 18000 (18 SLPM) (< 6000 models) 80000(80SLPM) (<20000 models)	sccm (SLPM)
Maximum flow change	500 (< 1000 models); 3000 (< 6000 models) 7500(<20000 models)	sccm/sec
Leakage rate	$<1x10^{-8}$ He	atm cc /sec
Calibration	Air @ 0°C, 101.325 kPa	
Storage temperature	-20 ~ +70	°C
Compliance	RoHS; REACH	
CE	IEC 61000-4-2; 4-8	
Wetted materials	Stainless steel 304; silicon nitride; Ablestik 84-3J; FR4	

Note 1. Allow the product to warm up for 60 seconds for the best performance.

2. Response time shown is the default. It can be programmed to the fastest <2 msec.

8. Technical notes for the product performance

8.1 Measurement principles

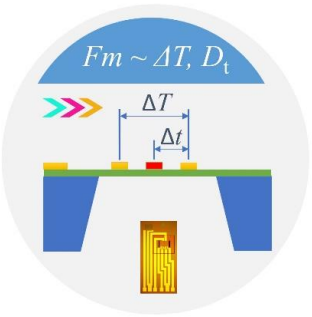


Figure 8.1: Illustration of the measurement principle.

The products utilize micro-machined (MEMS) calorimetric sensing with thermal diffusivity detection and data process technology. A thermal signal generator with a pair of sensing elements up and downstream of the micro heater is precisely manufactured and separated at predefined micrometer distances on a chip surface with excellent thermal isolation. When fluid flows through the sensing chip, the fluid carries the thermal signal downstream. The sensing elements register the temperature differences and measure the fluidic thermal diffusivity, further correlated to the fluid mass flow rate via the calibration process.

Compared to the calorimetric sensing products offered by other manufacturers, this sensing approach provides a large dynamic range with a better performance against environmental parameter alternations. It removes some gas sensitivities for gases with the same diffusivity and much-improved the linearity when a gas conversion factor is used for the metering of the non-calibration gases.

8.2 Precautions for the best performance of the product

8.2.1 Contamination

It is critical to have the measurements performed in a contamination-free environment for data accuracy. Excessive contaminants such as vapors will lead to data deviation or even product malfunctions in severe cases.

8.2.2 Altitude changes

Unlike other products, the sensor's design has a built-in pressure balancer that prevents membrane deformation due to altitude changes. Therefore, the sensor is intrinsically insensitive to altitude change-induced errors. The specified altitude in Sec 7.1 has been thoroughly tested.

8.2.3 Excessive humidity or condensation

The humidity change will not alter the performance of the sensor. However, if excessive humidity is present, resulting in condensation, the measurement port or channel could be blocked or altered, resulting in very unreliable data output. Please filter or use other tools to prevent this situation from occurring when using this product.

8.2.4 Metrology verification

Testing the products with local metrology tools will be performed in almost all cases. It should be noted that for this particular sensor, special care should be applied while performing such a task.

The gauge pressure tests are relatively simple, and the metrology data should be well reproduced if the pressure is tested under a stable media condition.

For the mass flow rate comparison, however, a stable flow system must be ensured in addition to the flow system setup conditions recommended by OIML R137. This is because the current product is designed for a small pressure loss. Therefore the sensor does not have a strong flow restrictor or conditioners to handle the flow instability that may exist in the system. Therefore to compare the metrology data, the user should ensure the system is stable. Otherwise, the output could be noisy, and metrology deviations would be inevitable. If such cases are present, please contact the manufacturer for further solutions.

Because of the small package space, the humidity response could be slower than specified for temperature and humidity measurement. For additional information, please contact the manufacturer.

9. Warranty and Liability

(Effective January 2018)

APSP warrants the products sold hereunder, properly used, and installed correctly in normal circumstances and service. As described in this user manual, it shall be free from faulty materials or workmanship for 180 days for OEM products and 365 days for non-OEM products from the date of shipment. This warranty period includes any statutory warranty, and any repair or replacement serviced product shall bear the same terms in this warranty.

APSP makes no warranty, representation, or guarantee and shall not assume any liability regarding the suitability of the products described in this manual for any purposes that are not specified. The users shall be held full responsibility for validating the performance and suitability of the products for their particular design and applications. For any misusage of the products out of the scope described herein, the user shall indemnify and hold APSP and its officers, employees, subsidiaries, affiliates, and sales channels harmless against all claims, costs, damages, and expenses or reasonable attorney fees from direct or indirect sources.

APSP makes no other warranty, express or implied, and assumes no liability for any special or incidental damage or charges, including but not limited to any damages or charges due to installation, dismantling, reinstallation, etc., other consequential or indirect damages of any kind. To the extent permitted by law, the exclusive remedy of the user or purchaser and the limit of APSP's liability for any and all losses, injuries, or damages concerning the products, including claims based on contract, negligence, tort, strict liability, or otherwise shall be the return of products to APSP, and upon verification of APSP to prove to be defective, at its sole option, to refund, repair or replacement of the products. Regardless of form, no action may be brought against APSP more than 365 days after a cause of action has accrued. The products returned under warranty to APSP shall be at the user or purchaser's risk of loss and will be returned at APSP 's risk of loss. Purchasers or users are deemed to have accepted this limitation of warranty and liability, which contains the complete and exclusive limited warranty of APSP. It shall not be amended, modified, or its terms waived except by APSP 's sole action.

This manual's product information is believed to be accurate and reliable at the time of release or made available to the users. However, APSP shall assume no responsibility for any inaccuracies and errors and reserves the right to make changes without further notice for the relevant information herein.

This warranty is subject to the following exclusions:

(1) Products that have been altered, modified, or have been subject to unusual physical or electrical circumstances indicated but not limited to those stated in this document or any other actions which cannot be deemed as proper use of the products;

(2) Products that have been subject to chemical attacks, including exposure to corrosive substances or contaminants. In the case of battery usage, long-term discharge, or leakage-induced damages;
(3) Products that have been opened or dismantled for whatever reasons;
(4) Products that have been subject to working conditions beyond the technical specification as described by this manual or related datasheet published by the manufacturer;
(5) Any damages incurred by the incorrect usage of the products;
(6) APSP does not provide any warranty on finished goods manufactured by others. Only the original manufacturer's warranty applies;
(7) Products that are re-sold by unauthorized dealers or any third parties.

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Sensors and Power

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