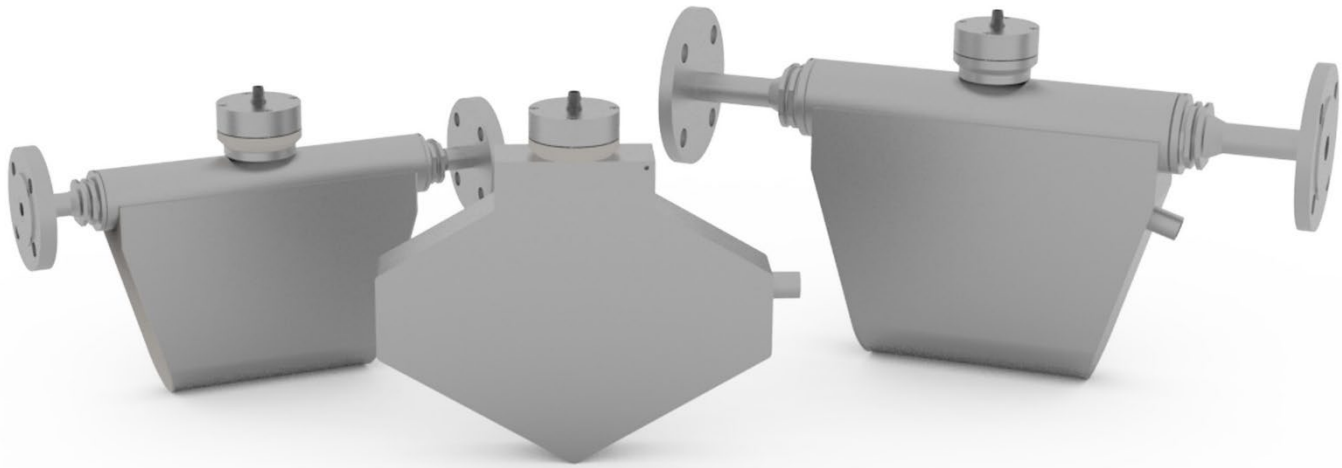
Coriolis Technology



Quick Start Guide

Coriolis Mass Flow Meter with TCA signal converter

Manual-Version

TCA_Q_EN_250601_E001

Please check whether new instructions have been published on our homepage.

Preface

This Quick Start Guide contains the essential instructions to install, wire and operate your new Mass Flow Meter. The measuring device is calibrated and pre-configured for general industrial applications. If the configuration of the transmitter requires changes, please follow this instruction or download the complete instruction manual from the Website.

Additional information to this manual can be downloaded from the website or is part of the scope of delivery. Supplementary information are listed below:

Type of document	Part of delivery (paper print)	Website Download
Declaration of Conformity (CE and PED)	✓	✓
Calibration Certificate	✓	on request
Instruction manual: • Dimensional drawings for the mechanical installation • Circuit diagrams for the electrical installation • Information about maintenance, calibration and service • Complete technical data	✗	✓

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1. General Information

The Coriolis Mass Flow Meters are intended to measure simultaneously mass flow, volume flow, temperature, and density. The equipment consists of a flow sensor and a direct mounted signal converter, see

Fig. 1. The ingress protection rating is up to IP67 (NEMA 4X).

The signal converter provides an A-coded M12 5 pin plug (male) for power supply, RS485 communication interface and a configurable frequency output. The device is equipped with a multicolor LED which is visible through a translucent seal. The multicolor LED indicates operation and status of the device.

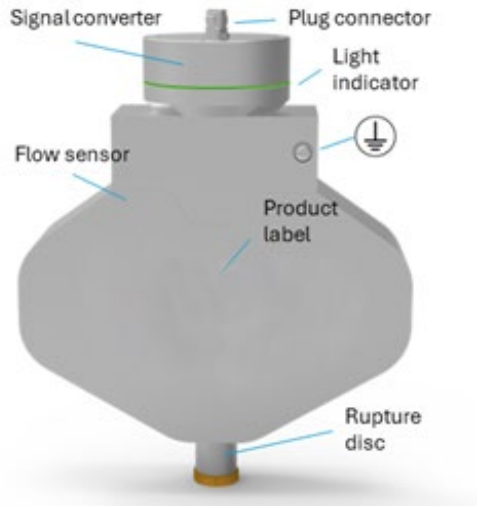


Fig. 1: Flow meter components

The device is delivered as ordered and important information, i.e., flow rate, process temperature and pressure as well as approvals are shown on the product label. Examples of the product label and signal converter markings are shown in Fig. 2.

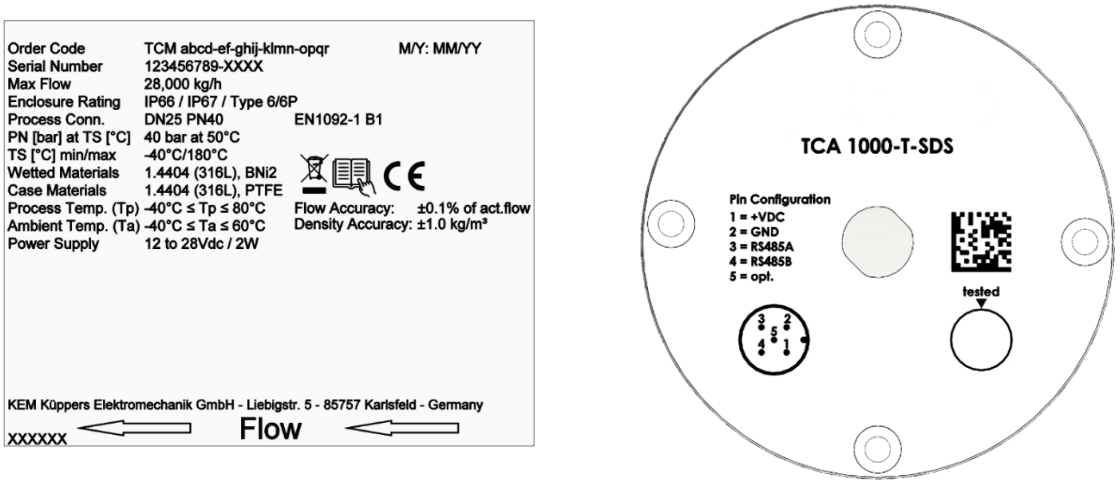
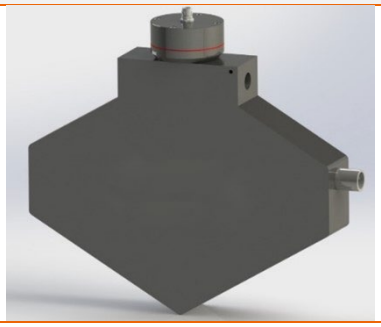
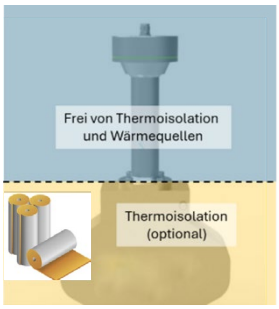


Fig. 2: Example of a product label (left) and imprint on the signal converter lid (right)

The process temperature rating depends on the ordered model code. Available options are listed in Tab. 1. The listed Ta and Tp ranges are applicable for horizontal and vertical installation (see Fig. 3 and Fig. 4) in non-hazardous locations. The allowed maximum process temperature Tp(max) also refers to the maximum enclosure surface temperature. For process/enclosure surface temperature above +80 °C, a rod extension defined by the model code is required to avoid temperature damage and safety risks at the signal converter.

In applications where thermal insulation of the flow meter is necessary, insulation material should be placed on the sensor enclosure only. It is not allowed to cover the signal converter or the connector rod. Avoid any heat sources within 0.5 m of the signal converter and the connector rod.

Temperature	Order code		
	TCM****-**-S***-****	TCM****-**-H***-****	TCM****-**-T***-****
ambient (Ta)	-40 °C ... +60 °C / -40 °F ... +140 °F		
process (Tp)	-40 °C … +80 °C -40 °F … 176 °F	-40 °C … +150 °C -40 °F … +302 °F	-40 °C … +200 °C -40 °F … +392 °F
			

Tab. 1: Process temperature related versions for non-hazloc installation

Before installing the device, check the delivered goods for correctness and completeness using your order confirmation and delivery documents. Report damages immediately to the shipping company and keep the damaged parts for clarification.

2. Mechanical installation

2.1. General remarks

For safe operation and a long lifetime of the flow meter, note the following instructions. Contact customer support for any technical or installation-related questions.

- The flow meter can be operated within a wide **process pressure range**. Ensure that the maximum allowed working pressure (PS) cannot be exceeded. The pressure PS is shown on the product label (see Fig. 2) and depends on device type, selected process connection and process temperature. The device can be damaged if operated outside the specified pressure limits.

- The flow meter can be operated within a wide **process and ambient temperature range**. Ensure that the temperature limits, which are shown on the product label, are not exceeded. Protect personnel from exposure to hot or cold surfaces using protective equipment. Energy transfer into or out of the process can be prevented by insulation. Do not cover the signal converter or the connector rod to allow heat dissipation.

- The flow meter can be operated with a wide range of **media**. Ensure that all wetted parts are compatible with the measured fluid at process temperature. Improper material selection can cause corrosion and subsequent damage or even hazards. Wetted materials are stated on the product label.

- The flow meter can be operated with **abrasive media**, which might reduce long-term pressure rating and accuracy due to erosion. Additionally increased wear of the internal tubing may cause sudden failure of the sensor. To prevent those risks, shortening of the inspection or re-calibration intervals is strongly advised.

- The flow meter can be operated with a wide range of **gases, liquids, gas - liquid mixtures or liquid - solid particle mixtures** without parameter adjustment of the signal converter. The best meter performance will be achieved with single phase flow of gas or liquid. Mixed phase flow or wet gas flow can cause a significant decrease of mass or volume flow rate and density accuracy. For improvement of the measurement performance, contact customer support for guidance.

- For safety reasons, all flow meters are equipped with a **rupture disc** at the sensor enclosure (see
- Fig. 1). A rupture disc is a pressure relief element to protect systems from over-pressurization. In an unlikely case of a flow tube leak, the rupture disc element will open once the internal case pressure exceeds approximately two bar(g). To avoid personal injury or property damage, connect a pipe or hose to the rupture disc housing (G ½") to direct the relieved liquid and/or gas from the meter's case through the rupture disc to a safe location, away from operators in the area.

2.2. Mounting in a pipeline

The flow meter can be mounted in horizontal (see Fig. 3) or vertical pipelines (see Fig. 4). If the medium might contain solid particles, mount the meter as shown in position "A", in all other cases as shown in position "B". For vertical installation, please consider that solid particles and entrained gas could be trapped in the bends of the flow tube, causing a decrease of measuring accuracy. For an optimal long-term performance please flush or drain the sensor sufficiently.

Install the meter in a well-supported pipeline to a solid, non-vibrating base as close to the meter as possible. Alternatively, the TCM 0325 through TCM 3100 sensors have two M6 threaded mounting holes.

Avoid any physical connection/support between the facility structure and the flow meter enclosure. Decouple vibrating pipelines from the flow sensor using flexible hosing.

Make sure that any valves, pumps, and the flow meter are running without cavitation. Prevent the flow meter from running in partially filled conditions by choosing adequate pipework or by adding additional valves.

Due to the design of the internal device tubing, the TCM 0325 through TCM 3100 sensors could trap process fluid. The device should be drained before removing it from the line or changing the fluid to avoid injury or contamination.

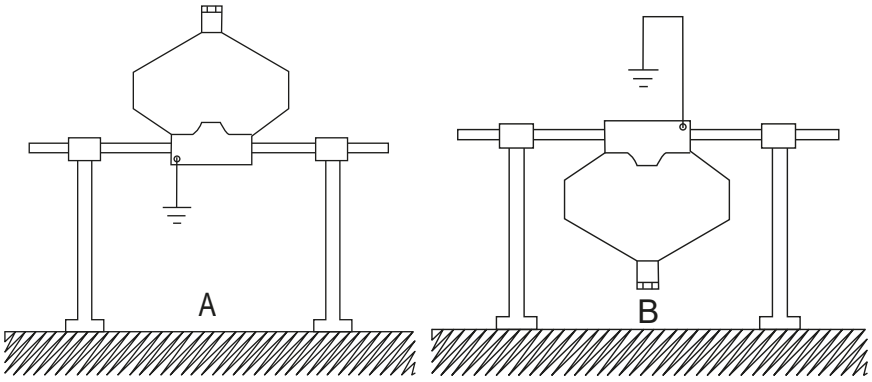


Fig. 3: Horizontal installation

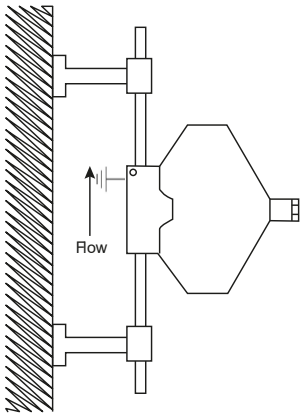


Fig. 4: Vertical installation

3. Electrical installation

3.1. General installation

The flow meter, consisting of a flow sensor and signal converter, is not designed to be repaired or disassembled by the customer. The screws on the signal converter enclosure lid are sealed with warranty marks. It is not allowed to break the warranty seal without guidance from customer support.

The signal converter is equipped with a M12 5-pin plug socket (male, A-coded) for the PLC connection and power supply. The M12 pin assignment is shown in Fig. 2 (right). To avoid EMC influences, use shielded twisted-pair wires with a cross-section of minimum 0.25 mm² (AWG23) for pins 1 and 2 (+VDC and GND) and pins 3 and 4 (RS485+ and RS485-) with an overall length of less than 300 m. Connect the cable shield to the signal converter and to the PLC.

Protective Earth

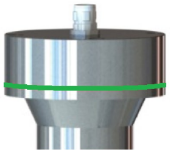
The protective earth grounding must be provided via the marked threaded hole at the flow sensor.

Power supply

For non-hazardous location installations, the power supply of 12 to 28 Vdc shall be connected to pins 1 and 2. The signal converter is equipped with a polarity reversal protection. The typical power consumption is below two Watts in normal operation.

Light signal

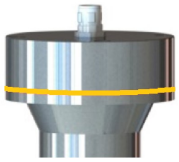
After powering up, the firmware continuously reads the flow meter parameters and hardware functionality to indicate the operational state via light signals, as described as follows.



Ready state

Normal operation – Green light

During normal operation of the flow meter the transmitter will show a steady or a moving green light.

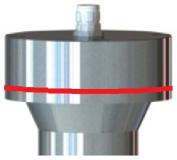


Start-up / Warning state

Start-up or warning state – Yellow light

During start-up, the transmitter will show the yellow light for approx. 15 seconds. During operation the yellow light indicates one or more warnings. The device is fully functional, though measuring accuracy may be reduced.

Verify the warning monitor registers for further details or troubleshooting (see chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**)



Error state

Error – Red light

When a single or multiple high-level errors occur, the light indicator will switch to red.

The flow meter is partially or completely failing due to critical malfunctions. Measurement values are set to fault state.

Verify the error monitor registers for further details or troubleshooting (see chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**)

3.2. Communication interface

The RS485 2-wire communication interface is connected to pins 3 and 4. The PLC is intended to be a Modbus RTU client with point-to-point communication or multidrop communication of up to 247 server devices. The wiring schematics are shown in Fig. 5 and Fig. 6.

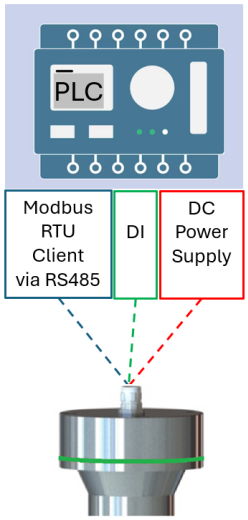


Fig. 5: Point-to-point configuration

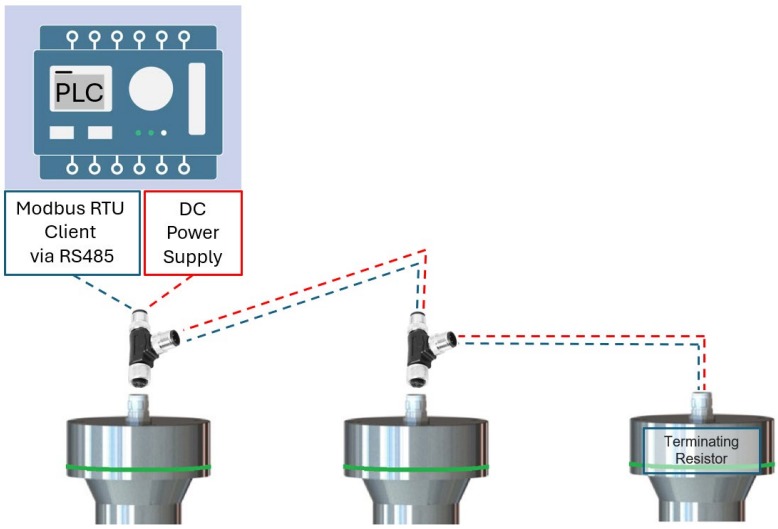


Fig. 6: Multidrop configuration of devices

If not ordered otherwise, the default Modbus RTU communication settings are shown in Tab. 2. In case of changes of communication settings, the new parameters need to be stored in the device memory (Register 200, see **Fehler! Verweisquelle konnte nicht gefunden werden.**) and the device needs to be restarted. Further information about the communication protocol are provided in Section 4.

Register name	Register No.	Default settings	Valid settings
Device address	1202 (uint32)	[1]	1 … 247
Baud rate	1204 (uint32)	[6]	[0] 2400, [1] 4800, [2] 9600, [3] 19200 [4] 38400, [5] 57600, [6] 115200
Parity/Stop bits	1206 (uint32)	[1]	[0] non / 2 [1] even / 1 [2] odd / 1
Term. resistor	1208 (uint32)	[0]	[0] disabled [1] enabled (120 Ω)
Byte order (float32)	3-2-1-0 (Big-endian)		
Register addressing	Zero-base register addressing		
Functional codes	0x03 (read holding register) 0x10 (write multiple register)		
Bit number	16, 32 or 64 (see register list)		

Tab. 2: Listing of the default communication settings

3.3. Active digital output

The signal converter provides a square wave signal output on pins 5 and 2 of the M12 connector. The output frequency is proportional to the selected process value. Frequencies of up to 15 kHz can be generated and the signal's duty-cycle is adjustable. The output is actively powered by the flow meter. The output frequency is updated every ten milliseconds.

The frequency output is intended for high dynamic process control if the maximum achievable update rate of the Modbus queries is insufficient or if the jitter of query responses is not acceptable. The output can be configured to provide flow rate (mass, volume, or standard volume), density or temperature.

Tab. 3: lists the default configuration of the digital output. To change the configuration permanently settings need to be stored in the device memory.

The frequency output shall be connected to pins 5 and 2 if a point-to-point communication is established. For a multidrop communication the frequency output should be disabled by default (register no: 808 and register value: 0).

Register name	No.	Default settings	Valid settings
Ausgewählte Prozessparameter [i)]	808 (uint32)	[2]	[0] Simulationsmodus [1] Dichte [2] Massenstrom [3] Volumenstrom [4] Std. Volumenstrom [5] Prozesstemperatur
Unterer Bereich des Prozesswerts	800 (float32)	0	unbeschränkt
Oberer Bereich des Prozesswerts	802 (float32)	Max. Durchflussrate	unbeschränkt
Unterer Frequenzwert (Hz)	804 (float32)	0	0 … 10.000
Oberer Frequenzwert (Hz)	806 (float32)	10.000	0 … 10.000
Simulationsmodus f_{out} (Hz)	810 (float32)	0	0 … 10.000
Einschaltdauer der f_{out} (%)	812 (float32)	50	1…99

i) Der Prozesswert bezieht sich auf die ausgewählte Einheit, siehe Kapitel 4.3.1.

Tab. 3: Auflistung der Einstellungen des Frequenzausgangs

4. Interface communication description

4.1. General information

The device acts as a server in a 2-wire Modbus RTU RS485 bus system. Terminal RS485A on the device must be connected to terminal D+ / RS485A on the client/host system. Terminal RS485B on the device must be connected to terminal D- / RS485B on the client/host system. A point-to-point communication or a multidrop installation can be established, as shown in Fig. 5 and Fig. 6. These connection types correspond to a half-duplex communication where the addressed server device will reply to a request from the client/host system.

A standard MODBUS modem can be used to communicate with the TCA.
KEM Flow Measurement offers the TCA-COM module, which has the following advantages:

- Preconfigured M12 connector that connects directly to the TCA electronics.
- Power supply to the TCA via the USB port of the computer used.

To further simplify the configuration of the TCA, KEM provides the KEM Product Configuration Tool (KEM PCT). With this tool, which can be downloaded from the KEM website after registration, all parameters of the TCA can be adapted to the application requirements. The KEM Product Configuration Tool, together with the TCA-COM module, allows easy configuration of the TCA electronics!

Modbus queries, responses, and exceptions

A Modbus query is assembled from the following blocks:

- Device address: 1 … 247 (selectable)
- Function code: 0x03 (read holding register) and 0x10 (write multiple register)
- Data field: depending on function code
  - data field contains 32-bit integer, or float values of up to 80 bytes
  - float value uses the byte order: “big-endian”
- Checksum (CRC): calculated according to the Modbus regulations.

*Tab. 4 and **Fehler! Verweisquelle konnte nicht gefunden werden.** show examples of Modbus queries for both function codes.*

Query: mass flow rate (Register 1730)				**Response: [6.10383] float32**		
Device address	1 byte	0x01		Device address	1 byte	0x01
Function code	1 byte	0x03		Function code	1 byte	0x03
Start register address	2 bytes	0x00F7		Byte count	1 byte	0x04
Quanty of registers	2 bytes	0x0002		Register 1	2 bytes	0x40C3
				Register 2	2 bytes	0x5293
Checksum (CRC)	2 bytes	0x75F9		Checksum (CRC)	2 bytes	0x62C2
Query: mass flow unit (Register 3406)				**Response: [6] kg/h** (see **Fehler! Verweisquelle konnte nicht gefunden werden.**)		
Tx = [01 03 0D 4E 00 02 07 70]				Rx = [01 03 02 00 06 38 48]		

Tab. 4: Function code 0x03 examples (Read holding registers)

Query: Mass totalizer high precision (Reg.2438)				**Response: [7028.15] Double precision float**		
Device address	1 byte	0x01		Device address	1 byte	0x01
Function code	1 byte	0x10		Function code	1 byte	0x10
Start: register address	2 bytes	0x0986		Byte count	1 byte	0x04
Quanty of registers	2 bytes	0x0004		Registers 1 / 2	2 bytes	0x40BB7426 66666666
				Registers 3 /4	2 bytes	
Checksum (CRC)	2 bytes	0x23BF		Checksum (CRC)	2 bytes	0x6818
Query: mass totalizer unit (Register 3404)				**Response: [1] kg** (see **Fehler! Verweisquelle konnte nicht gefunden werden.**)		
Tx = [01 03 0D 4C 00 02 ED C7]				Rx = [01 03 02 00 01 79 84]		

Tab. 5: Function code 0x10 example (Read holding registers)

The device provides exception responses of five bytes length (device address, function code plus a constant value of 0x80, exception code, and checksum). The following exception codes are possible.

- 0x01 (Illegal function): The requested function is not existing/not implemented.
- 0x02 (Illegal data address): The start address or data length is not existing/not allowed.
- 0x03 (Illegal data value): The transferred data are out of range or parameter are write-protected.

4.2. Relevant process values

The process values comprise all directly measured or computed process parameters, or mass/volume totalizers. The process parameter registers are updated every ten milliseconds.

4.2.1. Permanent configuration settings

The following chapters describe how configuration settings can be customized. All configuration settings are permanently stored to the device memory. To save the customized settings to the memory, a value of 0x8 must be written to register 200. If the saving process is not triggered, all changes to the configuration will be lost during a power cycle and the last saved configuration will be loaded during the next start-up. The storing register parameters are listed in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Register name /No.	Description
Store or load device configuration settings 200 (uint32) Privileges: read / write	[8] Store: all registers
	[16] Load: all registers

Tab. 6: Permanent configuration settings

4.2.2. Process value registers

The registers for the process values and corresponding units are listed in **Fehler! Verweisquelle konnte nicht gefunden werden.**. The process values shall be interpreted as single or double precision float value in “Big-endian” byte order.

Fehler! Verweisquelle konnte nicht gefunden werden. *lists available configuration settings including a brief functional description.*

Process value registers				Unit registers			
Mass flow rate	1730	float32		Mass flow unit	3406	uint32	**Fehler! Verweisquelle konnte nicht gefunden werden.**
Density	2110			Density unit	3408		**Fehler! Verweisquelle konnte nicht gefunden werden.**
Process temperature	1822			Temperature unit	3400		**Fehler! Verweisquelle konnte nicht gefunden werden.**
Volume flow	2250			Vol. flow unit	3412		**Fehler! Verweisquelle konnte nicht gefunden werden.**
Frame temperature	1824			Temperature unit	3400		**Fehler! Verweisquelle konnte nicht gefunden werden.Fehler! Verweisquelle konnte nicht gefunden werden.**
Std. volume flow[i]	2350			Std. vol. flow unit	3414		**Fehler! Verweisquelle konnte nicht gefunden werden.Fehler! Verweisquelle konnte nicht gefunden werden.**

i) For a correct standard volume flow calculation, reference density must be store by the user (register: 2302).

Tab. 7: Register of process values and corresponding units

Register name	No.	Description
Low-flow cutoff: Mass flow rate	1724	Type: float32 Privileges: read / write Low-flow cutoff sets the flow readings to ZERO when the actual flow drops below the entered value. The default value is 0.5 % of maximum mass flow rate of the device. The input value is the flow rate threshold at the selected mass flow unit.
High-flow cutoff: Mass flow rate	1726	Type: float32 Privileges: read / write High-flow cutoff suppresses flow readings above this value and fixes the flow reading to the entered value. The default value is 120 % of the maximum mass flow rate of the device. The input value is the flow rate threshold at the selected mass flow unit.
Flow direction	1622	Type: uint32 Privileges: read / write [0] Forward Flow [1] Backward Flow (sign reversal)
Empty tube detection threshold	2104	Type: float32 Privileges: read / write The entered value defines a density threshold to detect an empty or a partially filled flow meter. If the measured density falls below the threshold, a high-level error flag is raised, and the process values are set zero. The empty tube detection option is deactivated by default. The entered value is [0].
Reference density for standard volume calculation	2302	Type: float32 Privileges: read / write The entered value defines gas reference density at specific reference condition and is used for the standard volume flow calculation. It is the user's responsibility to set and store the reference density according to the gas type and reference conditions. The default value is 1.2 kg/m³.

Tab. 8: Configuration settings of the process values

4.2.3. Totalizer registers

The device provides three independent double precision totalizers for mass, volume, and standard volume. The “Grand Total” is a non-resettable flow counter. The custom totalizers No. 1 and No. 2 can be re-set and their status is either “running” or “paused”. Different counting modes can be chosen. The totalizer values are continuously written to the permanent memory of the device to avoid data loss during brown-out.

Fehler! Verweisquelle konnte nicht gefunden werden. lists relevant totalizer registers, configuration settings including a brief functional description.

Register name	No.	Description
Grand Total: Mass / Volume / Std Volume	2432/2632/2832	Totalizer of type: float32 (Privileges: read only) (for Grand total: Operation mode [3], State [0])
Total no. 1: • - Mass • - Volume • - Std Volume	2434 2634 2834	
Total no. 2: • - Mass • - Volume • - Std Volume	2436 2636 2836	
Grand Total (high precision): Mass / Volume / Std Volume	2438/2638/2838	Totalizer of type: float64 (Privileges: read only) (for Grand total: Operation mode [3], State [0])
Total no. 1 (high precision): Mass / Volume / Std Volume	2442/2642/2842	
Total no. 2 (high precision): Mass / Volume / Std Volume	2446/2646/2846	
Operation mode “Total No. 1”: Mass / Volume / Std Volume	2416/2616/2816	Totalizer configuration register (uint32 read/write): [0] Forward flow count [1] Reverse flow count [2] Difference between forward / reverse flow [3] Sum between forward and reverse flow
Operation mode “Total No. 2”: Mass / Volume / Std Volume	2424/2624/2824	
State of “Total No. 1”: Mass / Volume / Std Volume	2418/2618/2818	Totalizer state register (uint32 read/write): [0] accumulating flow (running) [1] not accumulating flow (paused) [2] RESET totalizer and state: running [0] [3] RESET totalizer and state: paused [0]
State of “Total No. 2”: Mass / Volume / Std Volume	2426/2626/2826	
Totalizer unit: Mass / Volume / Std Volume	3404/3412/3416	Totalizer unit register (uint32 read/write) Selected unit is valid for all totalizer

Tab. 9: Register of available totalizer and configuration settings

4.3. Relevant device configuration commands

The device configuration is customizable, and the following chapter describes the most relevant commands. A complete description of configuration commands is available in the instruction manual on the Website.

4.3.1. Unit registers

The engineering units for process values (flow rates, density, temperature, and totalizer) can be selected via the following registers.

Register: 3406	g/s	g/min	g/h	g/d	kg/s	kg/min	kg/h	kg/d
[value] and conversion factor to g/s	[0] 1	[1] $6 \cdot e^{1}$	[2] $3.6 \cdot e^{3}$	[3] $8.64 \cdot e^{4}$	[4] $1 \cdot e^{-3}$	[5] $6 \cdot e^{-2}$	[6] 3.6	[7] $8.64 \cdot e^{1}$
	t[i]/s	**t[i]/min**	**t[i]/h**	**t[i]/d**	**lb/s**	**lb/min**	**lb/h**	**lb/d**
	[8] $1 \cdot e^{-6}$	[9] $6 \cdot e^{-5}$	[10] $3.6 \cdot e^{-3}$	[11] $8.64 \cdot e^{-2}$	[12] $2.2 \cdot e^{-3}$	[13] $1.32 \cdot e^{-1}$	[14] 7.937	[15] $1.91 \cdot e^{2}$
	tn sh[ii] /s	**tn sh[ii]/min**	**tn sh[ii]/h**	**tn sh[ii]/d**	**oz/s**	**oz/min**	**oz/h**	**oz/d**
	[16] $1.10 \cdot e^{-6}$	[17] $6.61 \cdot e^{-5}$	[18] $3.97 \cdot e^{-3}$	[19] $9.52 \cdot e^{-2}$	[20] $3.53 \cdot e^{-2}$	[21] 2.12	[22] $1.27 \cdot e^{2}$	[23] $3.05 \cdot e^{3}$

i) Metric tons

ii) Short US tons

Tab. 10: Listing of the available mass flow units

Register: 3412	l/s	l/min	l/h	l/d	m³/s	m³/min	m³/h	m³/d
[value] conversion factor to l/s	[0] 1	[1] $6 \cdot e^{1}$	[2] $3.6 \cdot e^{3}$	[3] $8.64 \cdot e^{4}$	[4] $1 \cdot e^{-3}$	[5] $6 \cdot e^{-2}$	[6] 3.6	[7] $8.64 \cdot e^{1}$
	ft³/s	**ft³/min**	**ft³/h**	**ft³/d**	**gal[i]/s**	**gal[i]/min**	**gal[i]/h**	**gal[i]/d**
	[8] $3.53 \cdot e^{-2}$	[9] 2.12	[10] $1.27 \cdot e^{2}$	[11] $3.05 \cdot e^{3}$	[12] $2.64 \cdot e^{-1}$	[13] $1.59 \cdot e^{1}$	[14] $9.51 \cdot e^{2}$	[15] $2.28 \cdot e^{4}$
	bbl[ii]/s	**bbl[ii]/min**	**bbl[ii]/h**	**bbl[ii]/d**	**kbbl[iii]/s**	**kbbl[iii]/min**	**kbbl[iii]/h**	**kbbl[iii]/d**
	[16] $6.29 \cdot e^{-3}$	[17] $3.77 \cdot e^{-1}$	[18] $2.26 \cdot e^{1}$	[19] $5.43 \cdot e^{2}$	[20] $6.29 \cdot e^{-6}$	[21] $3.77 \cdot e^{-4}$	[22] $2.26 \cdot e^{-2}$	[23] $5.43 \cdot e^{-1}$
	ml/s	**ml/min**	**ml/h**	**ml/d**	**in³/s**	**in³/min**	**in³/h**	**in³/d**
	[24] $1 \cdot e^{3}$	[25] $6 \cdot e^{4}$	[26] $3.6 \cdot e^{6}$	[27] $8.64 \cdot e^{7}$	[28] $6.1 \cdot e^{1}$	[29] $3.66 \cdot e^{3}$	[30] $2.20 \cdot e^{5}$	[31] $5.27 \cdot e^{6}$

i) US Gallones
ii) US Barrels
iii) 1000 times US Barrels

Tab. 11: Listing of the available volume flow units

Register: 3416	sl/s	sl/min	sl/h	sl/d	sm³/s	sm³/min	sm³/h	sm³/d
[Value] Conversion factor to sl/s	[0] 1	[1] 60	[2] $3.6\ e^{3}$	[3] $86.4\ e^{3}$	[4] $1\ e^{-3}$	[5] $60\ e^{-3}$	[6] 3.6	[7] 86.4
	sft³/s	**sft³/min**	**sft³/h**	**sft³/d**	**sgal/s**	**sgal/min**	**sgal/h**	**sgal/d**
	[8] $3.53{\cdot}e^{-2}$	[9] 2.12	[10] $1.27{\cdot}e^{2}$	[11] $3.05{\cdot}e^{3}$	[12] $2.64{\cdot}e^{-1}$	[13] $1.59{\cdot}e^{1}$	[14] $9.51{\cdot}e^{2}$	[15] $2.28{\cdot}e^{4}$
	sbbl/s	**sbbl/min**	**sbbl/h**	**sbbl/d**	**skbbl[iii]/s**	**skbbl[iii]/min**	**skbbl[iii]/h**	**skbbl[iii]/d**
	[16] $6.29{\cdot}e^{-3}$	[17] $3.77{\cdot}e^{-1}$	[18] $2.26{\cdot}e^{1}$	[19] $5.43{\cdot}e^{2}$	[20] $6.29{\cdot}e^{-6}$	[21] $3.77{\cdot}e^{-4}$	[22] $2.26{\cdot}e^{-2}$	[23] $5.43{\cdot}e^{-1}$
	ml/s	**ml/min**	**ml/h**	**ml/d**	**in³/s**	**in³/min**	**in³/h**	**in³/d**
	[24] $1{\cdot}e^{3}$	[25] $6{\cdot}e^{4}$	[26] $3.6{\cdot}e^{6}$	[27] $8.64{\cdot}e^{7}$	[28] $6.1{\cdot}e^{1}$	[29] $3.66{\cdot}e^{3}$	[30] $2.20{\cdot}e^{5}$	[31] $5.27{\cdot}e^{6}$

i) US Gallones
ii) US Barrels
iii) 1000 times US Barrels

Tab. 12: Listing of the available standard volume flow units

Register: 3408	kg/m³	kg/dm³	g/cm³	t/m³	kg/l	g/ml	lb/in³	lb/ft³	lb/gal[i]
[value] and conversion factor to kg/m³	[0] 1	[1] $1{\cdot}e^{-3}$	[2] $1{\cdot}e^{-3}$	[3] $1{\cdot}e^{-3}$	[4] $1{\cdot}e^{-3}$	[5] $1{\cdot}e^{-3}$	[6] $3.61{\cdot}e^{-5}$	[7] $7.79{\cdot}e^{1}$	[8] $8.345{\cdot}e^{-3}$
	oz/in³								
	[9] $5.780{\cdot}e^{-4}$								

i) US Gallones

Tab. 13: Listing of the available density units

Register: 3404	10µg	kg	g	mg	t[i]	oz	lb	t[ii]
[value] and conversion factor to 10µg	[0] 1	[1] $10{\cdot}e^{-9}$	[2] $10{\cdot}e^{-6}$	[3] $10{\cdot}e^{-3}$	[4] $10{\cdot}e^{-12}$	[5] $3.53{\cdot}e^{-7}$	[6] $2.21{\cdot}e^{-8}$	[7] $1.10{\cdot}e^{-11}$

i) Metric tons
ii) Short US tons

Tab. 14: Listing of the available mass units

Register: 3410	10µl	l	ml	cl	hl	mm³	cm³	dm³	m³
[value] and conversion factor to 10µl	[0] 1	[1] $1{\cdot}e^{-5}$	[2] $1{\cdot}e^{-2}$	[3] $1{\cdot}e^{-3}$	[4] $1{\cdot}e^{-7}$	[5] 10	[6] $1{\cdot}e^{-2}$	[7] $1{\cdot}e^{-5}$	[8] $1{\cdot}e^{-8}$
	in³	**ft³**	**gal**	**bbl**					
	[9] $6.10{\cdot}e^{-4}$	[10] $3.53{\cdot}e^{-7}$	[11] $2.64{\cdot}e^{-6}$	[12] $6.29{\cdot}e^{-8}$					

Tab. 15: Listing of the available volume units

Register: 3414	10sµl	sl	sml	scl	shl	smm³	scm³	sdm³	sm³
	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]

[value] and conversion factor to 10sµl	1	$1 \cdot e^{-5}$	$1 \cdot e^{-2}$	$1 \cdot e^{-3}$	$1 \cdot e^{-7}$	10	$1 \cdot e^{-2}$	$1 \cdot e^{-5}$	$1 \cdot e^{-8}$
	sin³	**sft³**	**sgal**	**sbbl**					
	[9] $6.10 \cdot e^{-4}$	[10] $3.53 \cdot e^{-7}$	[11] $2.64 \cdot e^{-6}$	[12] $6.29 \cdot e^{-8}$					

Tab. 16: Listing of the available standard volume units

Register: 3400	**°C**	**K**	**°F**	**°R**
[value] and conversion factor °C	[0] 1	[1] + 273.15	[2] × 1,8 + 32	[3] + 273,15 × 1,8

Tab. 17: Listing of the available temperature units

Register: 3418	**µs**	**ns**	**g/s**	**kg/min**	**kg/s**
[value] and conversion factor to µs	[0] 1	[1] $1 \cdot e^{3}$	[2] x mv	[3] x (mv / 1000) * 60	[4] x (mv / 1000)

mv = metrical variable

Tab. 18: Listing of the available zero offset units

4.3.2. Zero-offset adjustment

Under ideal conditions the Coriolis flow meter will indicate real “zero” mass flow at no flow conditions. Due to process conditions such as fluid density variation, temperature variation, pressure variation and mounting, which differ from the calibration conditions, the Coriolis flow meter might indicate a flow at no flow condition. To avoid this effect the customer should run a zero-offset adjustment, ideally under process conditions.

Once after installation and a device warm-up period of about 20 minutes, the meter should be zeroed at the actual operating conditions. An absolute flowrate of zero is required in situ using e.g., shut-off valves close to the inlet and outlet of the flow meter. Assure that valve leakage does not cause false mass flow readings. Conduct the adjustment procedure conscientiously.

Register name	No.	Description
Zero-offset procedure state	1604 (uint32)	Valid values are: [0] disabled [1] enabled and procedure is running. The state toggles to state [0] if the procedure is completed.
Duration of zero-offset procedure	1596 (uint32)	The range is between [5 … 120] s (default is 30 s).
Zero offset value	1610 (float32)	Value is in current mass flow units.
Standard deviation of zero-offset value	1612 (float32)	Value is in current mass flow units.
Error Code	1618 (uint32)	The result is checked for plausibility with regards to the average and standard deviation. If these values exceed limits a warning code is raised. Bit 0: Zero-offset procedure is running. Bit 3: Average offset value exceeds limit.

Tab. 18: Registers related to the zero-offset procedure

4.3.3. Signal filter

The TCA transmitter features high-end signal filtering for the raw signals coming from the Coriolis flow sensor. Flow rate and density filters are customizable to the application and installation requirements. The optimum filter settings are based on the system's requirements for the dynamic behavior of the flow meter. To trace quick flow rate changes and avoid latencies e.g., for dosing systems, the filter step response time should be minimized.

Process noise damping

The primary filter decreases the process noise by passing the flow meter's raw signals through a low-pass filter. The step response and cutoff frequency of the filter options are listed in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

The filter setting is applied to flow rate and density.

Register name /No.	Description			
Process noise filter ID 612 (uint32)	Privileges: read / write Ten process value filter options are available. The specified step response time is defined as the time unit 90 % of the target value is achieved.	ID	Step response time	Cutoff freq.-3 db
		[0]	0 s	100 Hz
		[1]	0.06 s	20 Hz
		[2]	0.13 s	10 Hz
		[3]	0.28 s	5 Hz
		[4]	0.57 s	2 Hz
		[5]	0.7 s	1 Hz
		[6]	1.3 s	0.5 Hz
		[7]	2.5 s	0.2 Hz
		[8]	4.5 s	0.1 Hz
		[9]	9 s	0.05 Hz

Tab. 19: Listing of the process noise filter setting

Output filter

The secondary filter is intended to individually reduce noise on the output process variables by using an EWMA-filter (Exponentially Weighted Moving Average). The EWMA-filter constant defines the weighting factor between past and current measurement values. E.g., if the value is set to 0.2, 80 % of old values and 20 % of the actual value will be considered in the next computation loop. The filter constant registers are listed in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Register name	No.	Description
Filter constant for mass flow rate	1722 (float32)	Value between [0…1] (default value: 0.2)
Filter constant for volume flow rate	2242 (float32)	
Filter constant for standard volume flow rate	2342 (float32)	
Filter constant for density	2102 (float32)	
Filter constant for process temperature	1842 (float32)	

Tab. 20: Listing of customizable signal filters

4.3.4. Error and Warning code interpretation

The flow meter does not have any customer serviceable parts. Therefore, troubleshooting capabilities are limited. To monitor the status of the device, the transmitter software provides four registers to report warnings. Additionally, its operational state is visualized with a status light turning green, yellow, or red.

In case of a high-level error (red light), check the following:

- Power supply works within specified voltage range.
- The device is fully drained or filled.

High-level errors are raised if the device cannot reach normal operation state. In error state all process output values are set to zero. The error state bits are listed in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Register No.	Bit	Description
4000 (uint32)	0	Main controller not ready
	1…6	Internal communication errors
	7…20	Specific hardware errors
4002 (uint32)	0	Sensor A amplitude below 15 mV
	1	Sensor B amplitude below 15 mV
	2	Current density falls below empty tube detection threshold: register 2104)
	3	Power supply below threshold
	4	Power supply above threshold

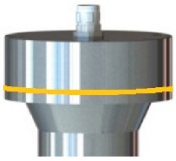
Tab. 21: Error state code interpretation

Warnings are flagged, as soon as the device detects implausible readings or limit violations, which decrease measurement quality or may even cause damages to the device. When process value limits are exceeded, certain warnings are reported. In this case, the process values are kept at the limit values until they fall below the threshold again. **Fehler! Verweisquelle konnte nicht gefunden werden.** lists possible warning codes.

If the device shows a warning code, check the following.

- The device is fully drained or filled.
- General installation recommendations are considered.

If special operating parameters cause warning codes, contact our technical support for further advice and troubleshooting.



Register No.	Bit	Description
4004 (uint32)	0…3	Process temperature above or below specified limit (see product label) Impact: Risk of damage to the flow meter
	4, 5	Process temperature sensor errors (temperature reading is fixed at 20 °C) Impact: reduced accuracy for flow rate and density
	8…17	Internal signal verification warnings
	18	Density below low limit (actual density reading is set to 1 kg/m³) Impact: reduced accuracy for volume flow rate and density
	19	Density above maximum limit Impact: reduced accuracy for volume flow rate and density
	20	Unstable process values or entrained gas warning Impact: reduced accuracy for flow rate and density
	21	Mass flow rate above maximum limit Impact: reduced accuracy for flow rate and density
4006 (uint32)	0…8	Internal communication warnings
	9, 10	Supply voltage below 7 V or above 28 V
	11, 12	Processor temperature below -40 °C or above +85 °C Impact: Risk of damage to the flow meter
	13, 14	PCB temperature below -35 °C or above +75 °C Impact: Risk of damage to the flow meter

Tab. 22: Low-level error and warning code interpretation

4.3.5. Flow meter diagnosis parameter

For detailed analysis of the critical error codes, it might be useful to read the following diagnostic registers.

Register name	No.	Description
Raw flow reading	1730 (float32)	Filtered raw flow reading
Sensor A amplitude	606 (float32)	Sensor at the inlet position: [value] in mV
Sensor B amplitude	608 (float32)	Sensor at the outlet position: [Value] in mV
Current of the drive circuit	642 (float32)	Current for tube vibration [value] in mA
Sensor frequency	604 (float32)	Natural frequency of measuring tubes [Value] in Hz
Product serial number	3240 (uint32)	Unique serial number with up to 16 digits
Order Code of the flow meter	3200…3218 (hex32)	Four string digits of the model code per register

Tab. 23: Read-only diagnosis registers

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