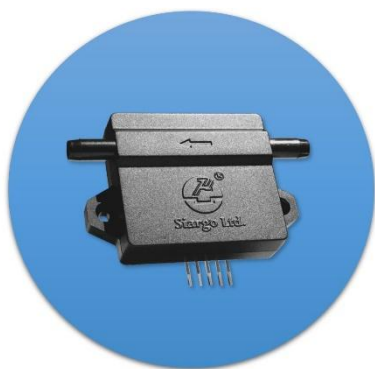


FS4001E User Manual

VD.0.01

MEMS mass flow sensors



MEMS Mass Flow Sensors

with thermal calorimetric sensing technology

FS4001E Series

User Manual

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Siargo Ltd.

4677 Old Ironsides Drive, Suite 310,
Santa Clara, California 95054-1857,
USA

Tel: +1(408)969-0368

Email: Info@Siargo.com

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Attention!

- Please carefully read this manual before operating this product.
- Do not open or modify any hardware that may lead to irrecoverable damage.
- Do not use this product if you suspect any malfunctions or defects.
- Do not use this product for corrosive media or in a strong vibrational 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, even if it operates at a low voltage; any electrical shock might lead to some unexpected damage.
- The gas to be measured should be clean and free of particles, as light particles may be accumulated inside the tiny pressure port 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.

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1. Overview

All contact information can be found at the end of this manual.

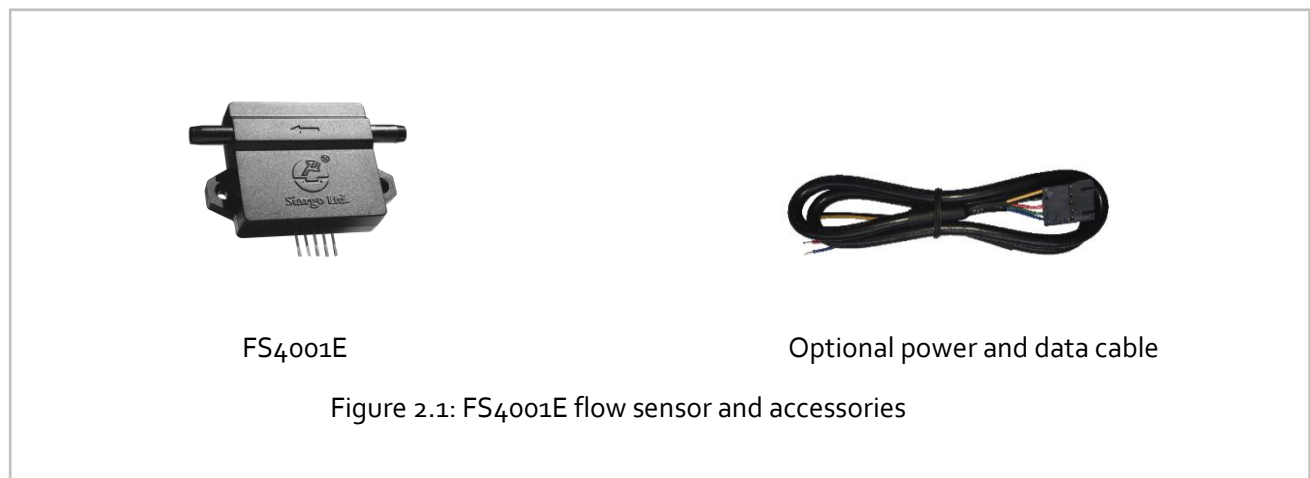
This manual provides essential information for the FS4001E series of mass flow sensors for testing, leakage detection, instrumentation, and medical applications. The product performance, maintenance, and troubleshooting, as well as the information for product order, technical support, and repair, are also included.

The FS4001E sensors are manufactured with the company's proprietary MEMS (micro-electro-mechanical systems) sensing and package technology that offers primarily the mass flow rate measurements of a full scale from 30 to 1000 sccm with a dynamic range of 100:1, and the maximum pressure rating of 5 bar (75 psi).

2. Receipt / unpack of the products

Upon receipt of the products, please check the packing box before dismantling the packing materials. Ensure no damage 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. For any further actions, please refer to the return and repair section in this manual.

If the packing box is intact, open it to find the product (either the sensor formality per the actual order), along with the power and data cable if included, as shown below.



Please check immediately for 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 you can. 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, which your sales agent should send. In most cases, this manual shall be made available to the customer before the actual order.

Please note that the sensor has a pinout that is designed to be directly placed onto a printed circuit board. Therefore, the power and data cable is an option that will not come with the order automatically.

3. Knowing the products

3.1 Product description

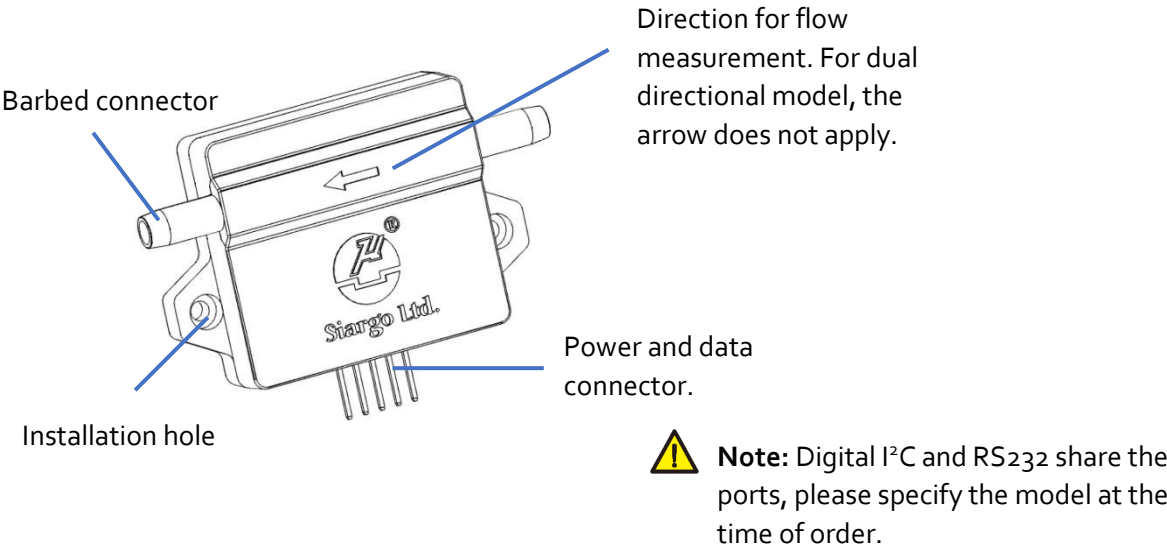


Figure 3.1: FS4001E parts description

3.2 Power and data pinout description

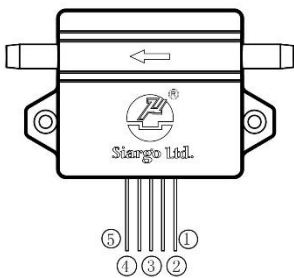


Table 3.1: FS4001E pin assignment.

PIN	DEFINITION
1	SCL, I ² C clock / RS232 RX
2	GND, ground
3	VCC, power supply, 8~24Vdc
4	Analog output, 0.5 ~ 4.5 Vdc
5	SDA, I ² C data / RS232 TX

Figure 3.2: Connections Pins: 2.54 mm centers, 0.635 mm square

⚠ Note: The product offers two digital communications options, I²C or RS232, which can be selected during the ordering process. These two communication protocols share the ports as defined in Table 3.1. For the detailed protocols of the corresponding option, please refer to Section 5.

3.3 Mechanical dimensions

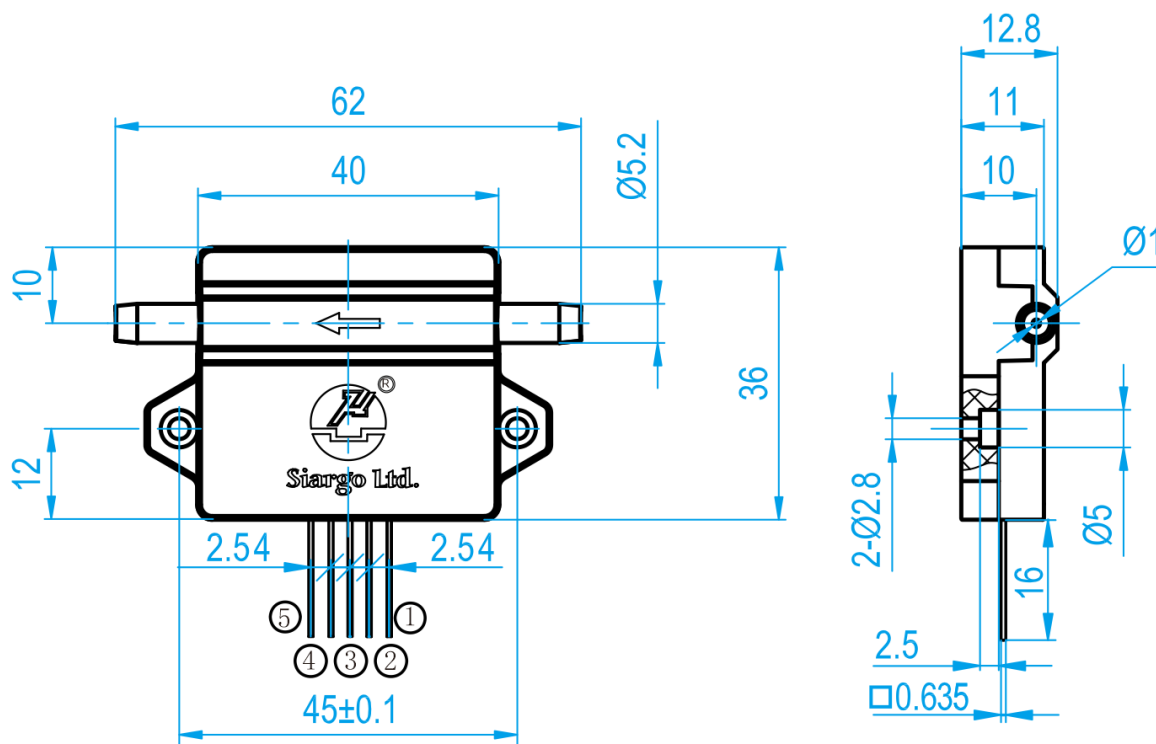


Figure 3.3: FS4001E mechanical dimensions.

4. Installation

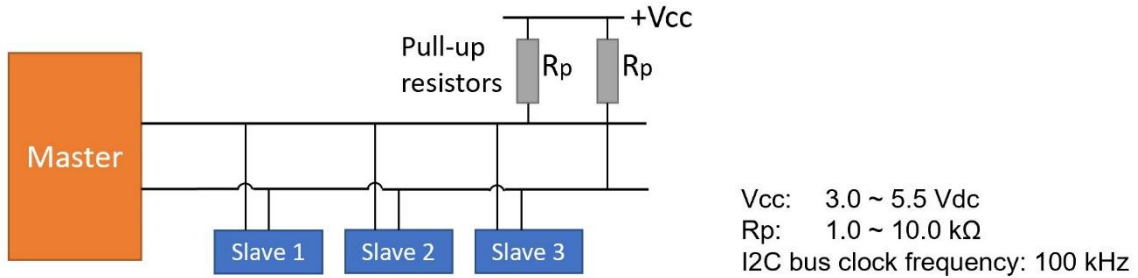
Do not open or alter any part of the product, which would lead to malfunction and irrecoverable damage.

For the installation, the product comes with a barbed connector; a soft pipe connection is usually applied. The sensor can be soldered directly onto the PCB, or a cable can be used for the data and power. Make sure the mechanical leakage proof of the connections and all electrical precautions are applied. Please ensure the electrical pins are properly engaged, especially when using a cable for the connection. It should be noted that the sensor is designed for medium to low pressure per the applications; therefore, the system design would be necessary for the flow stability and related flow noises.

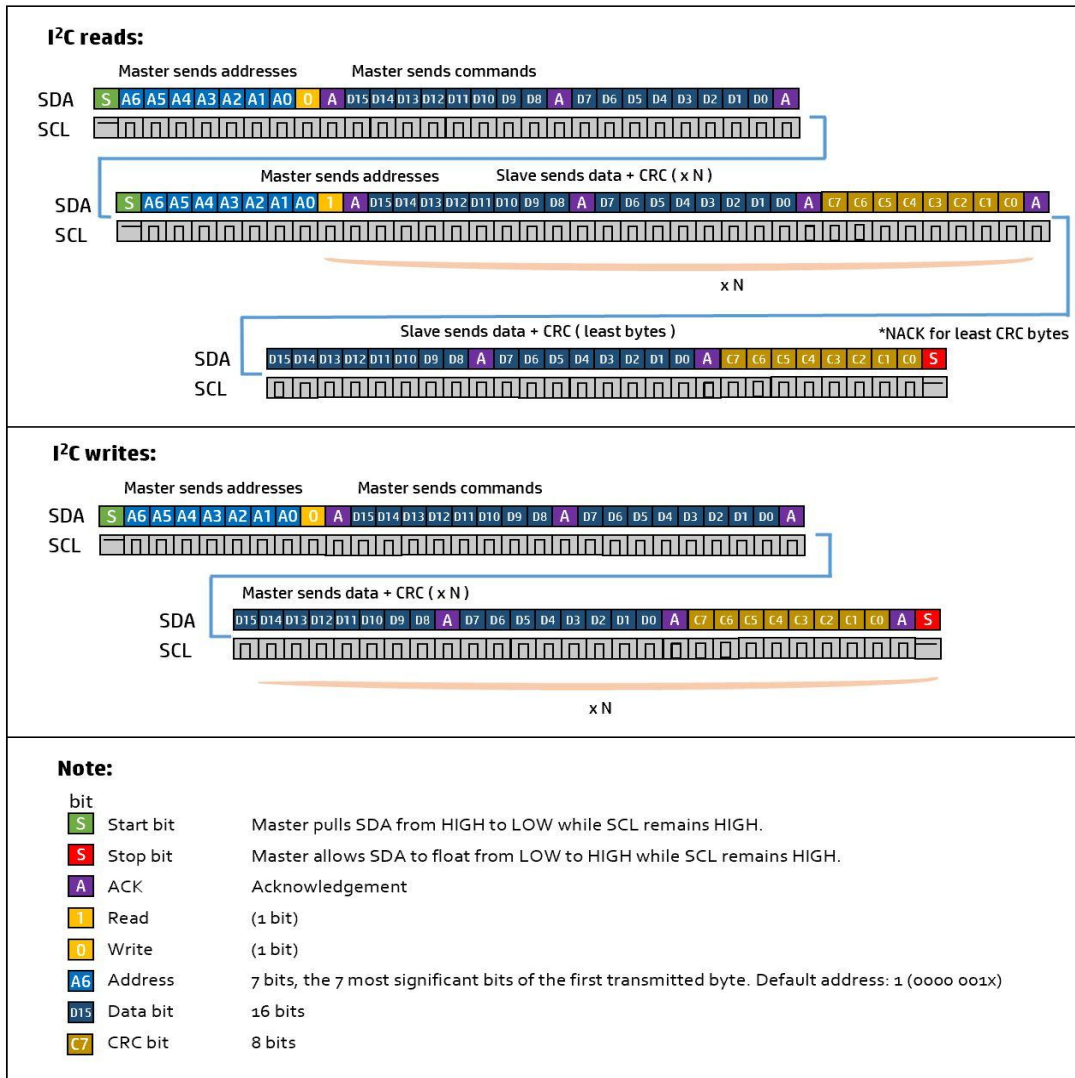
5. Digital communication descriptions

5.1 I²C interface

5.1.1 I²C interface connection diagram



5.1.2 I²C interface read/write sequences



5.1.3 I²C interface command description

Please note the addition of the CRC in the protocol. If you are using an older version, you may need to update your firmware for the current products.

Command Byte	Length (int 16)	Command Name	Read/Write	Notes
0x00A4	1	I ² C address	Read/Write	Int 16. Bit 0 is the R/W flag bit. bits 1 ~ 7 are available; bit 8 ~ bit 15 = 0. The default I ² C address is 1. Hex: 0x0002 (write) /0x0003 (read), Bin: 0000 0000 0000 0010 (write) 0000 0000 0000 0011 (read).
0x0030	6	Sensor serial number	Read	ASCII
0x003A	2	Flow rate	Read	Int 32/1000 sccm
0x008B	1	Gas correction factor (GCF)	Read/Write	The gas conversion factor for the applicable gas differs from that of the calibration gas.
0x008C	1	Filter depth	Read/Write	Int 16, 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.
0x00Fo	1	Reset the offset of the differential pressure	Write	Fixed value, 0xAA55
0x00FF	1	Write protection	Write	Fixed value, 0xAA55 Write protection disabler for a set value to a specific register.

Note:

1. The I²C address is set to bits ~ 1, e.g., if the I²C address is 1 (0000 001x), the write address will be 0x02 (0000 0010), and the read address will be 0x03 (0000 0011).
2. GCF table

Gas type	Correction factor
Air	1000
Oxygen (O ₂)	1000
Nitrogen (N ₂)	1000
Argon (Ar)	1000
Carbon dioxide (CO ₂)	540

5.1.4 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 table below. To calculate the checksum, use only these two previously transmitted data bytes.

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

5.2 RS232 Modbus communication protocol

The RS232 communication protocol is based on the standard Modbus RTU Half-plex mode communication protocol. Refer to Table 3.2 for the cable connection.

Note: FS4001E will work well with the FS4001 RS232 communication protocol. Please get in touch with the manufacturer.

5.2.1 Hardware connection

The RS232 hardware connection is illustrated below.

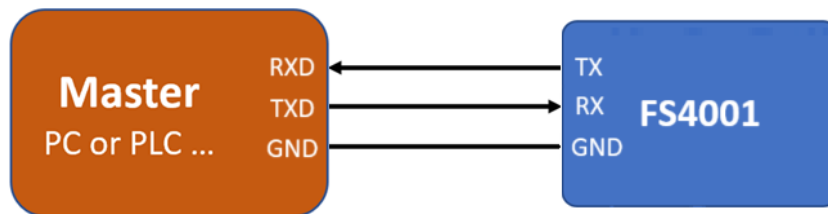


Figure 5.1: RS232 hardware

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 (default)
Start bits	1
Data bits	8
Stop bits	1
Even/Odd parity	None
Bits period	104.2 μ sec
Bytes period	1.1458 msec
Maximum data length	20
Maximum nodes	247

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
T ₁ -T ₂ -T ₃ -T ₄	8 bit	8 bit	N 8 bit ($20 \geq n \geq 0$)	16 bit	T ₁ -T ₂ -T ₃ -T ₄

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

Address: 0x01.

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

Data: The address of the register, the 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. In the framing, the BYTE_L will come first, followed by the BYTE_H. The last one is the STOP signal.

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

5.2.3 Function codes

The Modbus function codes applied for the product are a subclass 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 a single register	Write one single 16-bit register
0x10	Set multiple registers	Write multiple registers

5.2.4 Registers

The product (FS4001E) has multiple registers available for the assignment of the various functions. With these functions, the user can obtain data from products, such as product addresses and flow rates from the registers, or set 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 the address and baud rate. Once the user completes the register value change, the write protection will be automatically re-enabled to prevent incidental data loss.

Table 5.4: Registers

Functions	Description	Register	Modbus
Serial number	Serial number of the product (R)	0x0030 ~ 0x0035	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)	0x00Fo	40241 (0x00Fo)
Write protection	Write protection of selected parameters (W)	0x00FF	40256 (0x00FF)

Notes: 1, R – Read-only, W – Write only, R/W – Read and write.

2. For the * marked functions, please disable the write protection before executing the command.

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

SN, Serial number	0x0030 ~ 0x0035	Write	N
		Read	Y
Description	Series Number of the product, SN		
Value type	ASCII		
Notes	SN= value(0x0030), value(0x0031),...,value (0x0035); e.g., 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 32		
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 sccm		

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 the applicable gas differs from that of the calibration gas.		
Value type	UINT 16		
Notes	The GCF of air is 1000 (default), usually read from register 0x008B. Notes: 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 get in touch with the manufacturer.		

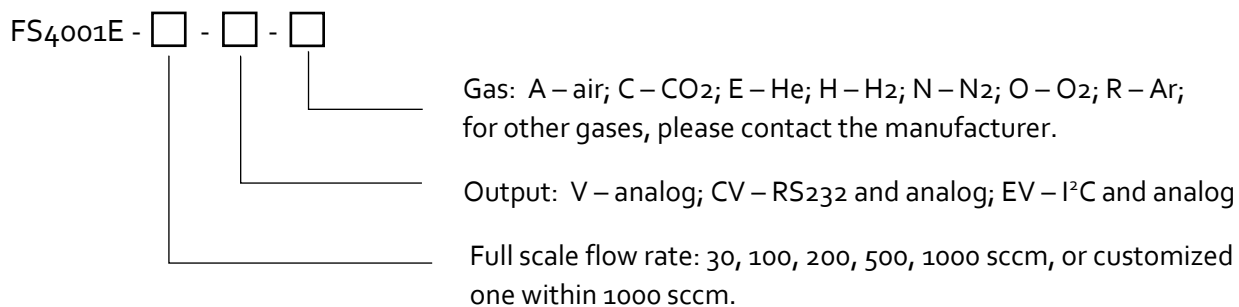
Digital filter depth	0x008C	Write	Y
		Read	Y
Description	Data sampling setting in the software filter		
Value type	UINT 16		
Notes	0 ~ 9 programmable, corresponding to $2^0 \sim 2^9$ data sampling in the software filter. The default value is 3, corresponding to $2^3 = 8$ data sampling. Notes: Please disable the write protection before executing this command.		

Offset calibration	0x00Fo	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 0x00Fo. Notes: When you execute this command, make sure 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.		

6. Product selection

The product part number is composed of the product model number and suffixes, indicating each of the selectable parameters. Refer to the following for details.



Note: For CO₂, the maximum flow rate is 500 sccm.

7. Product performance

7.1 Technical specifications

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

	Value	Unit
Flow range ¹	0 ~ 30, 100, 200 0 ~ 500, 1000	sccm
Accuracy (total error band)	±(1.5+0.5FS)	%
Repeatability	(0.5+0.15FS)	%
Turn-down ratio	100:1	
Response time	65 (default), 4, 8, 16, 33, 131 selectable	msec
Working temperature	-10 ~ +55	°C
Temperature coefficient	±0.08	%/°C
Working pressure	-0.08 ~ +0.5	MPa
Pressure loss (max.)	20 30	
Humidity	<95 (no condensation)	%RH
Analog null shift	±30	mVdc
Power supply	8 ~ 24	Vdc
Working current	<50	mA
Output	Linear, Analog: 0.5 ~ 4.5 Vdc / Digital: RS232, I ² C	
Mechanical connection	Hose coupling (Barbed)	
Maximum overflow	3 10	SLPM
Maximum flow change per second	0.5 1.5	SLPM/sec
Weight	15	g
Storage temperature	-20 ~ +70	°C
Calibration	Air @ 20°C, 101.325kPa	
Compliance	RoHS; REACH	
CE	IEC 61000-4-2;4;8	

Notes: 1. For CO₂, the maximum flow rate is 500 sccm.

2. Calibration with real gas is optional. Please get in touch with the manufacturer for further information.

7.2 Analog output

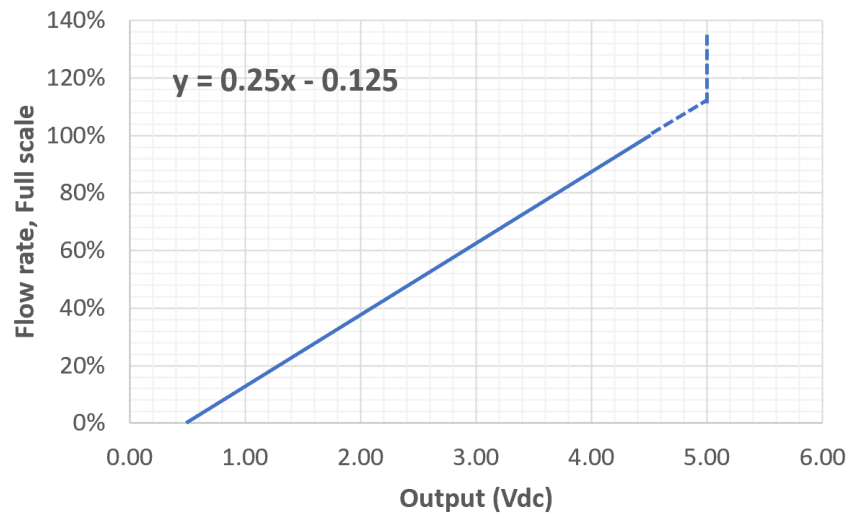


Figure 7.1: Typical analog output.

7.4 Wetted materials and compatibility

The product flow channel is made of polycarbonate. The sensing element comprises silicon, silicon nitride, and silicon dioxide. The sensor chip surfaces are passivated with silicon nitride and silicon dioxide. The electronic sealing is provided by LOCTITE Ablestik 84-3J. Another wetted material that may be exposed is FR-4.

8. Technical notes for the product performance

8.1 Measurement principles

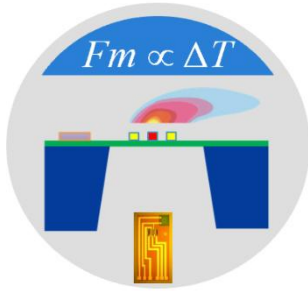


Figure 8.1: Measurement approach illustration.

The products utilize the Company's proprietary micro-machined (MEMS) calorimetric sensing and data processing technology. A thermal signal generator with a pair of sensing elements upstream and downstream of the microheater is precisely manufactured and separated at predefined micrometer distances on a chip surface with excellent thermal isolation. When a fluid is flowing through the sensing chip, the fluid carries the thermal signal downstream. The sensing elements register the temperature differences, which are then correlated with the fluid mass flow rate via the calibration process.

The calorimetric sensing approach offers an extensive dynamic range with better performance against environmental parameter alternations. Please refer to the company's US patents and other publications made available to the public for additional information.

8.2 Precautions for the best performance of the product

8.2.1 Altitude changes

Unlike some other products on the market, the design of the sensor 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.

8.2.2 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 changed. This would result in a very unreliable data output. Please use other tools to prevent this situation from occurring when using this product.

8.2.3 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 taken while performing such a task.

The gauge pressure tests are relatively simple; as long as the pressure is tested under stable media conditions, the metrology data should be well reproduced.

For the mass flow rate comparison, however, in addition to the flow system setup conditions recommended by OIML R137, a stable flow system must be ensured. This is because the current product is designed for a slight pressure loss; therefore, the sensor lacks a strong flow restrictor or conditioners to handle the flow instability that may exist in the system. Thus, 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 get in touch with the manufacturer for further solutions.

For temperature and humidity measurement, due to the limited space in the package, the response time for humidity measurement may be slower than specified. For additional information, please get in touch with the manufacturer.

9. Warranty and Liability

(Effective January 2018)

Siargo warrants that the products sold hereunder will be used appropriately and installed correctly under normal circumstances and service conditions. 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 is inclusive of any statutory warranty. Any repair or replacement of a serviced product shall bear the same terms in this warranty.

Siargo 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 in this manual. The users shall be held fully responsible for validating the performance and suitability of the products for their particular design and applications. For any misuse of the products out of the scope described herein, the user shall indemnify and hold Siargo 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.

Siargo 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., or any 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 Siargo'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 Siargo, and upon verification of Siargo 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 Siargo more than 365 days after a cause of action has accrued. The products returned under warranty to Siargo shall be at the user or purchaser's risk of loss and will be returned, if at all, at Siargo'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 Siargo. It shall not be amended, modified, or its terms waived except by Siargo's sole action.

This manual's product information is believed to be accurate and reliable at the time of release or when made available to the users. However, Siargo shall assume no responsibility for any inaccuracies and/or 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, as 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 damage;
- (3) Products that have been opened or dismantled for whatever reason;
- (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) Siargo does not provide any warranty on finished goods manufactured by others. Only the original manufacturer's warranty applies.
- (7) Products that unauthorized dealers or any third parties resell.

10. Service/order contact and other information

Siargo Ltd. is making every effort to ensure the quality of its products. For questions or product support, please get in touch with your direct sales representative. If you need additional assistance, please get in touch with customer service at the address listed below. We will respond to your request in a timely fashion and work with you toward your complete satisfaction.

For sales or product orders, please get in touch with the local sales representatives or distributors listed on the company's webpage: www.Siargo.com.

For any returns, please get in touch with your direct sales representative to obtain an RMA. If you require further assistance, please get in touch with info@siargo.com for additional information or a Return Materials Authorization (RMA) before returning the product to the factory for servicing, including calibration. Please specify in your email message the product's status as clearly as possible, indicating your intention to return it to the factory, and include your shipping address. Be sure to write the RMA on the returned package or include a letter with the RMA information.

Direct customer service request(s) should be addressed to

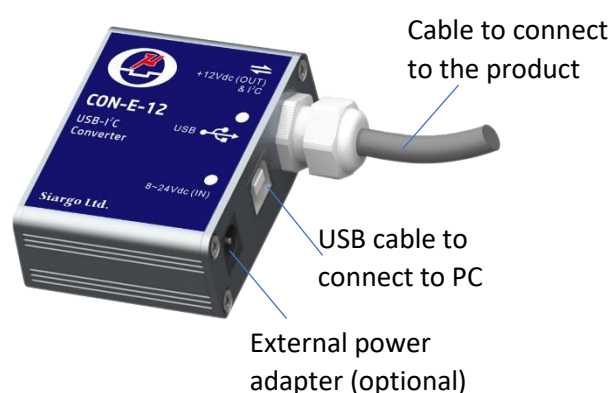
Siargo Ltd.
4677 Old Ironsides Drive, Suite 310,
Santa Clara, California 95054-1857, USA
Tel: +1(408)969-0368
Email: Info@Siargo.com

For further information and updates, please visit www.Siargo.com.

Appendix I: Sensor evaluation kit

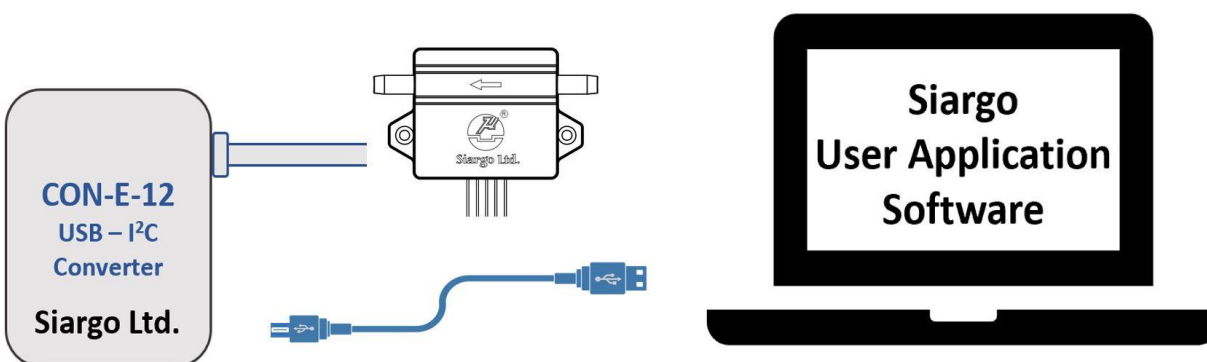
Siargo offers a sensor evaluation kit, including a digital data converter, USB data cable, and User Application software, that allows the user to evaluate the product performance on a Microsoft Windows-based computer. The user can read and visualize the flow rate of the product, obtain the totalized values, and save the data for further analysis. It can read from up to 128 sensors with the I²C interface in serial.

For further information and purchase of the evaluation kit, please get in touch with the manufacturer or the sales representative.



Each converter has a fixed cable that can be directly connected to the product. The USB cable connected to the PC is also included.

For most of the products, the power from the PC via the USB cable will be sufficient to power the sensor product; no external power will be required. However, for multiple sensors in serial, the power via the USB cable may not be enough; an external power adapter with 8~24Vdc will be required.



Appendix II: Document history

Revision VD.o.01 (August 2025)

- Corrections.

Revision VD.o (May 2025)

- FS4001 has been upgraded; the new part number is FS4001E.
- No spec changed. (MEMS chip change to 4th GEN MEMS chip with Thermal-D technology, and circuit altered to match the 4th GEN MEMS chip.)
- Update the I²C and RS232 communication protocols. The sensor can communicate with the FS4001 I²C protocol, which is listed in Appendix II.

Revision VC.o.04 (October 2024)

- Corrections of technical specifications.

Revision VC.o.03 (July 2024)

- Corrections.

Revision VC.o.02 (July 2023)

- Update contact address and corrections.

Revision VC.o.01 (July 2022)

- Update service and sales contact.

Revision VC.o (July 2021)

- The new format, additions.

Revision VB.4 (October 2020)

- Revised ISO 45001.

Revision VB.3 (October 2019)

- Corrected the pressure drop.

Revision VB.2 (November 2018)

- Add the GCF setting and reading commands.

Revision VB.1 (July 2018)

- Added maximum overflow and maximum flow change.

Revision VB.o (April 2018)

- Revised the I²C sequences and I²C commands description.

Revision VA.9 (September 2017)

- Added I²C and its connection, and protocol;
- Added the revision history (Appendix).