Instruction Manual

mini CORI-FLOW™ MI series

Industrial Coriolis Mass Flow Meters/Controllers for Liquids and Gases

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ATTENTION
Please read this document carefully before installing and operating the product.
Not following the guidelines could result in personal injury and/or damage to the equipment.
Keep this document for future reference.

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Disclaimer

The illustrations in this document serve to provide general notices regarding correct operation. The illustrations are simplified representations of the actual situation and may differ from the actual product.

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Symbols in this document

Important information. Disregarding this information could increase the risk of damage to the equipment, or the risk of personal injuries.

Tips, useful information, attention points. This will facilitate the use of the instrument and/or contribute to its optimal performance.

Additional information available in the referenced documentation, on the indicated website(s) or from your Bronkhorst representative.

Receipt of equipment

Check the outside packaging box for damage incurred during shipment. If the box is damaged, the local carrier must be notified at once regarding his liability. At the same time a report should be submitted to your Bronkhorst representative.

Carefully remove the equipment from the box. Verify that the contents of the package was not damaged during shipment. Should the equipment be damaged, the local carrier must be notified at once regarding his liability. At the same time a report should be submitted to your Bronkhorst representative.

If the product is damaged, it should not be put into service. In that case, contact your Bronkhorst representative for service.

- *Check the packing list to ensure that you received all items included in the scope of delivery.*
- *Do not discard spare or replacement parts.*

See Removal and return instructions for information about return shipment procedures.

Equipment storage

- The equipment should be stored in its original package in a climate controlled storage location.
- Care should be taken not to subject the equipment to excessive temperatures or humidity.
- See technical specifications (data sheet) for information about required storage conditions.

Warranty

Bronkhorst® products are warranted against defects in material and workmanship for a period of three years from the date of shipment, provided they are used in accordance with the ordering specifications and not subject to abuse or physical damage. Products that do not operate properly during this period may be repaired or replaced at no charge. Repairs are normally warranted for one year or the balance of the original warranty, whichever is the longer.

See also section 9 (Guarantee) of the Conditions of sales:
www.bronkhorst.com/int/about/conditions-of-sales/

The warranty includes all initial and latent defects, random failures, and indeterminable internal causes. It excludes failures and damage caused by the customer, such as contamination, improper electrical hook-up, physical shock etc.

Re-conditioning of products primarily returned for warranty service that is partly or wholly judged non-warranty may be charged for.

Bronkhorst High-Tech B.V. or affiliated company prepays outgoing freight charges when any part of the service is performed under warranty, unless otherwise agreed upon beforehand. The costs of unstamped returns are added to the repair invoice. Import and/or export charges as well as costs of foreign shipping methods and/or carriers are paid by the customer.

General safety precautions

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

Before operating, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables for cracks or breaks before each use.

The equipment and accessories must be used in accordance with their specifications and operating instructions, otherwise the safety of the equipment may be impaired.

If required, replace fuses with the same type and rating for continued protection against fire hazard.

Opening the equipment beyond the wiring terminal box cover is not allowed. There are no user serviceable parts inside. In case of a defect please return the equipment to Bronkhorst High-Tech B.V.

One or more warning signs may be attached to the product. These signs have the following meaning:

General warning; consult the instruction manual for handling instructions

Surface may get hot during operation

Shock hazard; electrical parts inside

To maintain protection from electric shock and fire, replacement components must be obtained from Bronkhorst. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Non-safety related components may be obtained from other suppliers, as long as they are equivalent to the original component. Selected parts should be obtained only through Bronkhorst, to maintain accuracy and functionality of the product. If you are unsure about the suitability of a replacement component, contact your Bronkhorst representative for information.

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1 Introduction

1.1 Scope of this manual

This manual contains general product information, installation and operating instructions and troubleshooting tips for the **MI Series Industrial mini CORI-FLOW™** industrial mass flow meters and - if combined with an external valve - controllers for liquids and gases.

1.2 Intended use

The **MI Series Industrial mini CORI-FLOW™** is designed to measure and/or control mass flow rates of non-aggressive gases and liquids in a fluid system at conditions as specified at ordering time and as stated on the serial number label. The instrument is less suitable for use with corrosive, erosive, reactive or otherwise aggressive media, as these can cause wear and damage to the measuring tube.

The instrument is built into a robust, weatherproof housing, making it especially suitable for operation in a wide range of industrial environments, like pilot plants.

Any other use than mentioned here is considered unintended.

The wetted materials incorporated in the MI Series Industrial mini CORI-FLOW™ are compatible with media and conditions (e.g. pressure, temperature) as specified at ordering time. If you are planning to use the product (including any third party components supplied by Bronkhorst, such as pumps or valves) with other media and/or other conditions, always check the wetted materials (including seals) for compatibility. See the technical specifications of the product and consult third party documentation (if applicable) to check the incorporated materials.

Responsibility for the use of the equipment with regard to its intended use, suitability for the intended application, cleaning and compatibility of process media with the applied materials lies solely with the user.

The user is responsible for taking the necessary safety measures to prevent damage and/or injury while working with the equipment and process media (as described in the associated Material Safety Data Sheets).

Where appropriate, this document recommends or prescribes safety measures to be taken with respect to media usage or working with the described equipment under the specified conditions. However, this does not relieve the user of aforementioned responsibility, not even if such is not explicitly recommended or prescribed in this document.

Bronkhorst High-Tech B.V. cannot be held liable for any damage and/or injury resulting from unintended, improper or unsafe use, or use with other media and/or under other process conditions than specified at ordering time.

1.3 Product description

The Bronkhorst® **MI Series Industrial mini CORI-FLOW™** is an accurate mass flow meter and controller for measuring gas and liquid flows, virtually independent of pressure and temperature changes. It can be operated analog, via RS-232 or HART, or via an optional fieldbus interface (CANopen, DeviceNet™, EtherCAT®, Ethernet/IP, FLOW-BUS, Modbus (RTU/ASCII/TCP), POWERLINK, PROFIBUS DP, and PROFINET). For RS-232 and FLOW-BUS communication, Bronkhorst offers free tooling software (e.g. FlowPlot).

Measuring principle

MI Series Industrial mini CORI-FLOW™ instruments contain a uniquely shaped, single loop sensor tube, forming part of an oscillating system. When a fluid flows through the tube, Coriolis forces cause a variable phase shift, which is detected by sensors and fed into the integrally mounted printed circuit board. The resulting output signal is strictly proportional to the real mass flow rate, independent of fluid density, temperature, viscosity, pressure, heat capacity or conductivity. Coriolis mass flow measurement is fast, accurate and inherently bi-directional. The **MI Series** features density and temperature of the fluid as secondary outputs.

Multi-range

The **MI Series Industrial mini CORI-FLOW™** offers multi-range functionality: factory calibrated ranges can be re-ranged to a different full scale range. The analog output and the digital measured value are scaled accordingly. Switching between ranges can be done via the RS-232 interface or the fieldbus interface (if applicable), or with a Bronkhorst® readout and control unit (E-8000, BRIGHT).

The instrument comes with a calibration certificate for all supported full scare flow ranges. The actual full scale of the instrument is set to a value as ordered and can be found on the serial number label.

Custom I/O options

The Main connector and the Actuator connector (see Product overview) each can provide additional input/output functionality, selectable from a wide range of options (see Customized I/O options). In addition to the various analog signal options and the standard RS-232 communication, there are such options as RS-485 communication, digital frequency/pulse output, alarm output/reset, valve purge/close and analog valve output.

1.4 Product overview

Left side

1. Fluid inlet
2. Indication LEDs
3. Fieldbus connection gland 1 (optional)
4. Fieldbus connection gland 2 (optional)
5. Cover

Right side

6. Additional actuator/remote display connector (optional)
7. Main connector
8. Bronkhorst® valve connector (optional)
9. Fluid outlet

Depending on the ordering details, fittings and/or connectors on your instrument might differ from the images above.

1.5 Calibration

The MI Series has been factory calibrated. Periodical inspection, recalibration or verification of the accuracy may be subject to individual requirements of the user. Whenever necessary, contact your Bronkhorst representative for information and/or making arrangements for recalibration.

Bronkhorst certifies that the instrument meets the rated accuracy. Calibration has been performed using measurement standards traceable to the Dutch Metrology Institute (VSL).

1.6 Maintenance

Inexpertly servicing instruments can lead to serious personal injury and/or damage to the instrument or the system it is used in. Servicing must therefore be performed by trained and qualified personnel. Contact your Bronkhorst representative for information about cleaning and calibration. Bronkhorst has trained staff available.

- The MI Series needs no regular maintenance if operated properly, with clean media, compatible with the wetted materials, avoiding pressure and thermal shocks and vibrations.
- The instrument's fluid path (the wetted parts) may be purged with a clean, dry and inert gas or flushed with a non-aggressive and non-corrosive cleaning liquid.
- In case of severe contamination, cleaning the the wetted parts may be necessary.

1.7 Documentation

The MI Series comes with all necessary documentation for basic operation and maintenance. At some points this document refers to other documents, most of which can be downloaded from the Bronkhorst website. Insofar as agreed upon within the framework of the sales agreement, calibration certificates, test certificates and material certificates are included in the scope of delivery.

*The documentation listed in the following table is available on the **MI Series** product pages under **www.bronkhorst.com/products** :*

Type	Document name	Document no.
Manuals	Instruction Manual MI Series Industrial mini CORI-FLOW™ (this document)	9.17.120
Technical documentation	Hook-up diagram Analog, RS-232, HART	9.16.199
	Hook-up diagram DeviceNet™, CANopen	9.16.262
	Hook-up diagram EtherCAT®, Ethernet/IP, Modbus TCP, POWERLINK, PROFINET	9.16.200
	Hook-up diagram FLOW-BUS	9.16.201
	Hook-up diagram Modbus (ASCII/RTU)	9.16.202
	Hook-up diagram PROFIBUS DP	9.16.203
	Hook-up diagram custom bus & I/O configurations	9.16.205
	Dimensional drawing	7.14.001

The documentation listed in the following table can be downloaded from ***www.bronkhorst.com/downloads*** *:*

Type	Document	Document no.
General documentation	EU Declaration of Conformity	9.06.059
Instruction manuals	Manual CANopen	9.17.131
	Manual DeviceNet™	9.17.026
	Manual EtherCAT® interface	9.17.063
	Manual Ethernet/IP	9.17.132
	Manual FLOW-BUS interface	9.17.024
	Manual HART interface	9.17.121
	Manual Modbus interface	9.17.035
	Manual POWERLINK	9.17.142
	Manual PROFIBUS DP interface	9.17.025
	Manual PROFINET interface	9.17.095
	Manual RS-232 interface	9.17.027

2 Product specifications

Before installing the MI Series, check that the functional and technical properties of the product match your requirements. If you have a question about the product or if you find the product does not meet the specifications as ordered, do not hesitate to contact your Bronkhorst representative. See section Service for contact information.

The serial number label shows some essential technical specifications of the product as ordered (note that the image on the right does not necessarily reflect the actual specifications of your MI Series instrument):

- Flow/pressure rate(s)
- Process media
- Inlet and outlet pressure(s)
- Operating temperature

The model key on the second line of the label contains more detailed information about the technical properties of the product as ordered.

Where applicable, follow the directions on any additional labels in order to ensure a safe working environment and to comply with the regulations applicable to the product and its operating environment.

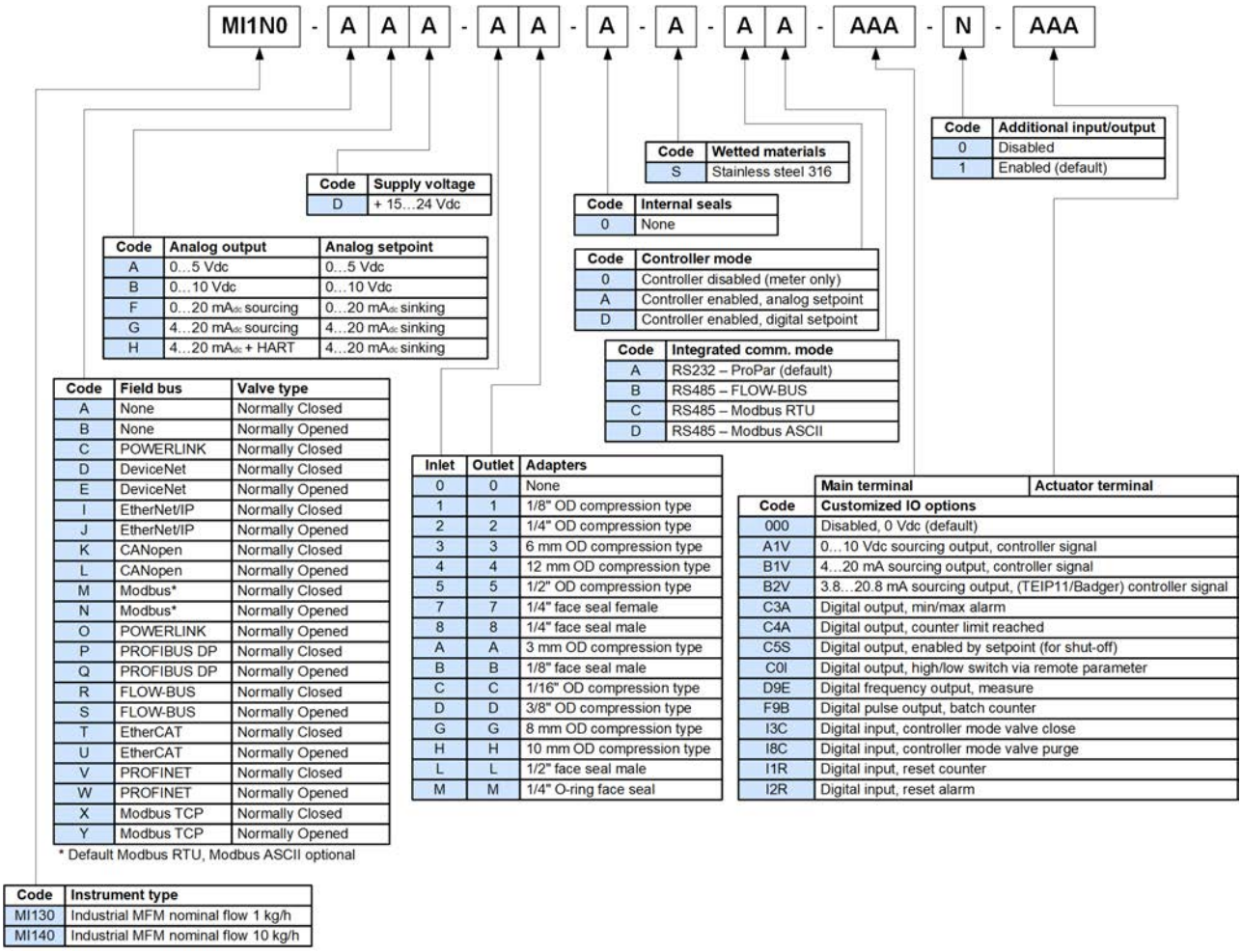
2.1 Pressure rating

*Bronkhorst® instruments are pressure tested to at least 1.5 times the specified operating pressure and outboard leak tested to at least 2 * 10^{-9} mbar l/s Helium.*

- *The test pressure is stated on a red label on the device; if this label is missing or if the test pressure is insufficient, the device must not be used and should be returned to the factory.*
- *Before installation, make sure that the pressure rating is within the limits of the normal process conditions and that the tested pressure is in accordance with the safety factor of your application.*
- *Disassembling and/or replacing fluid system related parts of the device will invalidate the test pressure and leak test specification.*

2.2 Model key

The model key contains information about the technical properties of the instrument as ordered. The actual properties of your instrument can be retrieved from the diagram below.



Code	Instrument type
MI130	Industrial MFM nominal flow 1 kg/h
MI140	Industrial MFM nominal flow 10 kg/h

Code	Supply voltage
D	+ 15…24 Vdc

Code	Analog output	Analog setpoint
A	0…5 Vdc	0…5 Vdc
B	0…10 Vdc	0…10 Vdc
F	0…20 mA$_{dc}$ sourcing	0…20 mA$_{dc}$ sinking
G	4…20 mA$_{dc}$ sourcing	4…20 mA$_{dc}$ sinking
H	4…20 mA$_{dc}$ + HART	4…20 mA$_{dc}$ sinking

Code	Field bus	Valve type
A	None	Normally Closed
B	None	Normally Opened
C	POWERLINK	Normally Closed
D	DeviceNet	Normally Closed
E	DeviceNet	Normally Opened
I	EtherNet/IP	Normally Closed
J	EtherNet/IP	Normally Opened
K	CANopen	Normally Closed
L	CANopen	Normally Opened
M	Modbus*	Normally Closed
N	Modbus*	Normally Opened
O	POWERLINK	Normally Opened
P	PROFIBUS DP	Normally Closed
Q	PROFIBUS DP	Normally Opened
R	FLOW-BUS	Normally Closed
S	FLOW-BUS	Normally Opened
T	EtherCAT	Normally Closed
U	EtherCAT	Normally Opened
V	PROFINET	Normally Closed
W	PROFINET	Normally Opened
X	Modbus TCP	Normally Closed
Y	Modbus TCP	Normally Opened

* Default Modbus RTU, Modbus ASCII optional

Inlet	Outlet	Adapters
0	0	None
1	1	1/8" OD compression type
2	2	1/4" OD compression type
3	3	6 mm OD compression type
4	4	12 mm OD compression type
5	5	1/2" OD compression type
7	7	1/4" face seal female
8	8	1/4" face seal male
A	A	3 mm OD compression type
B	B	1/8" face seal male
C	C	1/16" OD compression type
D	D	3/8" OD compression type
G	G	8 mm OD compression type
H	H	10 mm OD compression type
L	L	1/2" face seal male
M	M	1/4" O-ring face seal

Code	Internal seals
0	None

Code	Wetted materials
S	Stainless steel 316

Code	Controller mode
0	Controller disabled (meter only)
A	Controller enabled, analog setpoint
D	Controller enabled, digital setpoint

Code	Integrated comm. mode
A	RS232 – ProPar (default)
B	RS485 – FLOW-BUS
C	RS485 – Modbus RTU
D	RS485 – Modbus ASCII

	Main terminal	Actuator terminal
Code	Customized IO options	
000	Disabled, 0 Vdc (default)	
A1V	0…10 Vdc sourcing output, controller signal	
B1V	4…20 mA sourcing output, controller signal	
B2V	3.8…20.8 mA sourcing output, (TEIP11/Badger) controller signal	
C3A	Digital output, min/max alarm	
C4A	Digital output, counter limit reached	
C5S	Digital output, enabled by setpoint (for shut-off)	
C0I	Digital output, high/low switch via remote parameter	
D9E	Digital frequency output, measure	
F9B	Digital pulse output, batch counter	
I3C	Digital input, controller mode valve close	
I8C	Digital input, controller mode valve purge	
I1R	Digital input, reset counter	
I2R	Digital input, reset alarm	

Code	Additional input/output
0	Disabled
1	Enabled (default)

2.3 Customized I/O options

Optionally, MI Series instruments can be equipped with up to two additional input/output functions. These options are factory installed as specified at ordering time, and cannot be changed manually.

The model key on the serial number label contains information about the customized I/O configuration of your instrument. The possible configurations are described in the table below. Consult the hook-up diagram for custom bus and I/O configurations for an explanation of the codes.

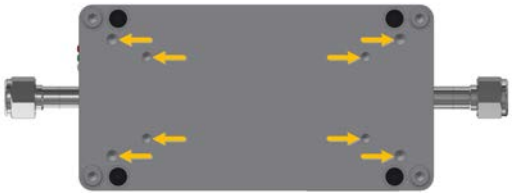
Code	Description
000	Disabled, M8/A2 is pulled down to 0Vdc (default selection)
A1V	0…10Vdc sourcing output, controller Analog signal for pump or external valve steering (control signal only) When the controller output is used for pump or external valve steering (mass flow meters only), make sure to set parameter *Valve maximum* to 0.3 [A]. For mass flow controllers, the controller output is limited to a value below 10Vdc, due to the maximum valve current restriction.
B1V	4…20mA sourcing output, controller Analog signal for pump or external valve steering (control signal only). When the controller output is used for pump or external valve steering (mass flow meters only), make sure to set parameter *Valve maximum* to 0.3 [A]. For mass flow controllers, the controller output is limited to a value below 20mA, due to the maximum valve current restriction.
B2V	3.8…20.8mA sourcing output, controller Analog signal for Badger Meter valve with TEIP11 signal converter (control signal only)
C3A	Digital output, min/max alarm During a min/max alarm, M8/A2 is pulled down to 0Vdc.
C4A	Digital output, counter alarm During a counter alarm, M8/A2 is pulled down to 0Vdc.
C5S	Digital output, enabled by setpoint (for shut-off control) M8/A2 is pulled down to 0Vdc at a controller setpoint, e.g. for shut-off valve activation. For factory selected analog control: If parameter *Control mode* is set for analog control by factory, the minimum setpoint at which the device (shut-off valve) connected to M8/A2 is activated is 1.9%. This prevents possible noise on the analog input activating the device accidentally. For factory selected digital control: If parameter *Control mode* is set for digital control by factory, the setpoint threshold for activating the device connected to M8/A2 is any value > 0. Note: If the instrument is forced into Valve Safe State, the digital output is not affected, so a (n/c) shut-off valve connected to M8/A2 will not close when the (n/c) controller is in Valve Safe State' Make sure to use 24Vdc power supply corresponding to the shut-off valve specifications.
C0I	Digital output, high/low switch via remote parameter (e.g. for shut-off valve control) M8/A2 is pulled down to 0Vdc when writing value 1 to parameter *IO switch status*, this is undone by writing value 0. A device connected to M8/A2 (e.g. a shut-off valve) can be activated/de-activated by writing parameter *IO switch status*. Note: If the instrument is forced into Valve Safe State, the digital output is also affected, so a (n/c) shut-off valve connected to M8/A2 will be closed when the (n/c) controller is in 'Valve Safe State'. Make sure to use 24Vdc power supply corresponding to the shut-off valve specifications.

Code	Description
D9E	Digital frequency output, measure Measurement value is translated to a frequency within given frequency range. The default frequency range to represent 0…100% flow is 0…10000 Hz. Any other frequency range must be specified on order.
F9B	Digital pulse output, batch counter M8/A2 is pulled down to 0Vdc when a given batch size is reached (during a given pulse length). By default, a pulse is given at each 1x the *Counter unit* batch value, with a pulse length of 1 second. For instance, when *Counter unit* is set to 'ln', a pulse is given each time 1 ln has passed through the instrument. An alternative pulse length must be specified on order. Provide a pull-up resistor of 5…10kOhm to create 15…24Vdc at M8/A2 (according to the applicable hook-up diagram).
I3C	Digital input, controller mode valve close Valve closes when M8/A2 is connected to 0Vdc. This option switches between the default *Control mode* and mode 'Valve Close' (value 3). When the default *Control mode* is digital, the default value is 0 (bus/RS-232), when the default *Control mode* is analog, the default value is 1 (Analog input).
I8C	Digital input, controller mode valve purge Valve is fully opened when M8/A2 is connected to 0Vdc. This option switches between the default *Control mode* and mode 'Valve Fully Open' (value 8). When the default *Control mode* is digital, the default value is 0 (bus/RS-232), when the default *Control mode* is analog, the default value is 1 (Analog input).
I1R	Digital input, reset counter The counter resets when M8/A2 is connected to 0Vdc.
I2R	Digital input, reset alarm The alarm resets when M8/A2 is connected to 0Vdc.

3 Installation

3.1 Mounting

For optimal performance, installation in a vibration free position is essential. The bottom of the instrument body is fitted with two sets of 4 mounting holes; use these mounting holes to fixate the instrument to a firm, rigid base or heavy, vibration free mass, such as a wall, a heavy rig or another stable construction. If such a facility is not available, Bronkhorst can supply special suspension pads for stable, vibration free fixation. These suspension pads are for upright mounting of the MI Series only and can be installed in the outer mounting holes. Contact your local Bronkhorst representative for more information.



- *Always use the mounting holes to fixate the instrument. Consult the dimensional drawing for the exact locations and size of the mounting holes.*
- *Also make sure that the instrument is not suspended by the piping and take adequate measures to isolate the instrument from vibrations in the piping.*

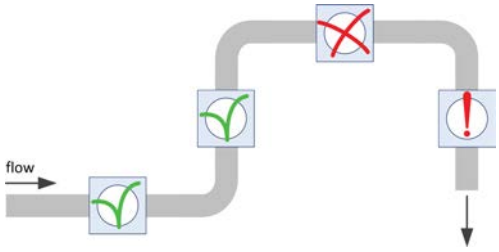
3.1.1 Orientation

Generally, the reliability of a MI Series instrument is not affected by the mounting orientation.

3.1.2 Location in fluid system

For **gas applications**: if there is a chance of condensation or if the gas stream can contain solid particles, it is advisable not to mount the instrument at the lowest point of a pipe segment. In more general terms, mount the instrument in a location where condensate or particles (if any) cannot accumulate inside the instrument's media conduits.

In **liquid applications**, the presence of gas bubbles in the liquid can cause measurement errors. If there is a risk of expansion of dissolved gas in the metered liquid, the instrument should be mounted in a pipe segment where gas bubbles cannot accumulate. The image to the right shows the preferable mounting locations.



- The best location is a horizontal pipe segment or a segment where the fluid direction is upward.

- Gas might accumulate in a horizontal segment if it is followed by a downward segment. Do NOT mount the instrument in a location like this.

- Mounting in a downward pipe segment with an open end is strongly dissuaded, especially if the pipe diameter is 1/2" or more. Gravity might cause the segment to drain; depending on the system dimensions and the viscosity of the metered fluid, this effect might be stronger or weaker.
- If the instrument is part of a closed fluid system, mounting the instrument in a downward pipe segment is not preferable, but may be considered if other mounting locations are more problematic.

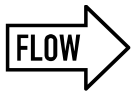
To minimize the risk of gas entrapment by cavitation, the preferred location to install a control valve is downstream from the instrument, for a pump the preferred location is upstream.

3.1.3 Piping requirements

- *For reliable performance, make sure the fluid stream is uncontaminated. If necessary, use an inlet filter to ensure a moisture, oil and particle free gas stream. Select a filter with a surface area and pore size that minimize the pressure drop.*
- *If back flow could occur, the use of a check valve is also recommended.*

3.1.4 Fluid connections

- Install the MI Series in the process line, in accordance with the direction of the FLOW arrow on the base of the instrument.
- For leak tight installation, follow the guidelines of the supplier of the fittings.



Bronkhorst® MI Series meters/controllers can be fitted with different fitting types (e.g. compression or face-seal) or special fitting types on request.

Check the fluid system for leak tightness after any modification and before applying full operating pressure, especially when using hazardous media (e.g. toxic or flammable).

After using the MI Series for the first time with low temperature media, re-tighten the fluid connectors in order to prevent leakage.

3.1.5 Mechanical isolation

- *If multiple MI Series instruments will be used in the same fluid system or close to each other, vibrations from one instrument might interfere with the resonance frequency of another, e.g. through piping or a mounting frame.*
- *Isolate instruments mechanically by mounting them on individual, rigid, stiff bases. Preferably, mount multiple instruments parallel to each other, and use flexible piping.*

3.2 Electrical connection

- Electrical connections must be made according to the applicable hook-up diagrams, using suitable cables with respect to required supply current, voltage loss, cable and gland diameters and operating conditions.
- When using self-assembled cables, follow the guidelines provided by the connectors' manufacturer.
- For use in fieldbus systems, follow the instructions of the cable supplier for the specific fieldbus system.
- Make sure that the power supply is suitable for the power ratings as indicated on the serial number label (see model key), and that double or reinforced insulation is used for the power supply.
- If a surge protection device is used, make sure its specifications match the power consumption of the application.
- Before powering up, make sure all required cabling is properly connected.
- Before each use, inspect cabling and connectors for damage.

*The equipment described in this document contains electronic components that are susceptible to **electrostatic discharge**. In order to prevent damage, proper handling procedures must be followed during installation, (dis)connecting and removing the electronics.*

*The equipment carries the CE-mark and is **compliant with the concerning EMC requirements**. However, EMC requirements can only be met using appropriate cables and connector/gland assemblies. Cable wire diameters must be sufficient to carry the supply current, and voltage loss must be kept as low as possible.*

*When connecting the product to other devices, be sure that the integrity of the shielding is not affected; **always use shielded cabling for signals and communication and do not use unshielded wire terminals.***

When in doubt about the suitability of your cabling, contact your Bronkhorst representative.

***Never** power the instrument simultaneously from **two different power sources** (e.g. fieldbus and Plug-in Power Supply). Doing so will blow the power line fuse on the wiring terminal box.*

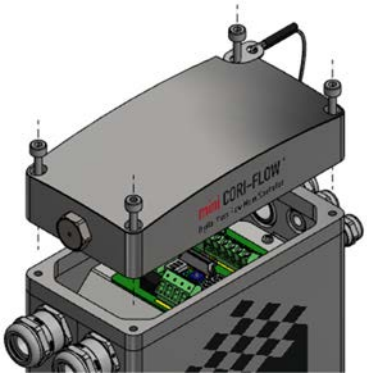
Always turn off electrical power before connecting or disconnecting equipment electrically.

3.2.1 Accessing wiring terminals

- *The instrument cover may only be opened in a clean, dry and non-hazardous environment.*
- *Before opening the cover, make sure that the operating environment is perfectly safe and that the electrical components cannot be affected by moisture or aggressive atmospheric components.*
- *Ensure that no particles, objects, etc. can fall into the instrument when the cover is open.*

To connect an instrument with custom gland connectors, the cover has to be removed in order to access the wiring terminal box. To remove the cover, unscrew the 4 screws on top of the instrument with a size 4 hex key and lift the cover from the instrument housing.

Refer to the applicable hook-up diagram for detailed wiring information. A hook-up legend is also printed on the inside of the cover.



All wiring terminals are suitable for cables with a core diameter from 0.25 to 1.5 mm^2.

- *To ensure proper shielding, connect the cable shielding with the glands before re-installing them to the instrument housing.*
- *For instruments with plastic cable glands, use the supplied clamps to connect the shielding to the metal base plate of the wiring terminal box.*

4 Operation

After correct installation and taking all necessary safety precautions, the MI Series can be used to measure and/or control flow.

4.1 Powering up

After cleaning at high temperature, allow the instrument to return to ambient temperature before turning it on.

To maintain control of the fluid system and ensure a safe situation, it is recommended to turn on power before applying fluid pressure and to switch off power only after the fluid system is depressurized.

When pressurizing, prevent pressure shocks by gradually bringing the fluid system to the required operating pressure.

For best performance, allow the device to warm up and stabilize for at least 30 minutes before starting measurement and/or control. This may be done with or without media flow.

When powering up, the instrument needs a couple of seconds to start up the electronics and perform a self-test. After successful initialization, the green LED will glow continuously to indicate that the instrument is ready to use.
After powering up, the control valve will act according the last known setpoint. When setpoint is 0, this means the valve closes (normally open) or stays closed (normally closed). The valve stays closed until the instrument receives a new valid setpoint from the active setpoint source.

4.2 First use

- *Despite the fact that everything necessary has been done to ensure the cleanliness of the product upon delivery, the presence of some remaining contamination cannot be ruled out completely.*
- *In order to prevent undesired reactions, purging the MI Series for a minimum of 30 minutes with a dry, inert gas (like Nitrogen or Argon) is recommended before first use. In systems for use with corrosive or reactive media, this is even absolutely necessary.*
- *During the manufacturing process, the instrument has been tested with water. Purging prior to first use is also recommended to remove any remaining water droplets.*

The very first time the instrument is used, adjusting the zero point is recommended. See Adjusting zero point for background information and instructions.

4.3 Preventing slug flow

Reliable measurement results can only be obtained if the fluid flows through the instrument in a single state (either gas or liquid). The following measures can help prevent so called 'slug flow' (two-phase flow):

Before starting measurement and control:

- *for liquid applications, remove (dissolved) gas from the system, by flushing the instrument and all fluid lines with the process fluid at a high flow rate.*
- *for gas applications, remove condensation from the system, by purging the instrument and all fluid lines with a dry gas at a high flow rate.*

During measurement and control:

- *avoid external heating or cooling (can cause gas bubbles in liquid or condensation of gas).*
- *avoid extreme pressure fluctuations (can cause cavitation in liquid or condensation of gas).*

4.4 After use

- *Depending on the properties of the process medium and the (expected) time until the next use, it is advisable to flush the fluid system with a suitable (cleaning) fluid after use.*
- *If the equipment has been used to process corrosive, reactive or hazardous media (e.g. toxic or flammable), cleaning the fluid system is imperative before it is exposed to air.*
- *If the equipment is not used for an extended period, the fluid system should be dry after use and after cleaning. If not, it should be purged with a dry, inert gas for a minimum period of 30 minutes.*

4.5 Powering down

- *Prior to powering down the MI Series, the fluid system should be depressurized.*
- *When depressurizing, prevent sudden pressure changes, by shutting off the fluid supply gradually.*

4.6 Valve Safe State

The MI Series Industrial mini CORI-FLOW™ can operate an external control valve, using the analog actuator output signal.

When a controlling instrument is not powered or cannot communicate with the fieldbus network (if applicable), all electrical valves operated by the instrument (whether integrated or external) automatically return to their default state. The default state is closed for 'normally closed' valves (n/c) and fully open for 'normally open' valves (n/o).

Check the serial number label or the technical specifications to see which valve type is used on your instrument (if applicable).

4.7 Temperature considerations

Although the MI Series Industrial mini CORI-FLOW™ has excellent temperature stability, the best accuracy is achieved when temperature gradients within and across the instrument are prevented. Observe the following attention points:

- Keep the media temperature as close as possible to the ambient temperature, and above the dew point of the ambient air.
- Do not allow the media temperature to drop more than 10 °C below the ambient temperature or take measures to prevent condensation.
- Always keep the media temperature above the freezing point.
- To prevent simultaneous heating and cooling of different parts of the instrument, make sure the ambient temperature is as stable and evenly distributed across the environment as possible.
- Prevent temperature shocks; heating or cooling should amount to no more than 1 °C per second.
- The MI Series will show an amount of self heating, due to power dissipation of the electronics. Depending on media and ambient temperature, this effect can be as large as 10 °C. In practice, there will be a balance between media temperature, self heating and ambient temperature.
- Operation in a cool environment can compensate somewhat for the effect of high media temperature.
- Heating and cooling effects also depend on the cooling/heat conductivity of the construction on which the instrument is mounted.

- *In normal operation mode, the fluid temperature should stay between -20 °C and 70 °C.*
- *The media temperature can be monitored with digital parameter* Temperature.

4.7.1 Preventing condensation

In a moist environment, water condensate may precipitate on the measuring tube if the media temperature is significantly lower than the ambient temperature. Condensed water increases the tube's mass, causing a density measurement error.

Continuous purging of the housing interior with a dry, inert gas like Nitrogen can help prevent condensation. Contact your Bronkhorst representative for setting up an optimal purging configuration.

4.7.2 Cleaning temperature

The MI Series may be cleaned with high temperature fluids. The maximum allowable temperature of the cleaning media depends on the ambient temperature:

- At ambient temperatures below 25 °C, the maximum allowable cleaning fluid temperature is 125 °C for a maximum of 30 minutes.
- At ambient temperatures from 25 °C, the maximum allowable cleaning fluid temperature is 105 °C for a maximum of 30 minutes.

- *With cleaning fluid temperatures above 70 °C, the instrument must be powered off during the cleaning cycle.*
- *After cleaning at high temperature, allow the instrument to return to ambient temperature before turning it on.*

4.8 Communication interface

The following table lists the communication interfaces the MI Series can be equipped with (ex factory):

Connector/terminal	Type	Communication standard	Fieldbus/protocol
Main	Analog	0…5Vdc 0…10Vdc 0…20mA 4…20mA	n/a
	Digital	RS-232	ProPar
		RS-485	FLOW-BUS Modbus (RTU/ASCII)
		HART	HART
Fieldbus	Digital	RS-485	FLOW-BUS Modbus (RTU/ASCII) PROFIBUS DP
		CAN	CANopen DeviceNet™
		Ethernet	PROFINET EtherCAT® EtherNet/IP Modbus TCP POWERLINK PROFINET

Which communication interface(s) the instrument is equipped with, is specified at ordering time:
- *In analog mode, the instrument is set to the specified voltage/current range.*
- *The fieldbus connection only provides the specified fieldbus interface (if ordered).*
- *A digital interface on the main terminal is optional.*

Simultaneous analog and digital operation

- *The instrument can be monitored and operated through the analog and a digital interface simultaneously, but it only accepts a setpoint from one of both (this is called the control mode; see Special parameters for more information).*
- *In analog mode, the analog input and output signals are translated to the digital setpoint and measure parameter respectively.*

4.8.1 Analog operation

With analog operation the following signals are available:

- output signal: measured value
- input signal: setpoint (controller only)

Setpoints below 2% of the full scale will be interpreted as 0%.

4.8.2 Digital operation

Digital operation (RS-232 or fieldbus) adds extra features to the instrument, such as:

- Direct reading with a readout/control module or host computer
- Diagnostics
- Multi-range functionality
- Device identification
- Secondary measurement outputs: density and temperature readout
- Adjustable minimum and maximum alarm limits (Alarms)
- (Batch) counter (Counter)
- No limitations on setpoint values below 2 %

4.8.2.1 RS-232 operation

RS-232 operation with the instrument is always possible through the micro USB service port near the wiring terminals (see Hardware interface), even if the instrument is configured for RS-485 operation. Connecting the service port with a standard micro USB to USB2.0 adapter cable to a Windows computer enables operation with the FlowWare software tools.

Digital Bronkhorst® instruments can be monitored and operated using the free **FlowWare** software tools for Windows. These tools provide a graphical interface to the ProPar protocol (used by FLOW-BUS), for monitoring and editing parameter values.

The FlowWare toolkit provides functionality for monitoring and operating digital instruments (Bronkhorst FlowSuite, FlowPlot) and selection of the active fluid and configuration of the fieldbus connection (if applicable). For instruments that support the definition and use of multiple fluids, FlowTune™ can be used to define and store fluids in the instrument and select the active fluid.

Digital instrument parameters are made accessible by **FlowDDE**, a Dynamic Data Exchange server (DDE) that handles communication between the instrument and (dedicated) client software in Windows (e.g. FlowPlot). FlowDDE can also be used by other client applications, such as Microsoft Office or custom made software, built with third party development software like LabVIEW or a SCADA platform.

*The FlowWare tools and associated documentation can be downloaded from the product pages on the Bronkhorst website: **www.bronkhorst.com/products***

*For more information about communication through the RS-232 interface, consult the **RS-232 manual** (document no. 9.17.027).*

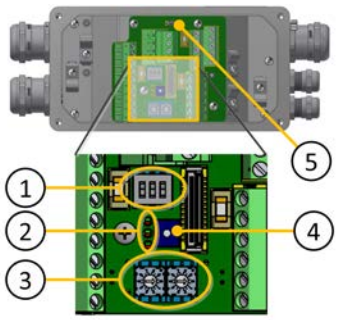
4.8.2.2 Fieldbus operation

Not all parameters described in this document are necessarily available with all digital interface types. For information about parameter access and availability for Bronkhorst® instruments in a specific fieldbus network, consult the according fieldbus manual.

4.9 Hardware interface

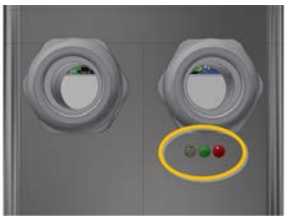
- *The instrument cover may only be opened in a clean, dry and non-hazardous environment.*
- *Before opening the cover, make sure that the operating environment is perfectly safe and that the electrical components cannot be affected by moisture or aggressive atmospheric components.*
- *Ensure that no particles, objects, etc. can fall into the instrument when the cover is open.*

The wiring terminal box under the instrument cover provides several hardware controls. Depending on the installed digital interface type, the following controls are available:



No.	Control	Function	No fieldbus	CANopen DeviceNet™ FLOW-BUS Modbus (ASCII/RTU)	EtherCAT® Ethernet/IP Modbus TCP POWERLINK PROFINET	PROFIBUS DP
1.	Bus termination switch	Bus termination		✓		✓
2.	Indication LEDs	Visual indications	✓	✓	✓	✓
3.	Rotary switches	Node address selection		✓		✓
4.	Multifunctional switch	Starting functions	✓	✓	✓	✓
5.	Service port (micro USB)	RS-232 communication	✓	✓	✓	✓

4.9.1 LED indications



The LED indications from the wiring terminal box are redirected to the exterior of the instrument. On the side of the fluid inlet, directly under the fieldbus connection glands (or sealing caps on instruments with no fieldbus interface), the instrument is equipped with 3 LED indicators:

Position	Color	Function
Left	● / ● (bi-color; green/red)	interface status*
Middle	● (green)	operational mode (Mode/MOD/RUN)**
Right	● (red)	error/warning messages (Error/Err/NET)**

*) The *Interface status* LED is only used by (Ethernet based) interface types EtherCAT®, POWERLINK and PROFINET.
**) Different interface types use specific names for the different indicator LEDs (indicated between brackets, also see the specific fieldbus manual).

The tables below list the different LED indications:

● **Mode**		
Pattern	**Time**	**Indication**
off	continuous	Power-off or program not running
on	continuous	Normal operation mode
short flash	0.1 sec on, 2 sec off	No bus communication, valves are in safe state
blink	0.2 sec on, 0.2 sec off	Special function mode; the instrument is busy performing a special function (e.g. autozero or self-test)
long flash	2 sec on, 0.1 sec off	Configuration mode; the baud rate and bus type for the Main terminal are set to 38400 and RS-232 FLOW-BUS (ProPar) respectively

● **Error**			
Pattern	**Time**	**Indication**	
on	continuous	Liquid application: measuring error (no liquid in measuring tube); flush instrument to remove gas **OR** Critical error; the instrument needs servicing before it can be used	
short flash	0.1 sec on, 2 sec off	**FLOW-BUS** **PROFIBUS DP** **Modbus** **EtherCAT®** **PROFINET**	Node occupied: re-install instrument No data exchange between master and slave (automatic recovery) Data is being received or transmitted Instrument is not in OP mode No application relation established
blink	0.2 sec on, 0.2 sec off	**FLOW-BUS**	Waiting for communication, check communication settings of all FLOW-BUS devices in the fieldbus setup. Usually the 'last node address' setting of one of the devices is incorrect.
long flash	2 sec on, 0.1 sec off	**PROFIBUS DP** **EtherCAT®** **PROFINET**	Requested parameter not available Configuration error Configuration error (e.g. a requested parameter is not available)

● Mode and ● Error (alternating)		
Pattern	**Time**	**Indication**
slow wink	1 sec on, 1 sec off	Alarm indication; minimum/maximum alarm, power-up alarm, limit reached or batch size reached
normal wink	0.2 sec on, 0.2 sec off	Wink mode; by sending a command to the *Wink* parameter, the instrument flashes its LEDs to indicate its position in a (large) system.
fast wink	0.1 sec on, 0.1 sec off	Selected action started (after releasing the multifunctional switch)

4.9.2 Multifunctional switch

Some special instrument functions can be started manually using the multifunctional switch near the indication LEDs. These functions are available in analog as well as in digital operation mode.

4.9.2.1 Normal operating functions

- In order to access these functions, press and hold the switch while the instrument is in normal operation mode (green LED lit continuously).
- As long as the switch is held, the LEDs show a repeating sequence of patterns, where each pattern indicates a function.
- All patterns in this sequence are continuous.
- Each pattern is shown for a number of seconds; in the table below, the column labeled *Hold time* indicates the time frame during which a pattern is shown.
- To start the required function, release the switch when the LEDs show the associated pattern.

● (green)	● (red)	Hold time	Function
off	off	0…1 sec	No action
off	off	1…4 sec	1. In case of a min/max alarm: reset alarm 2. FLOW-BUS: Auto-install to bus - lets instrument obtain free node address Note: min/max alarm (if any) has to be reset before auto install can be performed.
off	on	4…8 sec	Reset instrument; clear all warnings and error messages and restart the instrument
on	off	8…12 sec	Auto-zero; re-adjust the zero-point of the instrument (flow meters/controllers only)
on	on	12…16 sec	Enable FLASH mode for firmware update: • the instrument shuts down and both LEDs are switched off • at the next power-up, the instrument will be active again

- *See Adjusting zero point for background information and instructions on how to adjust the zero point of an instrument.*
- *Do not adjust the zero point before having taken notice of the instructions.*

4.9.2.2 Power-up functions

- In order to access these functions, press and hold the switch while powering up the instrument.
- The available functions are presented in a repeating sequence of patterns, where each pattern indicates a function.
- Indications in this sequence are flashing (0.2 sec on, 0.2 sec off).
- To start a function, release the switch when the LEDs show the pattern of the required function.

● (green)	● (red)	Time	Function
off	off	0…4 sec	No action
off	on	4…8 sec	Restore factory settings (except communication settings)
on	off	8…12 sec	FLOW-BUS only: Auto install to bus; let the instrument obtain a free node address from the FLOW-BUS system
on	on	12…16 sec	Activate configuration mode • The Main terminal is set to RS-232 communication (ProPar) at baud rate 38400 • In configuration mode, the green LED blinks 2 seconds on and 0.1 second off • Configuration mode remains active after powering down and can be deactivated by selecting this function again at the next start-up

4.9.2.3 Control mode - readout/change

Reading control mode

- By briefly pressing the switch 2 times within 1 second in normal operation mode, the instrument shows its current control mode with a series of consecutive LED indication patterns.
- The number of flashes corresponds to the current value of parameter *Control Mode* (see Special parameters).

Step	Pattern		Indication
1	Green	● ○	number of flashes indicates the tens of the parameter value
2	Red	○ ●	number of flashes indicates the units of the parameter value

Examples:

- for value 1 (control mode 'Analog input'), the green LED will flash 0 times and the red LED 1 time
- for value 22 (control mode 'Valve Safe State'), the green and red LED will each flash 2 times

Changing control mode

- By briefly pressing the switch 4 times with intervals of up to 1 second in normal operation mode, the instrument enters a state in which the control mode can be changed.
- This is done in 2 steps, each represented by a LED indication pattern (green or red; see table below).
- The number of flashes corresponds to the available values of parameter *Control Mode* (see Special parameters).
- At the start of each step, the according LEDs starts flashing fast (0.1 second on, 0.1 second off). By pressing and holding the switch, the associated action is started and the flashing slows (0.5 seconds on, 0.5 seconds off).

Step	Pattern		Maximum flash count	Action
1	Green	● ○	2	set tens of parameter value
2	Red	○ ●	9	set units of parameter value

To execute a step, follow these instructions:
- Press and hold the switch (flashing slows)
- To select value 0 (zero), release the switch within 1 second, otherwise:
- Count the number of LED flashes
- Release the switch when the required value is reached
- In case you lose count, keep the switch pressed and wait until the flash count reaches its maximum and restarts

On completion of step 1, the instrument automatically advances to step 2. When both steps have been completed, the instrument returns to its normal operation mode.
If the switch is not pressed within 60 seconds after starting a step, all changes are canceled and the instrument returns to its normal operation mode.

Note that this procedure also sets the default control mode of the instrument (contrary to changing the control mode digitally).

4.9.2.4 Network settings - readout/change

Reading network settings

- By briefly pressing the switch 3 times with intervals of up to 1 second in normal operation mode, the instrument shows its current node address and baud rate with a series of consecutive LED indication patterns:

Step	Pattern		Indication
1	Green	● ○	number of flashes indicates the tens of the node address
2	Red	○ ●	number of flashes indicates the units of the node address
3	Green and red (simultaneous)	● ●	number of flashes indicates the baud rate

Examples:
- for node address 35, the green LED will flash 3 times and the red LED 5 times
- for node address 116, the green LED will flash 11 times and the red LED 6 times

On DeviceNet™ the node address is called MAC ID.

The number of flashes for the baud rate indication is associated with the following baud rates:

Number of flashes (index)	Baud rate					
	FLOW-BUS	Modbus (ASCII/RTU)	PROFIBUS DP	CANopen	DeviceNet™	Ethernet based
0			automatically detected			
1	187500	9600	9600	1000000	125000	100000000
2	400000	19200	19200	800000	250000	
3		38400	45450	500000	500000	
4		56000	93750	250000		
5		57600	187500	125000		
6		115200	500000	50000		
7		128000	1500000	20000		
8		256000	3000000	10000		
9			6000000			
10			12000000			

Changing network settings

- By briefly pressing the switch 5 times with intervals of up to 1 second in normal operation mode, the instrument enters a state in which the node address and baud rate can be changed (non-Ethernet based protocols only; for Ethernet based protocols, network parameters are configured by the fieldbus master and cannot be set on the instrument).
- Changing network parameters with the multifunctional switch is done in 3 steps, each represented by a LED indication pattern (see table below).
- At the start of each step, the according LED(s) start(s) flashing fast (0.1 second on, 0.1 second off). By pressing and holding the switch, the associated action is started and the flashing slows (0.5 seconds on, 0.5 seconds off).

Step	Pattern		Maximum flash count	Action
1	Green	● ○	12	set tens of node address
2	Red	○ ●	9	set units of node address
3	Green and red (simultaneous)	● ●	10*	set baud rate index (number of flashes)

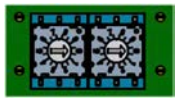
*) maximum count depends on the supported baud rates of the fieldbus. See the baud rate table above for supported baud rates and associated indexes.

To execute a step, follow these instructions:

- Press and hold the switch (flashing slows)
- To select value 0 (zero), release the switch within 1 second, otherwise:
- Count the number of LED flashes
- Release the switch as soon as the required value is reached
- In case you lose count, keep the switch pressed and wait until the flash count reaches its maximum and restarts

On completion of a step, the instrument automatically advances to the next step. When all required steps have been completed, the instrument returns to its normal operation mode.
If the switch is not pressed within 60 seconds after starting a step, all changes in the previous steps are cancelled and the instrument returns to its normal operation mode.

4.9.3 Rotary switches



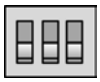
Using the MSD and LSD switches, the main fieldbus address (Fieldbus 1) of the instrument can be selected, in the range from 1 to 99. MSD (Most Significant Digit) sets the tens, LSD (Least Significant Digit) sets the units.

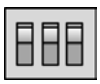
If both switches are set to 0, the node address is selected according to the digital parameter settings (see Network configuration), otherwise the rotary switch setting overrules the digital parameter settings.

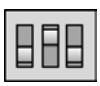
The switches can be adjusted using a small flat blade screwdriver.

4.9.4 Bus termination switches

To minimize signal reflections on the fieldbus network and achieve reliable data transfer over a FLOW-BUS, Modbus or PROFIBUS DP system, the network must be terminated properly. The bus termination DIP switches replace the termination resistors that are used normally for the according fieldbus types. On instruments that are installed at the beginning or at the end of the fieldbus, the DIP switches must be configured accordingly (**up = on, down = off**):

Normal (default): 

Begin terminator: 

End terminator: 

Consult the applicable fieldbus manual for information about setting up and terminating a FLOW-BUS, Modbus or PROFIBUS DP network.

4.9.5 Service port

The micro USB port provides an alternative way to operate the instrument via RS-232. With a micro USB to USB2.0 adapter cable, the instrument can be connected to a Windows computer. This enables RS-232 operation with the use of the free Bronkhorst® FlowWare software, even if the instrument is already being operated through one of the other interfaces (analog, RS-232 or fieldbus, if applicable).

4.10 Adjusting zero point

The zero point of a Bronkhorst® flow meter/controller (the measurement signal that indicates the absence of a flow) is factory adjusted at approximately 20 °C and atmospheric pressure (ambient conditions), with the instrument positioned upright. Under normal circumstances (i.e. at stable process conditions), the zero point will remain stable. However, over time several factors can induce a slight deviation of the measured value from the zero point, causing the instrument to detect a flow when in reality there is none. Readjusting the zero point eliminates this deviation.

- *After installation or relocation, always check the zero point.*
- *If the instrument still detects a (steady) flow while all valves are closed and the fluid system is leak tight, adjusting the zero point is recommended.*

The following factors can affect the zero-stability error (in order of importance):

- fluid temperature
- ambient temperature
- mounting orientation
- (upstream) pressure
- fluid density
- fluid viscosity
- vibrations from the environment
- pressure fluctuations

Zeroing an instrument requires that:

- the ambient conditions (temperature, pressure) match those of the operating environment of the instrument.
- the instrument is filled homogeneously and pressurized with the operational media, according to the typical process conditions.
- the instrument has been warmed up sufficiently.
- there is absolutely no flow through the instrument; preferably, this is achieved by closing a valve immediately after the outlet of the instrument (control valve, shut-off valve).

Blocking the flow through the instrument is essential; zeroing an instrument while there is still a flow will lead to measurement errors.

Adjusting the zero point of an instrument can be done by the following methods:

- manually (using the multifunctional switch)
- digitally (via RS-232 or fieldbus)
- with the autozero function of a Bronkhorst® readout and control unit

Once started, the procedure takes approximately 40 seconds to complete (longer if the output signal is unstable), regardless of the preferred method.

4.10.1 Digital procedure

Bronkhorst FlowSuite and FlowPlot provide an easy way to adjust the zero point of an instrument using RS-232 communication; the Autozero *function automatically performs the procedure described here.*

To adjust the zero point using digital communication, set parameter values in the following sequence (see section Digital parameters for more information about instrument parameters):

Sequence #	Parameter	Value	Action
1	Setpoint or fSetpoint	0	stop flow
2	Init Reset	64	unlock secured parameters
3	Control Mode	9	enable calibration mode
4	Calibration Mode	0	reset calibration mode
5	Calibration Mode	9	start zeroing

The green LED starts to blink fast, indicating that the zeroing procedure is in progress. On completion, the green LED lights up, while the output signal is 0 % (parameter *Measure* = 0). At the same time, parameter *Control Mode* returns to its initial value. If the procedure is successful, parameter *Calibration Mode* changes to 0 (idle). If the procedure fails, *Calibration Mode* changes to 255.

After performing the procedure, remember to set parameter Init Reset *to value 82 to lock secured parameters.*

Alternatively, when HART functionality is enabled, the procedure can easily be performed with a single HART command.

4.10.2 Manual procedure

The built-in autozero function of the instrument can be activated with the multifunctional switch (see Hardware interface). To start the autozero function with the multifunctional switch, follow these instructions:

1. Change the setpoint of the instrument to 0 (zero).
2. Press and hold the multifunctional switch. After 4 seconds, the red LED ● lights up; another 4 seconds later the red LED extinguishes and the green LED ● lights up.
3. At that moment (which is after 8 to 12 seconds), release the switch.

The green LED starts to blink fast, indicating that the autozero procedure is in progress. After (successful) completion, the green LED lights up continuously, while the output signal is 0 % (parameter *Measure* = 0).

5 Digital parameters

This section describes the most commonly used parameters for digital operation of the MI Series. Descriptions are grouped by category in tables as shown below:

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
[type]	RW 🔑	[x]…[y]	[DDE par]	[Pro]/[Par]	[address]/[register]

In this manual, parameter names are printed in italics (reverted to normal *where embedded in italics, like in this tip).*

Type

Unsigned char	1 byte unsigned integer (0…255)
Unsigned int	2 byte unsigned integer, MSB first (0…65535)
Unsigned long	4 byte unsigned integer, MSB first (0…4294967295)
Float	4 byte floating point, IEEE 32-bit single precision, MSB first
Unsigned char [x]	x byte text string

Access

R	Parameter value can be read
W	Parameter value can be written
🔑	Parameter is secured and only accepts values if parameter *Init Reset* is set to 'unlocked' first

Range

Some parameters only accept values within a certain range:

[x]	Minimum value
[y]	Maximum value

FlowDDE

Parameter number within FlowDDE

FLOW-BUS

FLOW-BUS uses the ProPar protocol, where parameters are identified by a unique combination of a process number and a parameter number.

- *For more information about setting up a FLOW-BUS network with Bronkhorst® instruments, consult the FLOW-BUS manual (see Documentation).*
- *For more information about the ProPar protocol, consult the RS-232 manual (see Documentation).*

Modbus

In the Modbus protocol, parameters are accessed by specifying their unique decimal register number or corresponding PDU address (Protocol Data Unit). The PDU address is the hexadecimal translation of the register number minus 1, e.g. register number 1 corresponds to PDU address 0x0000, register number 11 corresponds to PDU address 0x000A:

[address]	Hexadecimal PDU address
[register]	Decimal register number

Modbus address blocks are two bytes big. Larger data types use up to 8 subsequent address blocks, resulting in a maximum variable length of 16 bytes. Values longer than the maximum length are truncated.

For more detailed information about setting up a Modbus network with Bronkhorst® instruments, consult the Modbus manual (see Documentation).

Other interface protocols

Parameter descriptions in this document are based on their availability with FLOW-BUS, Modbus or RS-232 (ProPar) communication. Due to limitations in, for example, memory capacity or communication properties, definition files for other fieldbus systems usually do not make all parameters available.

Not all parameters described in this document are necessarily available with all digital interface types. For information about parameter access and availability for Bronkhorst® instruments in a specific fieldbus network, consult the according fieldbus manual.

5.1 Measurement and control

Measure

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	R	0…41942 (65535*)	8	1/0	0x0020/33

This parameter returns a dimensionless representation of the measured flow rate or pressure. The value 32000 corresponds to 100 %, the maximum value corresponds to 131.07 %.

**In case the instrument is prepared for bi-directional measurement, the negative signals with an output range of -73.73…-0.003% are represented by the range of 41943…65535, whereas the positive signals 0…131.07% are still represented by the range of 0…41942. (FlowDDE converts the numbers to negative values automatically).*

Setpoint

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	RW	0…32000	9	1/1	0x0021/34

This parameter is a dimensionless representation of the required flow rate or pressure. Value 32000 corresponds to 100 %.

Temperature

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	R	-250…500	142	33/7	0xA138…0xA139/41273…41274

This parameter returns the temperature in °C on the outside of the sensor tube, which is an approximation of the actual media temperature.

Density Actual

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	R	0…3.4E+38	270	116/15	0xF478…0xF479/62584…62585

This parameter returns the actual density measured by the instrument in kg/m^3. If the selected *Capacity Unit* is a volume flow type, the instrument uses this parameter for conversion of the measured mass flow to the selected unit.

5.1.1 Advanced measurement and control

fMeasure

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	R	-3.4E+38… 3.4E+38	205	33/0	0xA100…0xA101/ 41217…41218

This parameter represents the value of parameter *Measure*, expressed in the selected *Capacity Unit*. Its value is calculated from the dimensionless value of *Measure*, using the fluid set parameters *Capacity 100%* and *Capacity Unit*.

Fsetpoint

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…3.4E+38	206	33/3	0xA118…0xA119/ 41241…41242

This parameter represents the value of parameter *Setpoint*, expressed in the selected *Capacity Unit*. Conversion between *Fsetpoint* and the dimensionless value of *Setpoint* uses fluid set parameters *Capacity 100%* and *Capacity Unit*.

Setpoint Slope

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	RW	0…30000	10	1/2	0x0022/35

The value of this parameter represents the time it would take to adjust the setpoint if it were changed from 0 to 100 %. This feature can be used to smooth 'nervous' controller behavior, e.g. to reduce setpoint overshoot or undershoot.
The supported range corresponds to 0…3000 seconds. Default value = 0.

Example:
If *Setpoint Slope* = 100 it will take 10 seconds to adjust the setpoint if it is changed from 0 to 100%. A setpoint change of 20% will take (20%/100%)*10 seconds = 2 seconds.

Analog Input

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	R	0…65535	11	1/3	0x0023/36

This parameter contains a digital translation of the analog input signal (if applicable).

Valve Output

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned long	RW	0… 16777215	55	114/1	0xF208…0xF209/61961…61962

This parameter represents the controller output signal for control valve operation.

Sensor type

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	RW	0…255	22	1/14	0x8170/33127

The following sensor types are supported:

Instrument type	Value	Description
Controller	1	Liquid volume
	2	Liquid /gas mass
	3	Gas volume
Sensor	129	Liquid volume
	130	Liquid/gas mass
	131	Gas volume

5.2 Alarms

Alarm settings are most easily accessible using Bronkhorst FlowSuite, FlowPlot or FlowView or a Bronkhorst® readout and control unit.

The built-in alarm functionality can be used to handle different alarm types:
- system errors and warnings
- min/max alarms
- response alarms
- batch alarms
- master/slave alarms

The alarm type can be set with parameter *Alarm Mode*. When an alarm is activated, the type can be read out using parameter *Alarm Info*. An automatic setpoint change can be set using the parameters *Alarm Setpoint Mode* and *Alarm New Setpoint*. It is also possible to set an alarm delay, to prevent overreaction to small disturbances, using parameter *Alarm Delay Time*. The methods by which an alarm can be reset are controlled by *Reset Alarm Enable*.

Alarm Mode

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…3	118	97/3	0x0C23/3108

Available modes:

Value	Description
0	Alarm off
1	Alarm on absolute limits
2	Alarm on limits related to setpoint (response alarm)
3	Alarm at power-up(e.g. after power-down)

(On DeviceNet™ instruments, only modes 0 and 1 are available)

Alarm Info

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	R	0…255	28	1/20	0x0034/53

This parameter provides information about the event type(s) that triggered an alarm situation. The value is a bitwise summation of the issued alarm types; convert the value to binary to see which types are issued. The following alarm types can be issued:

Bit	Value	Type	Description
0	1	Error	Error flag raised
1	2	Warning	Warning flag raised
2	4	Minimum alarm	*Measure* < *Alarm minimum limit*
3	8	Maximum alarm	*Measure* > *Alarm maximum limit*
4	16	Batch counter alarm	Batch counter reached its limit
5	32	• This bit only: Power-up alarm	Alarm possibly caused by a power dip
		• If combined with bit 2 or 3: Response alarm	Difference between *Measure* and *Setpoint* too big
6	64	Master/slave alarm	Setpoint out of limits (caused by *Slave factor*)
7	128	Hardware alarm	Hardware error

Alarm Delay Time

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…255	182	97/7	0x0C27/3112

This value represents the time in seconds the alarm action will be delayed when an alarm limit has been exceeded. This value also delays the alarm off action if an alarm limit is no longer exceeded.
Default value = 0.

Alarm Maximum Limit

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	RW	0…32000	116	97/1	0x0C21/3106

Maximum limit for *Measure* to activate the maximum alarm situation (after *Alarm Delay Time*). Range 0…32000 represents 0… 100% signal. *Alarm Maximum Limit* must be greater than *Alarm Minimum Limit*.
Default value: 0.

Alarm Minimum Limit

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	RW	0…32000	117	97/2	0x0C22/3107

Minimum limit for *Measure* to activate the minimum alarm situation (after *Alarm Delay Time*). Range 0…32000 represents 0… 100% signal. *Alarm Minimum Limit* must be smaller than *Alarm Maximum Limit*.
Default value: 0.

Alarm Setpoint Mode

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…1	120	97/5	0x0C25/3110

Specifies whether or not to change the setpoint after an alarm situation is activated.

Value	Description
0	No setpoint change (default)
1	Change setpoint to *Alarm new setpoint*

Alarm New Setpoint

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	RW	0…32000	121	97/6	0x0C26/3111

New (safe) setpoint during an alarm until reset. Range 0…32000 represents 0…100% setpoint.
Default value: 0

Reset Alarm Enable

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…15	156	97/9	0x0C29/3114

Available reset methods. The value is a bitwise summation of the enabled methods; convert the value to binary to see which methods are enabled.
Default value: 15 (all bits/methods enabled)

The following methods are supported:

Bit	Value	Description
0	1	By hardware switch (if present)
1	2	Externally (obsolete)
2	4	By parameter *Reset*
3	8	Automatically (when alarm conditions no longer apply)

5.3 Counter

- *Counter settings are most easily accessible using Bronkhorst FlowSuite, FlowPlot or FlowView or a Bronkhorst® readout and control unit.*
- *When the instrument is powered down, it remembers the state of the counter. If the counter is active when the instrument is powered down, it is activated when powered up and then continues to count from the value at the time of power down.*

Counter Mode

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…2	130	104/8	0x0D08/3337

Available modes:

Value	Description
0	Counter off (default)
1	Counting up continuously
2	Counting up until limit reached (set by *Counter Limit*)

Counter Unit

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[4]	RW	see table below	128	104/7	0xE838…0xE839/59449…59450

This parameter contains the name of the counter readout unit.

Counter Unit supports the following values:

Mass	Normal volume (1.01325 bar(a), 0 °C)	Standard volume (1.01325 bar(a), 20 °C)	Custom volume (*Capacity Unit Pressure*, *Capacity Unit Type Temperature*)
ug, mg, g, kg	uln, mln, ln, mm3n, cm3n, dm3n, m3n	uls, mls, ls, mm3s, cm3s, dm3s, m3s	ul, ml, l, mm3, cm3, dm3, m3

Parameter Density (FlowDDE ID 170) is used to calculate Custom volume.

Counter Value

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0… 10000000	122	104/1	0xE808…0xE809/59401…59402

Current counter value in units selected with parameter *Counter Unit*.

Counter Limit

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…9999999	124	104/3	0xE818…0xE819/59417…59418

Counter limit/batch size in units selected with parameter *Counter Unit*.
Default value: 0.

Counter Setpoint Mode

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…1	126	104/5	0x0D05/3334

Specifies whether or not to change the setpoint after reaching the counter limit.

Value	Description
0	No setpoint change (default)
1	Change setpoint to *Counter new setpoint*

Counter New Setpoint

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned int	RW	0…32000	127	104/6	0x0D06/3335

New (safe) setpoint when a counter limit is reached until reset. Range 0…32000 represents 0…100% setpoint.
Default value: 0

Reset Counter Enable

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…15	157	104/9	0x0D09/3338

Available reset methods. The value is a bitwise summation of the enabled reset methods; convert the value to binary to see which methods are enabled.
Default value: 7 (bits/methods 0, 1 and 2 enabled)

The following methods are supported:

Bit	Value	Description
0	1	By hardware switch (if present)
1	2	Externally (obsolete)
2	4	By parameter *Reset*
3	8	Automatically (e.g. when counter value is reset)

5.4 Network configuration

*Changes made to the network settings will **not** be restored by a factory reset.*

Default settings
Network configuration is done ex factory as indicated on the serial number label or in the technical specifications. The table below shows the supported configurations for the available interface protocols (default settings are printed in bold):

Protocol	ProPar (RS-232)	FLOW-BUS	Modbus (RTU/ASCII)	PROFIBUS DP	CANopen	DeviceNet™	HART
Bus Address	**3**	**3**…125	**1**…247	0…**126**	1…**127***	0…**63**	0
Baud Rate	9600 19200 **38400** 57600 115200 230400 460800	**187500** 400000	9600 **19200** 38400 56000 57600 115200 128000 256000	**(autodetect)** 9600 19200 45450 93750 187500 500000 1500000 3000000 6000000 12000000	10000 20000 50000 125000 250000 **500000** 800000 1000000	**125000** 250000 500000	**1200**
Bus Parity	**0**	**0**	0, 1, **2**	**2**	**0**	**0**	**1**

*) Supported range for digital parameter; when using rotary switches to set the bus address, range is limited to 0…79.

Network configuration for Ethernet based fieldbus protocols is done automatically.

Fieldbus Interface Index

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…4	378	125/7	0x0FA7/4008

This parameter indicates the communication interface to which *Fieldbus 1 Address*, *Fieldbus 1 Baud Rate* and *Fieldbus 1 Parity* apply (see further). Each specific interface has its own index and corresponding network parameter values:

Value	Description
0	Fieldbus (fieldbus terminal B/C)
1	Fieldbus (main terminal M)
2	Display
3	Service port
4	HART

Fieldbus1 Address

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…255	199	125/10	0x0FAA/4011

Fieldbus1 Baud Rate

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned long	RW	0…1.0E10	201	125/9	0xFD48…0xFD49/64841…64842

Fieldbus1 Parity

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…2	335	125/12	0x0FAC/4013

The following values are supported:

Value	Description
0	No parity
1	Odd parity
2	Even parity

5.5 Fluid set

Fluid Set Index

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…7	24	1/16	0x0030/49

With this parameter, any of the pre-configured fluids (up to 8) can be selected. Each fluid has its specific (configurable) properties, such as *Fluid Name*, *Capacity*, etc.
Default value: 0 (fluid 1).

Note that the selected value is equal to the fluid number minus 1 (value 0 corresponds to fluid 1, value 1 to fluid 2, etc.)

Fluid Name

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[10]	RW	-	25	1/17	0x8188…0x818C/33161…33165

This parameter contains the name of the selected fluid.

Capacity 100%

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	1E-10… 1E+10	21	1/13	0x8168…0x8169/33129…33130

- This parameter represents the 100 % readout/control value (span), expressed in the *Capacity Unit* of the selected fluid.
- *Capacity 100%* is scaled when *Inlet Pressure*, *Fluid Temperature* or *Fluid Name* is changed for the selected fluid.

Capacity Unit

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[7]	RW	see below	129	1/31	0x81F8…0x81FB/33273…33276

This parameter represents the unit in which *Capacity 100%* is expressed.
Available units:

Mass flow	Normal volume flow (1.01325 bar(a), 0 °C)	Standard volume flow (1.01325 bar(a), 20 °C)	Custom volume flow (*Capacity Unit Type Pressure*, *Capacity Unit Type Temperature*)
ug/h, ug/min, ug/s, mg/h, mg/min, mg/s, g/h, g/min, g/s, kg/h, kg/min, kg/s	uln/h, uln/min, uln/s, mln/h, mln/min, mln/s, ln/h, ln/min, ln/s, ccn/h, ccn/min, ccn/s, mm3n/h, mm3n/m, mm3n/s, cm3n/h, cm3n/m, cm3n/s, m3n/h, m3n/min, m3n/s, scfh, scfm, scfs, sccm, slm	uls/h, uls/min, uls/s, mls/h, mls/min, mls/s, ls/h, ls/min, ls/s, ccs/h, ccs/min, ccs/s, mm3s/h, mm3s/m, mm3s/s, cm3s/h, cm3s/m, cm3s/s, m3s/h, m3s/min, m3s/s	ul/h, ul/min, ul/s, ml/h, ml/min, ml/s, l/h, l/min, l/s, cc/h, cc/min, cc/s, mm3/h, mm3/m, mm3/s, cm3/h, cm3/m, cm3/s, m3/h, m3/min, m3/s, cfh, cfm, cfs

Because of the maximum string length (7 characters), some unit names are abbreviated, for instance mm3n/m means mm^3n/min.

Capacity Unit Type Temperature

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	-273.15… 3.4E+38	245	33/10	0xA150…0xA151/41297…41298

This parameter defines a reference temperature for conversion of the measured mass flow to a volume flow. See also parameters *Capacity Unit* and *Counter Unit*.

Capacity Unit Type Pressure

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…3.4E+38	246	33/11	0xA158…0xA159/41305…41306

This parameter defines a reference pressure for conversion of the measured mass flow to a volume flow. See also parameters *Capacity Unit* and *Counter Unit*.

5.5.1 Advanced fluid set parameters

Note that the parameters described in this section do not contain any actual measurement values, but only fixed reference values, which can be used for capacity calculations, etc.

Inlet Pressure

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…3.4E+38	178	113/13	0xF168…0xF169/61801…61802

Upstream pressure of the selected fluid in bar(a)

Outlet Pressure

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…3.4E+38	179	113/14	0xF170…0xF171/61809…61810

Downstream pressure of the selected fluid in bar(a).

Fluid Temperature

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	-250…500	181	113/16	0xF180…0xF181/61825…61826

Temperature of the selected fluid in °C.

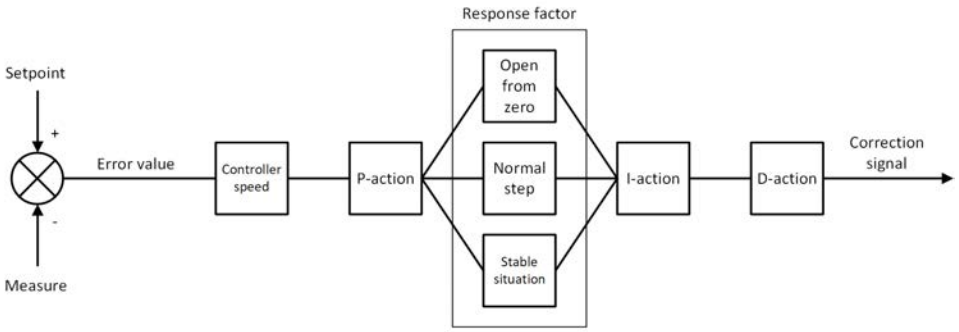
Density

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…3.4E+38	170	33/21	0xA1A8…0xA1A9/41385…41386

Density of the selected fluid in kg/m^3

5.6 Controller

The picture below is a simplified visualization of the PID controller algorithm (proportional, integral, derivative) used by digital Bronkhorst® instruments.



The controller speed controls the overall performance of the controller algorithm. Basically, to adjust the controller response, only the controller speed needs to be changed.

The algorithm is based upon the difference between the setpoint and the measured value (called the error value). The correction signal to eliminate the error is assembled from 3 components (giving the algorithm its name):
- The P-action (proportional) multiplies the error value by a constant factor, to adjust the measure towards the (new) setpoint.
- The I-action (integral) amplifies the correction signal with a factor depending on the integral of the error value over time.
- The D-action (derivative) reduces the strength of the P-action, to prevent overshoot when the (new) setpoint is reached.

The proportional action is enhanced by one of three additional response factors, depending on the control cycle stage:
- Open from zero: the setpoint is larger than zero and the measured value is below 2% of the full scale range.
- Normal step: the measured value differs more than 2% from the setpoint, typically after changing the setpoint (step).
- Stable situation: the measured value differs less than 2% from the setpoint.

*For more information about controlling characteristics, consult the **Instruction manual FlowPlot** (document no. 9.17.030).*

Control characteristics are optimized during production. These parameters should only be changed if absolutely necessary, and only by or under the supervision of trained service personnel.

Controller Speed

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0.2…5	254	114/30	0xF2F0…0xF2F1/62193…62194

This parameter sets the overall controller speed factor for the selected fluid. *Controller speed* is set ex factory between value '0.5' (slow) and '2' (fast). The default value is '1'.

PID-Kp

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…1E+10	167	114/21	0xF2A8…0xF2A9/62121…62122

PID controller proportional action, multiplication factor.

PID-Ti

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…1E+10	168	114/22	0xF2B0…0xF2B1/62129…62130

PID controller integral action in seconds.

PID-Td

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…1E+10	169	114/23	0xF2B8…0xF2B9/62137…62138

PID controller derivative action in seconds. The default value is 0.0.

Open From Zero Response

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…255	165	114/18	0x0E52/3667

Response factor, applied to proportional action when opening the valve from 0%.
- Default value: 128 (no correction)
- Other values adjust the controller gain (correction signal) as follows: Controller gain = *Controller Speed* * *PID-Kp* * $1.05^{(\text{response factor - 128})}$

Normal Step Response

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…255	72	114/5	0x0E45/3654

Response factor, applied to proportional action during normal control (at setpoint step).
- Default value: 128 (no correction)
- Other values adjust the controller gain (correction signal) as follows: Controller gain = *Controller Speed* * *PID-Kp* * $1.05^{(\text{response factor - 128})}$

Stable Situation Response

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…255	141	114/17	0x0E51/3666

Stable situation response, applied when the controller is stable (within a 2% band around the setpoint).
- Default value: 128 (no correction)
- Other values adjust the controller gain (correction signal) as follows: Controller gain = *Controller Speed* * *PID-Kp* * $1.05^{(\text{response factor - 128})}$

5.7 Master/slave configuration (FLOW-BUS)

Normally, there is no communication between the instruments in a fieldbus system. The FLOW-BUS protocol, however, provides a feature to set up a master/slave relationship between two instruments. The typical behavior of a slave instrument is to automatically set its own setpoint relative to the output (measurement value) of its master.

The output value of any instrument in a FLOW-BUS network is automatically available to all other instruments without extra wiring. A slave instrument can also be a master to other instruments.

To set up a master/slave relationship between instruments, set parameter *Control Mode* of the slave instrument to 'FLOW-BUS slave' (value 2) or 'FLOW-BUS analog slave' (value 13), depending on how the setpoint should be calculated.

The slave instrument polls the output value of its master periodically and uses the slave factor to set its own setpoint relative to the master's.

To prevent damage to the instruments an/or the system(s) they are connected to, be sure to avoid circular references between devices on the same fieldbus. The FLOW-BUS system does not have a protection mechanism.

Master Node

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	1…128	158	33/14	n/a

Sets the master node for the instrument.
Note that this parameter is only effective in a FLOW-BUS network (RS-485).

Slave Factor

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Float	RW	0…500	139	33/1	0xA108…0xA109/41225…41226

The controller output from the master instrument is multiplied by *Slave Factor*/100 % to get the slave instrument setpoint. In systems other than FLOW-BUS, *Slave Factor* is effective only if *Control Mode* is set to 'Analog slave', and the analog output signal of the master instrument is redirected to the input of the slave instrument.

Example:
- master output = 80 %
- *Slave Factor* = 50

⇨ slave instrument setpoint = 80 % x 50 %/100 % = 40 %

5.8 Device identification

User Tag

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[16]	RW	-	115	113/6	0xF130…0xF137/ 61745…61752

With this parameter, the instrument can be given a custom tag name, with a maximum of 16 characters.

Customer Model

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[16]	RW	-	93	113/4	0xF120…0xF127/ 61729…61736

This parameter is used to add extra information to the model number information, such as a customer-specific model number.

Serial Number

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[20]	R	-	92	113/3	0xF118…0xF11F/ 61721…61728

Instrument serial number for identification.

BHT Model Number

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[35]	RW	-	91	113/2	0xF110…0xF117/ 61713…61720

This parameter shows the Bronkhorst® instrument model type information.

Firmware Version

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[6]	R	-	105	113/5	0xF128…0xF12A/ 61737…61739

Revision number of the firmware

Identification Number

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW 🔑	0…255	175	113/12	0x0E2C/3629

Bronkhorst® (digital) device type identification number.

Device Type

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char[6]	R	-	90	113/1	0xF108…0xF10A/ 61705…61707

Device type information string; this parameter contains an abbreviation referring to the identification number.

5.9 Special parameters

Init Reset

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	82/64	7	0/10	0x000A/11

Init Reset is used to unlock secured parameters (marked with a 🔑 symbol) for writing. It supports the following values:

Value	Description
64	unlocked, secured parameters can be read and written to
82	locked, secured parameters are read-only

At power-up, *Init Reset* is always set to 'Locked' (value 82).

Reset

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	R	0…7	114	115/8	0x0E68/3689

This parameter is used to reset the program, counter or alarms.

Value	Description
0	No reset
1	Reset counter
2	Reset alarm
3	Reset counter
4	Reset and disable counter
5	Reset firmware program (soft reset)
6	Reset *Alarm info* error bit
7	Reset *Alarm info* warning bit

The Reset *parameter may be disabled by* Reset Alarm Enable *or* Reset Counter Enable. *Make sure the value is accepted by sending value 0 first.*

Wink

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char [27]	W	0…9*	1	0/0	0x0000/1

Sending any text string value between 1 and 9 to this parameter makes the indication LEDs (if present) blink for a couple of seconds. This can be useful in order to identify a specific device in a large fieldbus network.

*) Modbus only supports value 14592

Control Mode

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…255	12	115/1	0x0024/37

Control Mode is used to select different control modes of the instrument and determines from which source(s) it accepts a setpoint.

The following modes are available:

Value	List option	Description	Setpoint source
0	Bus/RS232	Normal digital operation	Fieldbus or RS-232
1	Analog input	Normal analog operation	Analog input
2	FLOW-BUS slave	Acting as slave instrument on FLOW-BUS	FLOW-BUS master
3	Valve close	Controller disabled, valve closed	
4	Controller idle	Controller disabled, valve frozen in current position	
7	Setpoint 100%	Setpoint fixed at 100 %	
8	Valve fully open	Controller disabled, valve fully open	
9	Calibration mode	Calibration mode enabled	
10	Analog slave	Acting as slave of other instrument in analog mode	Analog input
12	Setpoint 0%	Setpoint fixed at 0%	
13	FLOW-BUS analog slave	Acting as slave of other instrument on FLOW-BUS, slave factor set by analog input signal	Analog input
18	RS232	Controlling, default/safe state disabled	Fieldbus or RS-232
20	Valve steering	Controller disabled, setpoint redirected to *Valve Output*	
21	Analog valve steering	Controller disabled, analog input redirected to *Valve Output*	
22	Valve safe state	Instrument in default/safe state	

- Default value: 0 or 1 (as ordered).
- If *Control Mode* is changed to value 0, 1, 9 or 18, the instrument returns to the default value at the next power-up or reset. Other values are persistent.
- *Control Mode* 18 prevents the instrument from assuming its default/safe state in the event of a digital communication failure.
- The column labeled *List option* shows the control modes as used in Bronkhorst® software.

Calibration Mode

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0, 9, 255	58	1/4	0x0E61/3682

After enabling calibration mode by means of parameter *Control Mode*, this parameter is used to start the autozero function of the flow sensor. The following modes are supported:

Value	Description
0	Idle (no action)
9	Start zeroing
255	Error (result of previous calibration mode)

5.9.1 Default control mode

IO Status

Type	Access	Range	FlowDDE	FLOW-BUS	Modbus
Unsigned char	RW	0…255	86	114/11	0x0E4B/3660

The instrument is set to accept a setpoint from either an analog or a digital source. Although this setting can be changed with parameter *Control Mode*, the instrument usually returns to its default control mode at every power-up or reset. The default control mode can be set with parameter *IO Status*; to change it, use the procedures as described below.

Changing from digital operation to analog operation:
1. Set parameter *Init Reset* to 64 (unlocked)
2. Read parameter *IO Status*
3. Add 64 to the read value
4. Write the new value to parameter *IO Status*
5. Set parameter *Init Reset* to 82 (locked)

Changing from analog operation to digital operation:
1. Set parameter *Init Reset* to 64 (unlocked)
2. Read parameter *IO Status*
3. Subtract 64 from the read value
4. Write the new value to parameter *IO Status*
5. Set parameter *Init Reset* to 82 (locked)

The procedures described above do not change the value of parameter Control Mode. *To apply the new default control mode, reset or restart the instrument.*

6 Troubleshooting and service

- *Electronic problems can be traced by restarting the equipment.*
- *If the equipment starts up normally, the measurement and control behavior can be checked by applying fluid pressure.*
- *To track down problems in the fluid system, depressurize the fluid system and disconnect the suspected unit from the process line. Dirt or clogging might be quickly detected by visual inspection of disassembled fluid connections.*

If you suspect leakage, do not disassemble the device for inspection, but contact your Bronkhorst representative for service or repairs.

6.1 Errors and warnings

See LED indications for an explanation of all possible LED indications.

In case of problems during operation, error and warning information can be found in FlowDDE and FlowPlot. FlowDDE puts all errors and warnings on the console screen; FlowPlot provides several alarm and counter indicators. See also section Digital operation.

6.2 Replacing fuses

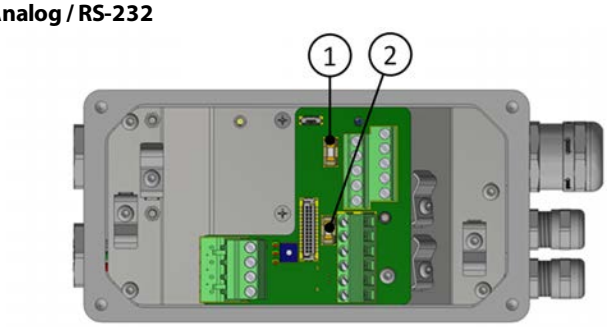
Fuses may only be replaced by qualified service personnel.

When replacing fuses, observe the following:
1. Before replacing a fuse, switch off the equipment and disconnect it from the electrical power source.
2. Before replacing a fuse, determine and solve the cause of the blow.
3. Always replace fuses with the same type (Littelfuse NANO$^{2®}$ Slo-Blo 2A; no 0454002).
4. If you are unsure about the suitability of a replacement fuse or if replacement fuses keep blowing, contact your Bronkhorst representative for support.

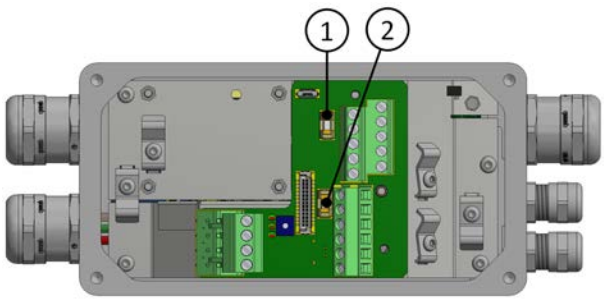
The images below indicate the locations of the fuses on the wiring terminal box under the instrument cover. The fuses protect the following wiring terminals (see the applicable hook-up diagram for wiring details):

1. Main
2. Actuator
3. Fieldbus

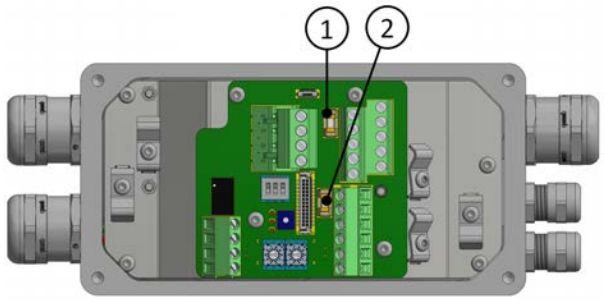
Analog / RS-232



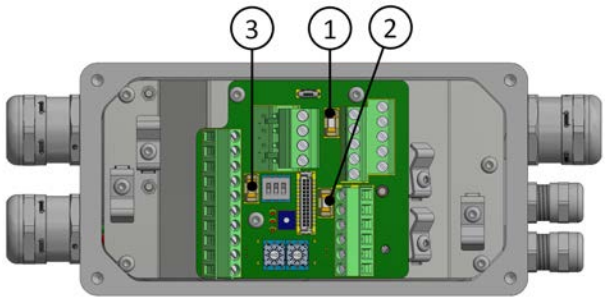
Ethernet based



PROFIBUS DP



FLOW-BUS / Modbus / DeviceNet™ / CANopen



6.3 Restoring factory settings

In case changes to the instrument configuration leads to non-recoverable erroneous behavior, the instrument can be reset to the pre-configured factory settings. This can be done with the following methods:

- via RS-232 communication, with the *Restore settings* function in FlowPlot
- with the multifunctional switch (see Multifunctional switch)
- with the *restore* function of a Bronkhorst® readout and control unit (BRIGHT, E-8000)

*Changes made to the network settings (bus address, baud rate, parity) will **not** be restored by a factory reset.*

6.3.1 Manual procedure

- *The instrument cover may only be opened in a clean, dry and non-hazardous environment.*
- *Before opening the cover, make sure that the operating environment is perfectly safe and that the electrical components cannot be affected by moisture or aggressive atmospheric components.*
- *Ensure that no particles, objects, etc. can fall into the instrument when the cover is open.*

To restore the factory settings using the multifunctional switch, follow these instructions:

1. Make sure electrical power to the instrument is switched off.
2. Press and hold the multifunctional switch, while powering up the instrument. After 4 seconds ,the red LED ● starts flashing (0.2 seconds on, 0.2 seconds off).
3. At that moment (which is after 4 to 8 seconds), release the switch.

6.4 Common issues

Symptom	Possible cause	Action
No communication between instruments and readout/control unit	No power supply	• Check power supply • Check cable connection • Check cable hook-up
	Fuse blown	Replace fuse
	Sensor failure	Return equipment to factory
Red LED glows continuously	Slug flow (combined gas and liquid flow)	Make sure the measuring tube only contains either gas or liquid (see First use)
	Hardware error	Return equipment to factory
No (fieldbus) communication	No power supply	• Check power supply • Check cable connection • Check cable hook-up
	Fuse blown	Replace fuse
	Invalid node address	Change node address (see Network configuration)
	Other	Reset instrument and/or restart master. If problem persists, contact Bronkhorst.
No output signal	No power supply	• Check power supply • Check cable connection • Check cable hook-up
	Fuse blown	Replace fuse
	Inlet pressure or differential pressure too low	Increase inlet pressure
	Piping, filters and/or control valve clogged or blocked	• Clean system (flush with clean, dry air or a non-aggressive cleaning liquid (e.g. ethanol or isopropyl alcohol) • For external proportional control valves: supply 0…15 Vdc and operational inlet

Symptom	Possible cause	Action
		pressure to valve and slowly increase voltage. If valve does not open, clean parts and re-adjust valve
	Sensor failure	Return equipment to factory
• Control behavior unstable • Red LED flashes irregularly	Measurement disturbed by vibrations	• If possible, avoid installation in close proximity of mechanical vibration • Reduce sensitivity to vibrations by using a mass block, shock absorbers, and flexible tubing
	Inlet pressure unstable	Eliminate pressure fluctuations, e.g. by installing a pressure regulator
	Gas accumulation in tubing	Flush the system to remove gas Tip: use frequency or density signal to detect presence of gas bubbles
	Wrong controller settings	Adjust settings (e.g. with FlowPlot)
	Control valve damaged	Return equipment to factory
No flow (sending a setpoint has no effect)	No fluid supply	Check upstream components for obstruction, e.g.: • fluid lines • valves • filters
	Inlet pressure or differential pressure out of bounds	Set inlet pressure to a value within specifications
Measured value rises, but never reaches setpoint	Piping, filters and/or control valve clogged or blocked	• Clean system (flush with clean, dry air or a non-aggressive cleaning liquid (e.g. ethanol or isopropyl alcohol) • For external proportional control valves: supply 0…15 Vdc and operational inlet pressure to valve and slowly increase voltage. If valve does not open, clean parts and re-adjust valve
	Inlet pressure too low	Increase inlet pressure
	Outlet pressure too high	Check/decrease outlet pressure
	Process outlet blocked	Check process outlet and downstream piping
• Measured value or output signal (much) lower than setpoint • Pressure signal gradually decreasing without setpoint change	Inlet pressure or differential pressure too low	• Increase inlet pressure • Use instrument in conditions it was designed for
	Process gas condensation	Decrease inlet pressure or increase gas temperature
	Piping or filters blocked or contaminated	Clean system
	Sensor blocked or contaminated	Clean sensor
	Valve blocked or contaminated	Clean valve
	Supplied fluid type does not match configured fluid type	Supply equipment with other fluid or change fluid type in instrument configuration
Measured value or output signal indicates a flow, while there should be none	Mounting orientation and/or ambient conditions changed significantly	• Use instrument in conditions it was designed for • Adjust zero point (see Adjusting zero point)
	System leakage	Check the system for leakage. Follow vendor instructions when installing third party

Symptom	Possible cause	Action
		components (e.g. adapters, tubing, valves)
Continuous maximum measured value or output signal	Inlet pressure too high	Check inlet pressure
	Valve fully open	• Close valve • Check if valve is in safe state (normally open valves); remove cause if necessary (see Valve Safe State)
	Sensor failure	Return equipment to factory

6.5 Service

If you have a question about a product or if you find the product does not meet the specifications as ordered, do not hesitate to contact your Bronkhorst representative. To enable us to help you quickly and effectively, make sure to have the serial number (SN) ready whenever seeking contact with your Bronkhorst representative about a specific item.

For current information about Bronkhorst® and worldwide service addresses, please visit our website:

www.bronkhorst.com

Do you have any questions about our products? Our Sales department will gladly assist you selecting the right product for your application. Contact sales by e-mail:

sales@bronkhorst.com

For after-sales questions, help and guidance, our Customer Care department is available by e-mail:

aftersales@bronkhorst.com

No matter the time zone, our experts within the Customer Care department are available to answer your request immediately or take appropriate further action. Our experts can be reached at:

+31 859 02 18 66

Bronkhorst High-Tech B.V.
Nijverheidsstraat 1A
NL-7261 AK Ruurlo
The Netherlands

7 Removal and return instructions

When returning materials, always clearly describe the problem, and, if possible, the work to be done, in a covering letter.

Instrument handling:

1. Purge all fluid lines (if applicable)
2. If the instrument has been used with toxic or otherwise hazardous fluids, it must be cleaned before shipping
3. Disconnect all external cabling and tubing and remove the instrument from the process line
4. If applicable, secure movable parts with appropriate transport safety materials, to prevent damage during transportation
5. The instrument must be at ambient temperature before packaging
6. Insert the instrument into a plastic bag and seal the bag
7. Place the bag in an appropriate shipping container; if possible, use the original packaging box

Add documentation:

- Reason of return
- Failure symptoms
- Contaminated condition
- Declaration on decontamination

It is absolutely required to notify the factory if toxic or dangerous fluids have been in contact with the device!
This is to enable the factory to take sufficient precautionary measures to safeguard the staff in their repair department.

All instruments must be dispatched with a completely filled in 'Declaration on decontamination'. Instruments without this declaration will not be accepted.

*A safety information document containing a 'Declaration on decontamination' form (document no 9.17.032) can be downloaded from the **Service & Support** section of the Bronkhorst website (**www.bronkhorst.com**).*

Important:
Clearly note, on top of the package, the customs clearance number of Bronkhorst High-Tech B.V.:

NL801989978B01

(only if applicable, otherwise contact your Bronkhorst representative for local arrangements.)

Parameter index

Parameters