Fluidcontrol

Bühler Particle Monitor

BPM

Installation and Operation Instructions

Original instructions

BE150102
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Read this instruction carefully prior to installation and/or use. Pay attention particularly to all advises and safety instructions to prevent injuries. Bühler Technologies can not be held responsible for misusing the product or unreliable function due to unauthorised modifications.

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Contents

1 Introduction

1.1 Intended Use

This product is a hydraulic component.

This device is an optical particle monitor used to monitor the cleanliness of fluids. It uses the principle of light extinction (attenuation of radiation) and measures particles in the fluid.

The measured values were converted into standardised cleanliness classes and output on the display. Various ports can be used to read and transmit the measurement data.

It connects to the system with the fluid via two Minimess© M16x2 ports.

The product may be used as follows:

– Monitoring the cleanliness of a fluid,

– Contamination level trend analysis.

The product is only intended for professional use, not for private use.

The intended use also includes reading and understanding this documentation, particularly chapter Safety instructions [> page 6] in full.

1.1.1 Improper Use

Any use not specified under intended use is considered improper use, thus prohibited.

Installing or using unsuitable products in safety-related applications can cause intended operating states in the application resulting in personal injury and/or property damage. Therefore only use a product for safety-related applications if this use is expressly specified and permitted in the product documentation. For example, in Ex protection areas or in safety-related parts of a control unit (functional safety).

Conveying media other than those listed in chapter Technical Data [> page 53] is prohibited.

Bühler Technologies GmbH assumes no liability for damages due to improper use. The user is solely responsible for the risks associated with improper use.

1.2 Glossary

Abbreviation/designation	Meaning
ON	Ordinal number
APC	Automatic particle counter
MTD	Medium test dust
mm	Two-digit minute indication
ss	Two-digit second indication
µm(c)	Particle size information when using ISO-MTD

1.3 Functionality

The BPM is an optical particle monitor which uses the principle of light extinction.

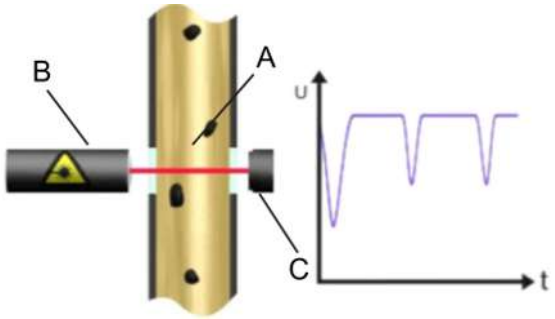


Fig. 1: Layout and measuring principle of a particle monitor

It consists of a perfused measuring cell (A), a laser (B) and a photodiode (C).

The laser penetrates the measuring cell and hits the photodiode. If a particle passes through the laser beam, the intensity detected by the photodiode is reduced. The larger the particle, the lower the intensity.

The BPM particle monitor will monitor both the contamination level and the cleanliness trend of fluids. The absolute accuracy may be different from particle monitors calibrated according to ISO 11171:99. However, the deviation is less than an ordinal number. Changes are displayed very accurately.

With continuous cleanliness monitoring, changes in the machine can be detected very early.

The quick warning allows taking measures without further heavy contamination, thus possible damage to the entire system.

1.4 Component list

Fig. 2: Component list

1	*Hydraulic fluid connection*	2	*Device front panel*
3	*"Power" indicator light*	4	*"Alarm" indicator light*
5	*Display*	6	*Hydraulic fluid connection*
7	*Select key*	8	*DOWN key*
9	*Sensor cable connection M12x1*	10	*UP key*

1 + 6 Hydraulic fluid connection

The device is equipped with two M16x2 Minimess© connections. These are typically used to connect two Minimess© hoses to connect the particle monitor to the system carrying the fluid. The direction of flow is not important for measurement.

2 + 5 device front panel and display

By default, the display shows the last cleanliness classes detected and the time remaining to the next measurement, or the remaining measurement time.

3 "Power" indicator light

This lights up green when connected to the operating voltage.

4 "Alarm" indicator light

This lights up red when there is an internal alarm. Various alarms can be configured for the device. Please observe the explanations throughout these operating instructions.

7 Select key [↵]

The select key is used to jump to the next menu level; when configuring values, the select key is used to jump to the next number.

8 DOWN key [▼]

10 UP key [▲]

These keys are used to navigate the menu and scroll through the entries.

9 Sensor cable connection M12x1

The device is equipped with an 8-pin M12x1 connection for connecting a sensor cable.

The assignments of the sensor cable and its connection are explained in further descriptions in these operating instructions.

Other key functions:

– Back

simultaneously press UP key [▲] DOWN key [▼].

– Change values:

Use the UP key [▲] or the DOWN key [▼] to select a parameter from the menu. Press the select key to select the parameter. Then change the value with the UP [▲] or DOWN [▼] key. Press the select key after the last available digit to apply the changes. When jumping to the next level up before pressing the select key at the end, the changes will not be saved.

1.5 Model key

BPM - 100 - 000 - 1DC2S1A

Type designation
BPM Bühler Particle Monitor

Version
100 Standard compact unit

Outputs
1DC2S1A 1x RS232/CAN
2x Switching signal input output
1x analog signal 4...20 mA

Item no.	Model
1530001000	BPM-100-000-1DC2S1A

1.6 Scope of Delivery

– Bühler Particle Monitor BPM
– Product Documentation
– 2x Minimess coupler (preinstalled)
– Factory calibration certificate

2 Safety instructions

2.1 Important advice

This device may only be used if:

- The product is being used under the conditions described in the operating- and system instructions, used according to the nameplate and for applications for which it is intended. Any unauthorized modifications to the device will void the warranty provided by Bühler Technologies GmbH,
- the specifications and markings in the type plate are observed,
- the limits in the data sheet and the instructions must be observed,
- monitoring equipment / protection devices must be connected correctly,
- the device is protected from mechanical damage and vibration,
- service and repairs not described in these instructions is performed by Bühler Technologies GmbH,
- using genuine replacement parts.

These operating instructions are a part of the equipment. The manufacturer reserves the right to change performance-, specification- or technical data without prior notice. Please keep these instructions for future reference.

Signal words for warnings

DANGER	Signal word for an imminent danger with high risk, resulting in severe injuries or death if not avoided.
WARNING	Signal word for a hazardous situation with medium risk, possibly resulting in severe injuries or death if not avoided.
CAUTION	Signal word for a hazardous situation with low risk, resulting in damaged to the device or the property or minor or medium injuries if not avoided.
NOTICE	Signal word for important information to the product.

Warning signs

These instructions use the following warning signs:


General warning


General information


Laser warning

2.2 General hazard warnings

The equipment must be installed by a professional familiar with the safety requirements and risks.

Be sure to observe the safety regulations and generally applicable rules of technology relevant for the installation site. Prevent malfunctions and avoid personal injuries and property damage.

The operator of the system must ensure:

- Safety notices and operating instructions are available and observed,
- The respective national accident prevention regulations are observed,
- The permissible data and operational conditions are maintained,
- Safety guards are used and mandatory maintenance is performed,
- Legal regulations are observed during disposal,
- compliance with national installation regulations.

Maintenance, Repair

Please note during maintenance and repairs:

- Repairs to the unit must be performed by Bühler authorised personnel.
- Only perform conversion-, maintenance or installation work described in these operating and installation instructions.
- Always use genuine spare parts.
- Do not install damaged or defective spare part. If necessary, visually inspect prior to installation to determine any obvious damage to the spare parts.

Always observe the applicable safety and operating regulations in the respective country of use when performing any type of maintenance.

CAUTION	**Laser**
	The particle monitor contains a laser which, when used properly, is classified as a Class 1 laser according to DIN EN 60825-1:2001-11. The accessible laser beam is safe under reasonably foreseeable conditions. In Class 1 laser equipment, e.g. blinding, impairment of colour vision and nuisance cannot be ruled out in the upper performance range.

CAUTION	**Danger due to improper use**
	Property damage The particle monitor may only be used as specified in chapter "Intended Use". **Hydraulic oil leaks or spills** Environmental pollution and contamination of the groundwater. Use oil binder to soak up leaked hydraulic oil. **Contamination due to liquids and foreign objects** Premature wear - malfunctions - risk of damage - property damage. Ensure cleanliness during installation to prevent foreign objects, e.g. welding beads or metal shavings from entering the hydraulic lines and causing wear and malfunctions in the product. Ensure the connections, hydraulic lines and add-on parts (e.g. gauges) are clean and free from shavings. Before initial use, verify all hydraulic and mechanical connections are connected and tight and that all seals and fasteners on plug connections are properly installed and undamaged. Use residue-free industrial wipes to remove lubricants and other contamination. Ensure the connections, hydraulic lines and add-on parts are clean. Ensure contaminants cannot enter when closing the connections. Ensure cleaners do not enter the hydraulic system. Do not use polishing wool or cleaning cloths giving up fluff. Do not seal with hemp.

2.3 Notices on the product

At the back of the device you will also find the notice specifying the laser class as per DIN EN 60825-1 next to the type plate.

Fig. 3: Laser class notice

NOTICE	**Functional limit**
	Damage to the pressure equalisation membranes. Impairment of protection class IP67. At the back of the device is a pressure equalisation membrane which must never be damaged. Take the appropriate care when working on the back of the device. At the back of the device is a decal indicating the laser beam between a Minimess connector and the connection for the sensor cable.

At the back of the device is a decal indicating the laser beam between a Minimess connector and the connection for the sensor cable.

Fig. 4: Laser beam notice

3 Transport and storage

Only transport the product inside the original packaging or a suitable alternative.

The equipment must be protected from moisture and heat when not in use. It must be stored in a covered, dry, dust-free room at room temperature.

4 Installation and connection

4.1 Installation site requirements

Please observe this information when determining the installation site:

- Connect the particle monitor in the bypass to a pressure line.
- Any direction of flow is permitted.
- The pressures should as constant as possible.
- The pressure may vary, however pressure peaks or strong fluctuations are not permitted.
- The volume flow must be constant, between 50 ... 400 ml/min.
- The flow control or pressure reduction must always be installed downstream from the particle monitor in the return, as these can produce turbulences or air bubbles which can result in faulty measurements.
- If a pump is required to generate the necessary flow rate, it should be low pulsation and installed upstream from the particle monitor.
- Otherwise bubbles may occur when installed on the suction side, which will cause faulty measurements.
- If air bubbles in the system are suspected, a settling section in form of an approx. 2 m hose will be required in front of the device.

4.2 Hydraulic Connection

The sensor has two 1/4" screw connections and comes with factory installed Minimess connectors. The system pressure generates the necessary flow rate and may need to be throttled downstream from the device.

Any direction of flow is permitted.

The device should be installed in an accessible location to be able to read the display and operate the console. The risk of larger particles settling increases with the length of the line. Furthermore, particularly when using higher viscosities and Minimess lines the pressure should be sufficiently high to set the volume flow between 50 and 400 ml/min.

The Minimess connections can be replaced with any other screw connection. In this case, please note the maximum tightening torque of 25 Nm.

Dirt, shavings or other contaminants must not enter the device when replacing the couplers.

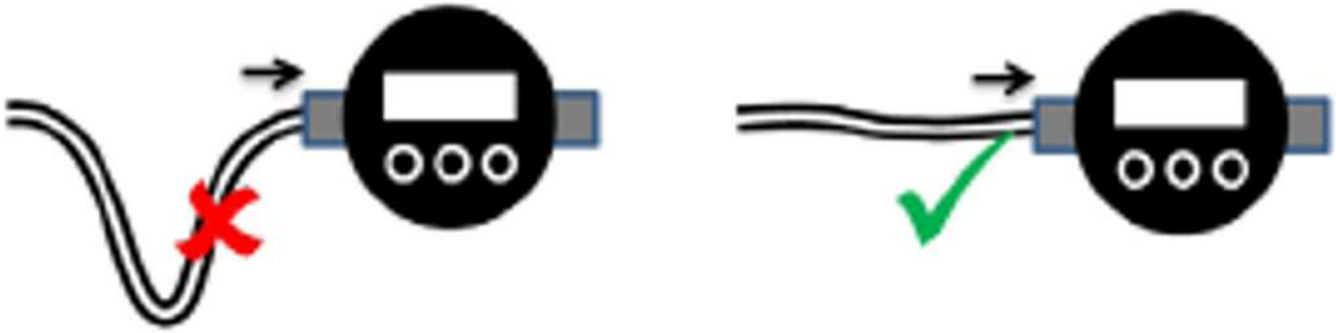


Fig. 5: Hydraulic connection, avoid blind holes in the supply line

Installation should be in the hydraulic circuit in a location relevant to the measuring task with constant pressure conditions.

The pressure may vary, but must not have peaks or strong fluctuations.

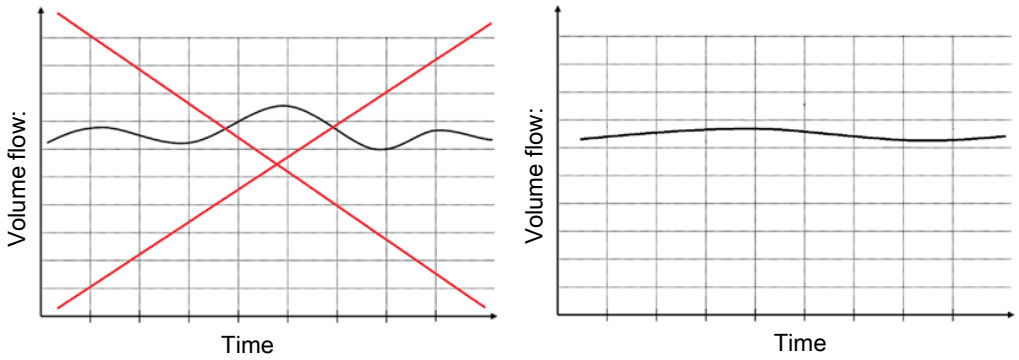


Fig. 6: Volume flow parameters

NOTICE! Based on experience, connecting to the control oil line. This location typically has a moderate pressure and an outflow of max. 400 ml/min typically does not present a problem for the control circuit.

If there is no control circuit, the filtration/cooling circuit can often be used alternatively.

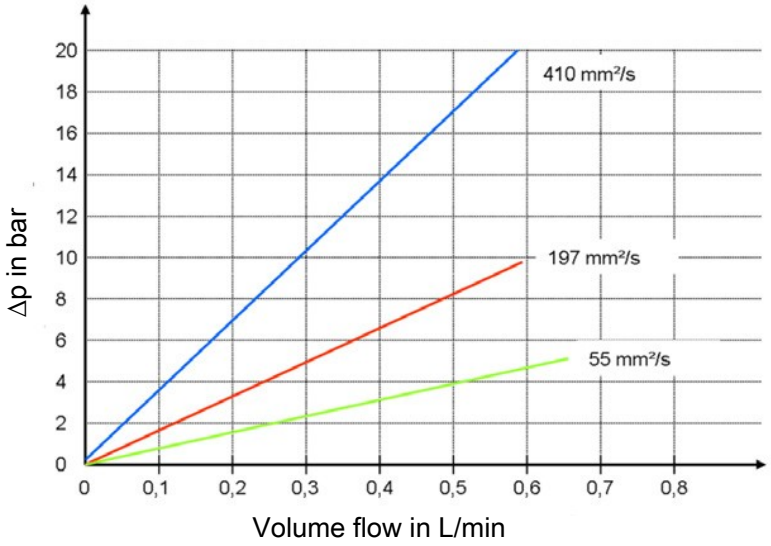


Fig. 7: Flow curve for various viscosities without Minimess connections

The image below shows the pressure difference arising depending on the volume flow for different viscosities. Along with specifying the necessary volume flow, this can be used to estimate the necessary pressure level.

4.3 Mount

The device has two mounting options:

Orientation	Mounting method	Torque	Length of engagement
Bottom	4 x M5	Max. 4 Nm (strength class 8.8)	Min. 5 +1 mm
Side	2 x M6	Max. 8 Nm (strength class 8.8)	Min. 6 +1 mm

4.4 Mechanical Load

The mechanical load of the device must not exceed the information in the following table.

Load	Frequency	Load
max. vibration in all three axes	5 ...9 Hz 9 ...16.5 Hz 16.5 ...200 Hz	Amplitude: +/-15 mm 3 g 10 g

Tab. 1: Permissible mechanical loads

Fig. 8: Prohibited mechanical stress

4.5 Electrical Connections

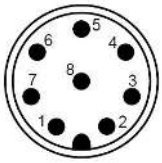
WARNING	**Faulty power supply** **Danger to life – risk of injury**
	The device must be installed by an electrician. Observe national and international regulations on the installation of electrical equipment.

Power supply as per EN50178, SELV, PELV, VDE0100-410/A1.

Switch off the machine for installation and connect the device per the following sections. Use a shielded sensor cable.

4.5.1 Pin Assignment (Top View)

Sensor plug pin assignment



Pin	Function
1	Power supply L+
2	Power supply L-
3	TxD, CAN low [OUT]
4	RxD, CAN high [IN]
5	Digital input (Start/Stop)
6	Analog output 4...20mA
7	Switching output (Open Collector/Alarm)
8	Signal earth
Shield	-

Tab. 2: Pin assignment

The sensor cable must be shielded. To ensure protective class IP67, only use suitable plugs and cables. The tightening torque for the plug is 0.1 Nm.

4.5.2 Analog Current Output (4..20 mA)

4.5.2.1 Measurement Without Load Resistor

The current should be measured with a suitable ammeter.

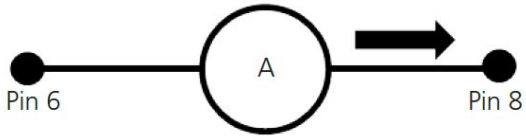


Fig. 9: Current measurement without load resistor

The ordinal numbers for the various standards are calculated according to the following tables.

4.5.2.2 Measurement With Load Resistor

The voltage should be measured with a suitable voltmeter.

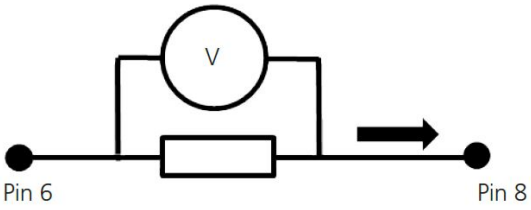


Fig. 10: Current measurement with load resistor

The ordinal numbers for the various standards are calculated according to the following tables.

The load resistance cannot be selected arbitrarily. It must be adjusted to the supply voltage. The maximum load resistance can be determined using the following formula:

$$R_{max}/\Omega = \frac{U/V - 2V}{20mA} - 100\ \Omega$$

Or alternatively use the following table:

R_{max}/Ω	Supply voltage/V
250	9
400	12
1000	24

Tab. 3: Maximum load resistance

4.5.2.3 Configuration

Which ordinal number and standard will be output via the analog current output can be selected in the device menu under "CONFIG. ANALOG".

4.5.2.4 Converting Analog Current Output To Ordinal Number

The analog current output supplies a signal of 4 to 20 mA. The following explains conversions into the respective ordinal numbers.

I/mA	ISO 4406:99	SAE AS 4059E
4	0	000
12	13	5
20	26	12

Tab. 4: Comparison chart current output to ordinal number ISO and SAE

I/mA	NAS 1638	GOST 17216
4	00	00
12	7	15
13	8	17
14	9	-
15	10	-
16	11	-
17	12	-
20	-	-

Tab. 5: Comparison chart current output to ordinal number NAS and GOST

Standard	Ordinal number formula
ISO 4406:99	1.625 ·I / mA - 6.5
SAE AS 4059 E	0.875 · I / mA - 5.5
NAS 1638	I / mA - 5
GOST 17216	2 · I / mA - 9

Tab. 6: Converting ordinal numbers

4.5.2.5 Sequential Data Output For ISO 4406:99 And SAE AS 4059E

The analog sequential data output function can be used for standards ISO 4406:99 and SAE AS 4059E. In this case, the four ordinal numbers are sequentially output via the analog interface (4..20mA) using a set time pattern.

Each sequence starts with a 20 mA signal for 4 seconds. The following shoes a complete output sequence with starting signal.

Sequential output is not available for NAS and GOST.

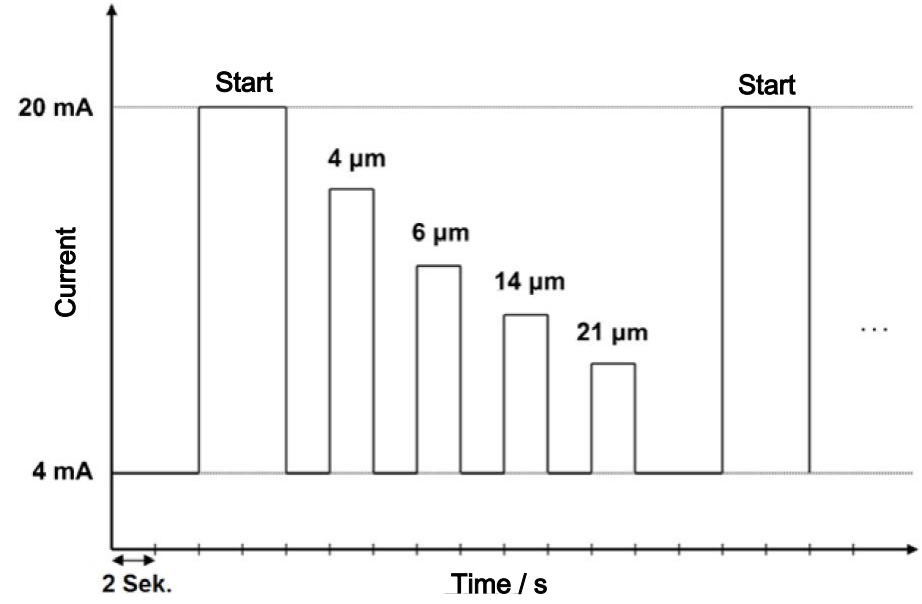


Fig. 11: Sequential data output

4.5.3 Switching Inputs And Outputs

4.5.3.1 Digital Input

The digital input is required for measuring mode: Digital I/O. Pin 5 must be connected to either L- or L+ to start and stop a measurement.

Additional information see chapter Digital I/O [> page 20].

4.5.3.2 Switching Output

When an alarm occurs, in addition to the red LED and the warning triangle in the display, this can also be identified via the alarm output on pin 7. See chapter Alarm Configuration [> page 21].

There are two options.

NOTICE! Pin 7 is not a switch in the sense of an NO contact. Depending on the alarm status, pin 7 is connected to earth (L-) or not connected (floating).

4.5.3.2.1 Option 1

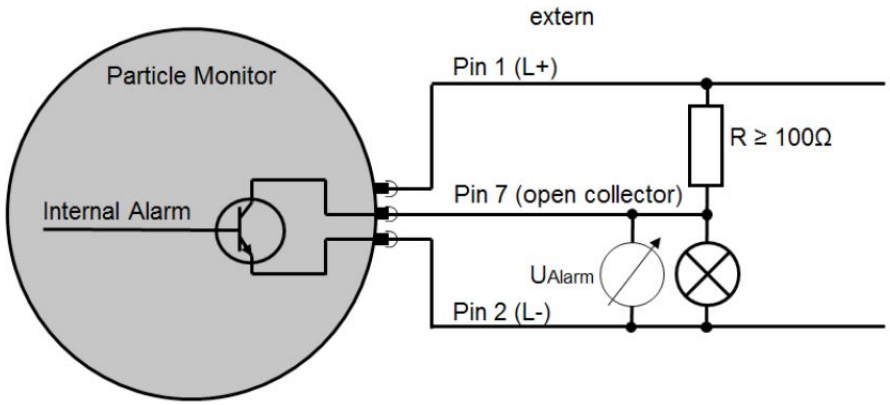
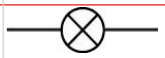
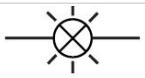


Fig. 12: Wiring diagram switching output option 1

Alarm	Explanation	With voltage measurement	When consumer connected
True	Internal transistor connects pin 7 to pin 2. The resistance R now prevents a direct short-circuit between pin 1 (L+) and pin 2 (L-).	U_{Alarm} = L- = 0 V R = 1...10 KΩ	 R ≥ 100 Ω
False	Pin 7 is not connected internally (floating).	U_{Alarm} = L+ R = 1...10 KΩ	 R ≥ 100 Ω

Tab. 7: Switching behaviour switching output option 1

4.5.3.2.2 Option 2

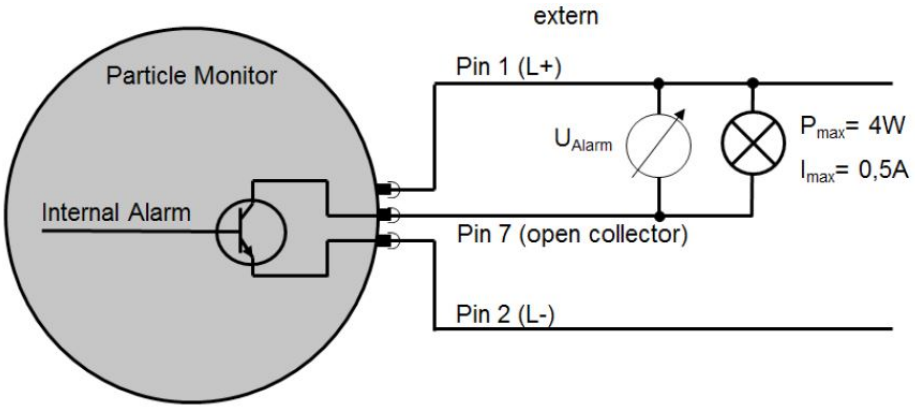
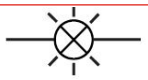


Fig. 13: Wiring diagram switching output option 2

Alarm	Explanation	With voltage measurement	When consumer connected
True	Internal transistor connects pin 7 with pin 2. The voltage is measured against L-.	U_{Alarm} = L+	 P_{max} = 4 W I_{max} = 0.5 A
False	Pin 7 is not connected internally (floating).	U_{Alarm} = L- = 0 V	 P_{max} = 4 W I_{max} = 0.5 A

Tab. 8: Switching behaviour switching output option 2

4.5.4 Calibration

The measuring instrument is calibrated based on ISO 11943.

The equipment required for calibration is primary calibrated according to ISO 11171, thus cannot be traceable to NIST SRM 2806A.

NOTICE! The sign µm (c) indicates particle size calibration using ISO-MTD test dust.

The calibration certificate of the device is valid for 18 months from initial calibration. Subsequent certificates are valid for 12 months.

4.5.4.1 Calibration Note

NOTICE! The function is disabled at the factory.

A message will be displayed when the device needs to be recalibrated. See image below. The device is still fully operational and supplies measurement results. Hold the enter key [↵] for 2 seconds to clear the message.

The message will then appear again after 500/800 and 900 hours. The device is still fully operational and supplies measurement results. Hold the enter key [↵] for 2 seconds to clear the message.

After 1000 hours the message will flash every 2 seconds. The device is still fully operational and supplies measurement results. It cannot be cleared.

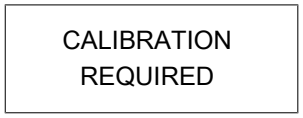


Fig. 14: Calibration warning display message

NOTICE! The calibration warning in the display can only be cleared by Bühler Technologies GmbH Service.

The hours remaining before the first message appears can be viewed in the device menu under “SENSOR PARAM > OPERATING HRS" ("HOURSCAL").

5 Operation and Control

NOTICE

The device must not be operated beyond its specifications.

5.1 Before Initial Use

Always read and understand the operating instructions before starting the equipment.

- Always observe the information related to intended use, operating conditions and technical data.
- Mount the particle monitor as per chapter Installation and connection [> page 10].
- Cables and hoses must be outside the area in which operating personnel moves around (tripping hazard).

5.2 Start Screen

The start screen shows the system status.

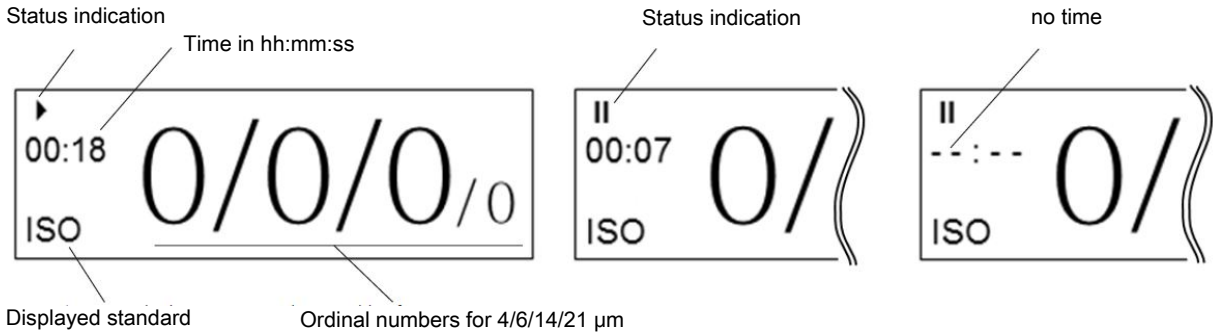


Fig. 15: Start screen, running and paused measurement, no time

5.2.1 Status Indication

- Measurement running ▶
- Laser adjusts ▶ (flashing) at the start of each measurement for approx. 2 to 3 seconds.
- Device paused II

5.2.2 Time

- Measurement running:
  Specifies the elapsed or remaining time for the current measurement depending on the operating mode. Specified in [minutes:seconds]
- Pause mode:
  Indicates the time until the next measurement. Specified in [minutes:seconds]
- When changing the pause time in pause mode and it is less than the elapsed time, the display will read "- - : - -". The information will display until the original time remaining has expired.
  After that, a new pause time is active.

5.2.3 Displayed Standard

Information about the current standard displayed, ISO, SAE, NAS or GOST. This is selected from the menu.

5.2.4 Ordinal Numbers

Display of the ordinal numbers for the last measurement. The number of ordinal numbers can vary depending on the selected standard. Standards GOST and NAS only show one ordinal number.

NOTICE! Ordinal numbers according to ISO 4406 between 1 and 6 are always displayed as ≤ 6. According to ISO 4406, the ordinal number for the 21 µm measuring channel is not analysed. The measured value, however, is displayed as additional information and indicated as a reduced size.

5.3 Menu And Operation

The [▲] or [▼] key is used to navigate the menu and entries. Press the select key [↵] to jump to the next level. To go back, simultaneously press the [▲] and [▼] key.

To change values, press the [↵] key to jump to the next place.

The number to change will be marked, then use the arrow keys [▲] and [▼] to change. Press [↵] after the last place to confirm and apply the changes.

Jumping to the higher level before the last confirmation, the changes will be discarded.

5.3.1 Menu Structure

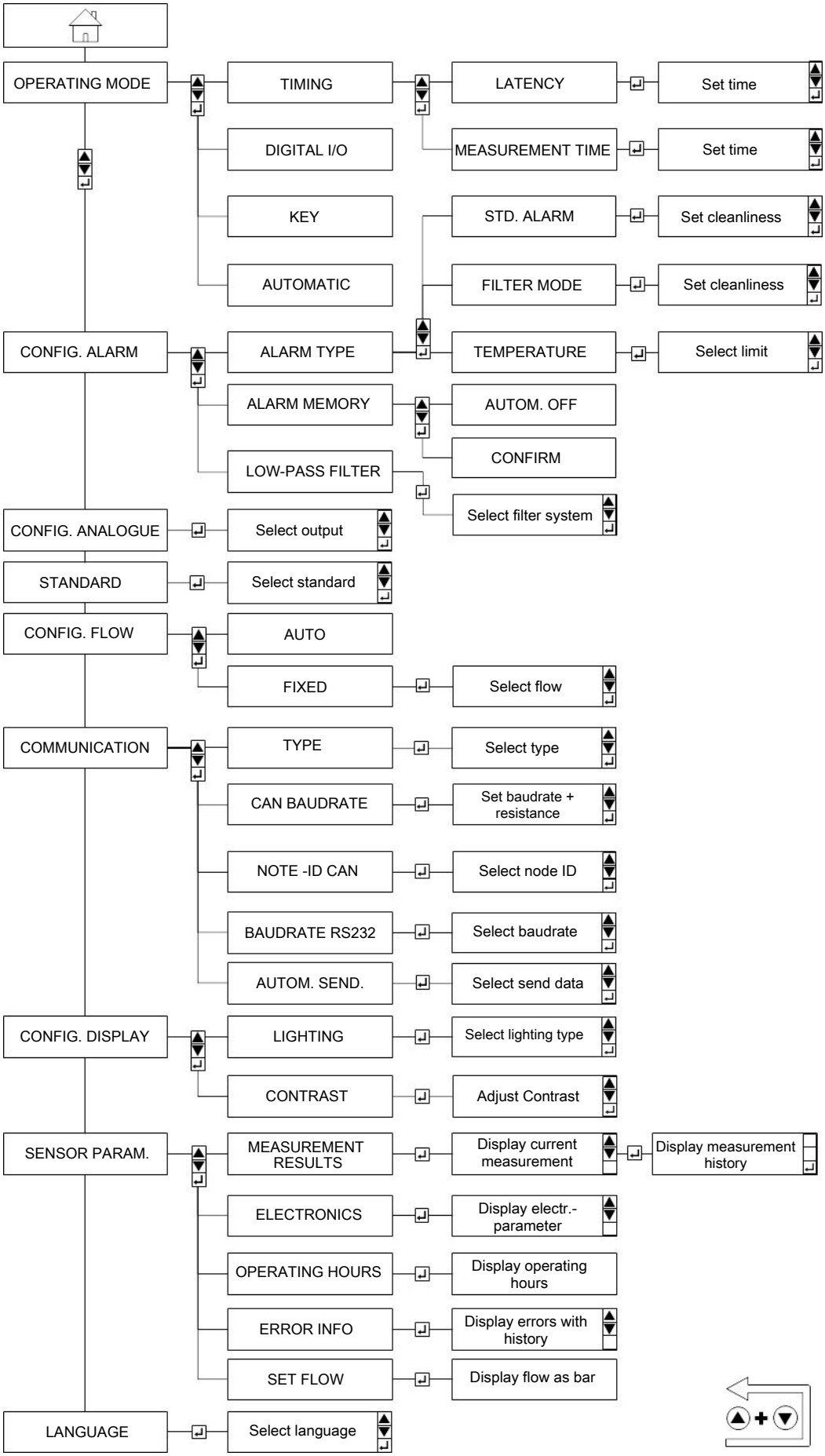


Fig. 16: Menu Structure

5.3.2 Operating Modes

There are four operating modes which can be configured in the menu.

When a measurement starts, the internal laser automatically adjusts. This process can be identified by the symbol [▶] flashing in the display and typically takes approx. 2 to 3 seconds. After this, the symbol will light up steady and measurement starts.

Pause mode can be identified by the [II] symbol.

NOTICE! Measurement times must be between 30 and 300 seconds. For cleanliness levels according to ISO 4406:99 of 15 (at 4 µm©) and better, the measurement time should be at least 120 seconds. The default is 60 seconds.

5.3.2.1 Timed Measurement

The BPM uses the set measurement time and pauses between measurements. Here, note the following setting options:

Setting limit	Min. value/seconds	Max. value/seconds
Measurement time	30	300
Pause time	1	86400 (24 h)
Measurement time factory setting	60	
Pause time factory setting	10	

Tab. 9: Setting limit timed measurement

The default setting of 60 seconds measurement time and 10 seconds pause yields a new measurement every 70 seconds.

Note on the time data in the start screen:

- Measurement running: Time remaining to the end of measurement (countdown)
- Pause mode: Time remaining to the next measurement (countdown)

5.3.2.2 Digital I/O

A measurement is running [▶] as long as pin 5 of the M12 plug is connected to the supply voltage (L+) or is not connected. When connecting pin 5 to earth (L-, Pin 2), pause mode [II] is active.

The maximum input current on pin 5 is 10 mA.

Note on the time data in the start screen:

- Measurement running: Elapsed time (incremental)
- Pause mode: Measurement time display for the last measurement (static display)

Assignment pin 5	Function
Supply voltage (L+)	Measurement running [▶]
Not connected	Measurement running [▶]
Earth (L-, Pin 2)	Pause mode [II]

Tab. 10: Assignment pin 5 for measuring mode I/O

5.3.2.3 Key

There are two options for starting and ending a measurement.

- Manually pressing the [↵] key.
- Using a "Start" and "Stop" command via the communication line. This can be done using RS232, CANopen or CAN J1939.

After completing a measurement, the measurement result will appear in the start screen. The recommended minimum and maximum measurement time must be observed.

Note on the time data in the start screen:

- Measurement running: Elapsed time (incremental)
- Pause mode: Measurement time display for the last measurement (static display)

5.3.2.4 Automatic

In automatic mode, the measurement time is determined dynamically depending on the flow rate and the particle concentration.

A measurement runs until the following conditions are met:

- A defined number of particles was detected AND
- the measurement time is at least 45 seconds OR
- the measurement time is greater than 300 seconds

Once the conditions are met, the result in determined and displayed. The number of necessary particle can be changed via the serial port with the command "WAutoParts". However, this should only be changed by an experienced user. The factory setting is 200.

Note on the time data in the start screen:

- Measurement running: Elapsed time (incremental).
- Pause mode: Not used, a new measurement is automatically started.

5.3.3 Alarm Configuration

5.3.3.1 Alarm Type

There are three different alarm modes which can be configured in the menu.

All three alarms are linked. If one of the three alarms is active, this is indicated by:

- Indicator light "Alarm" lights up red,
- Flashing warning triangle with exclamation point in the display,
- Alarm output pin 7 active,
- Specific bits set in the error codes (ERC).

NOTICE! Measurement results of 0 (ZERO) are considered implausible. In this case, alarm handling is ignored. This does not apply to the temperature alarm.

5.3.3.1.1 Standard Alarm

A separate limit can be set for each ordinal number (ON) measured. To ignore a size range, set the smallest value. The alarm is activated once a measured cleanliness class reaches or exceed the set limit.

Standard	Setting range	Value for deactivation	Alarm condition
ISO 4406:99	0, 1, 2 ... 28	0	ON 4 µm ≥ limit **OR** ON 6 µm ≥ limit **OR** ON 14 µm ≥ limit **OR** ON 21 µm ≥ limit
SAE AS 4059E	000, 00, 0, 1, 2...12	000	
NAS 1638	00, 0, 1, 2 ...12	00	ON ≥ limit
GOST 17216	00, 0, 1, 2 ...17	00	

Tab. 11: Alarm configuration standard alarm

5.3.3.1.2 Filter Mode

A separate limit can be set for each ordinal number (ON) measured. To ignore a size range, set the smallest value. The alarm is activated once a measured cleanliness class reaches or falls below the set limit.

Standard	Setting range	Value for deactivation	Alarm condition
ISO 4406:99	0, 1, 2 ... 28	0	ON 4 µm ≥ limit **OR** ON 6 µm ≥ limit **OR** ON 14 µm ≥ limit **OR** ON 21 µm ≥ limit
SAE AS 4059E	000, 00, 0, 1, 2...12	000	
NAS 1638	00, 0, 1, 2 ...12	00	ON ≥ limit
GOST 17216	00, 0, 1, 2 ...17	00	

Tab. 12: Alarm configuration filter mode

5.3.3.1.3 Temperature Alarm

Here you can set a temperature limit. The temperature alarm is active when the limit is reached or exceeded. To disable, set the limit to "00".

The measured temperature does not directly correspond to the measured oil temperature. Setting range: 00...85 (00 = disabled).

5.3.3.2 Alarm Memory

There are two options to remove an indicated alarm. The setting can be found in the menu.

1. Auto off

If the conditions for an alarm are no longer met, the alarm is automatically removed.

2. Confirm

The alarm will continue to be indicated, even if the conditions for an alarm are no longer met. It will be displayed until it is manually cleared.

It can be manually cleared by simultaneously pressing the UP [▲] and DOWN [▼] key.

5.3.3.3 Low-Pass Filter

Brief rises in the concentration (peaks) can occur in a hydraulic system which are not representative of the entire system, by using a hand valve. The BPM detects this change and indicates it accurately.

The low-pass filter ensures that if an alarm limit has been set, an alarm will not be triggered with every peak. The particle concentrations relevant for the alarm are smoothed internally and only output if a sustained measurement change triggers an alarm. The measurement output and display are not affected by the filtration.

- At a volume flow of 0 ml/min or an ISO class of 0 at 4 µm the filter function is automatically disabled.
- Setting range: 1...255 (1 = disabled)
- Factory setting: 2
- Recommended value: ≤ 10

The following chart shows a step response for various low-pass filter values. The table specifies how many measurements must be completed for the internal concentration to reach an alarm evaluation of 90 % of the actual concentration measured.

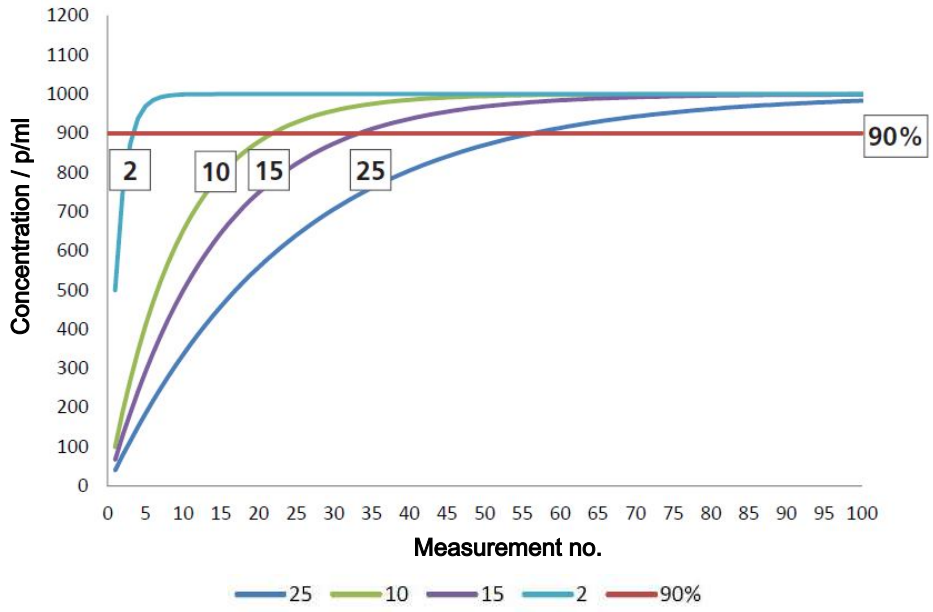


Fig. 17: Step response for low-pass filter values 2, 10, 15 and 25

Low-pass filter value	2	5	10	15	25	50	100
Number of measurements before 90%	3	10	21	33	56	113	229

Tab. 13: Low-pass filter values to reach the 90 % threshold

5.3.4 Analog Configuration

The measurement results can be output via the analog current output (4..20 mA). The following table shows a list of settings.

For measuring the current and conversions see Analog Current Output (4..20 mA) [> page 13].

Menu selection	Analog current output
4 µm	Status output of the ordinal number for 4 µm regardless of the configured standard ISO or SAE
6 µm	Status output of the ordinal number for 6 µm depending on the configured standard ISO or SAE
14 µm	Static output of the ordinal number for 14 µm depending on the configured standard ISO or SAE
21 µm	Static output of the ordinal number for 21 µm depending on the configured standard ISO or SAE
SEQUENTIAL (default)	Sequential output of the ordinal numbers for 4, 6, 14 and 21 µm depending on the configured standard ISO or SAE
NAS 1638	Output regardless of configured standard. So the LCD can show ISO, SAE or GOST, however the analog current output delivers the NAS.
GOST 17216	Output regardless of configured standard. So the LCD can display ISO, SAE or NAS, however the analog current output delivers GOST.

Tab. 14: Configuration analog current output

5.3.5 Standard

The cleanliness ouptut can be selected based on one of the following standards:

- ISO 4406:99
- SAE AS 4059E
- NAS 1638
- GOST 17216

Please remember, SAE AS 4059E will not analyse sizes 38 and 70 µm in separate channels.

The setting only applies to the display in the start screen. The internal memory and output via the digital interface (CAN or RS232) show all standards.

Which standard is selected can be seen at the bottom left of the start screen.

5.3.6 Flow Configuration

5.3.6.1 Automatic

In addition to the particle size and count, the BPM also calculates a volume flow index to calculate the particle concentration.

The calculated volume flow index is not an exact measurement of the volume flow. This is an internal calculation value which can be used as an indicator when installing and setting up the device. The device should not be considered or used as a flow meter.

5.3.6.2 Fixed

The particle concentration is then calculated based on the fixed volume flow. Enter the value in ml/min.

Please note, the actual and fixed volume flow must not be significantly different. Otherwise the particle concentration calculated from it will not be correct.

5.3.7 Communication

There are various settings which can be configured in the menu.

5.3.7.1 Type

Here you can select how the digital interface is configured. Only one type can be selected. The physical connection is always the same.

The types are:

– RS 232
– CANOpen
– CAN J1939
– AUTO CANOPEN (factory setting)
– AUTO J1939

The setting is activated after restarting the device.

When selecting "AUTO", the type is determined by the physical voltage level at the digital interface. The type (RS232 or CAN) is automatically detected once when switching on the device.

CANopen and CAN J1939 are operated at the same physical voltage levels. If type "CAN" is detected, the CANopen protocol is used (factory setting). To use J1939, "AUTO J1939" must be activated accordingly. For more information see chapter Configuration Commands [> page 30].

5.3.8 CAN Baudrate

The baudrate refers to the transfer rate of the CANopen and CAN J1939 protocol. The baudrate uses the physical unit kilobits per second.

The available settings are:

– 125 BAUD
– 250K BAUD
– 500K BAUD
– 1000K BAUD
– TERM. CAN

When activating "TERM. CAN", the transmission line in the device is terminated at a load resistance of 120 Ohm.

5.3.8.1 CAN Node ID

The node ID is the address used to address the device via the CAN Bus. The node ID is required for the CANopen and CAN J1939 protocol.

Setting range: 1 ... 127 (decimal)

Factory setting: 10 (decimal)

5.3.8.2 RS232 Baudrate

The baudrate refers to the transfer rate for the RS232 protocol. The baudrate uses the physical unit byte per second.

The available settings are:

– 9600 BAUD
– 19200 BAUD
– 57600 BAUD (transfer rate for firmware updates)
– 115200 BAUD

When connecting the device via the RS232 port, the superior instance must always run at the same baudrate.

5.3.8.3 Auto Send

When activating auto send, the measurement result is automatically output via the RS232 port immediately after the measurement. The data string sent corresponds to the response to the command "RVal".

For additional information see chapter Read Commands [> page 28].

Data string examples:

$Time:78.8916[h];ISO4um:0[-];ISO6um:0[-];ISO14um:0[-];ISO21um:0[-];SAE4um:000[-];
SAE6um:000[-];SAE14um:000[-];SAE21um:000[-];NAS:00[-];GOST:00[-];Conc4um:0.00[p/ml];
Conc6um:0.00[p/ml];Conc14um:0.00[p/ml];Conc21um:0.00[p/ml]; FIndex:50000[-];MTime:60[s];
ERC1:0x0000;ERC2:0x0000;ERC3:0x0000;ERC4:0x0800;CRC:Ä

5.3.9 Display Configuration

There are various display settings.

– Illumination:
  Choose whether the backlight is always on or automatically switches off after 10 seconds.
– Contrast:
  Adjust the contrast along a bar display.
  UP key [▲] = increase contrast

  DOWN key [▼] = reduce contrast Confirm with the enter key [↵]

5.3.10 Sensor Parameters

5.3.10.1 Measurement Results

Shows the results of the last valid measurements. Use the UP [▲] and DOWN [▼] key to show all results for a measurement. Use the enter key [↵] to jump to the previous measurement result.

Selecting the standard changes the appearance of the ordinal numbers.

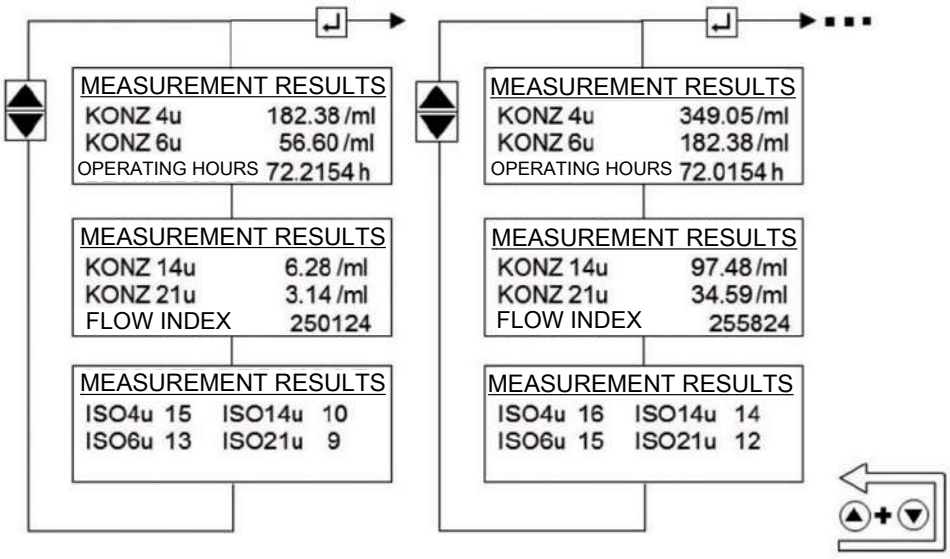


Fig. 18: Measurement result and history

5.3.10.2 Electronics

Shows internal sensor parameters. This cannot be changed by the user.

- Laser current:
  Current used to operate the internal laser. The value should be between 1 and 2.8 mA. If the value is outside this range, there is a risk of malfunction. See chapter Troubleshooting [> page 50].
- PD voltage:
  Voltage of the internal detector. The value should be between 3.7 and 4.3 V. If the value is outside this range, there is a risk of malfunction. See chapter Troubleshooting [> page 50].
- Temperature:
  Temperature of internal electronics. The value shown does not directly correspond to the oil temperature.
- Amplification:
  Adjusted amount for the internal detector.

5.3.10.3 Operating Hours

- Sensor:
  Operating hours counter for the device. The counter is active as soon as the device is powered.
- Laser:
  Operating hours counter for the laser. The counter is only active during a measurement procedure.
- Hourscal:
  Shows the hours until the next device calibration. If the value is 0 (ZERO), the time has either expired or the function is disabled. If the time is expired, a message will appear in the start screen.

5.3.10.4 Error Information

The BPM collects a variety of errors, information and operating statuses and combines these in four 16 bit values, the ERC (error code). These are always displayed in hexadecimal format.

The ERC's are generated and saved after every measurement. The display shows the last 256 ERC's. You can browse through these with the UP [▲] and DOWN [▼] key.

To ensure the ERC's can be allocated to the individual measurements, the respective operating hour is displayed at the top right.

- 1/256 = ERC for the last valid measurement
- 256/256 = ERC for the oldest valid measurement

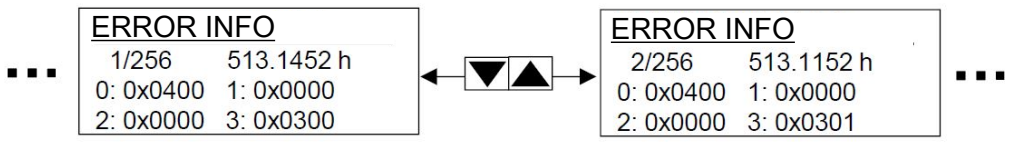


Fig. 19: Error information (ERC) display

5.3.10.5 Flow Settings

If the flow is auto detected, it can be displayed as a bar graph. The bar is scaled from 50 to 400 ml/min. The display is used to check the correct flow during initialization.

The display is refreshed every 10 seconds.

The flashing letters L (Low) and H (High) indicate the value is above or below the limit, which must be avoided.

If the flow is configured as a fixed static value, this will also be indicated. However, in this case the bar will not change.

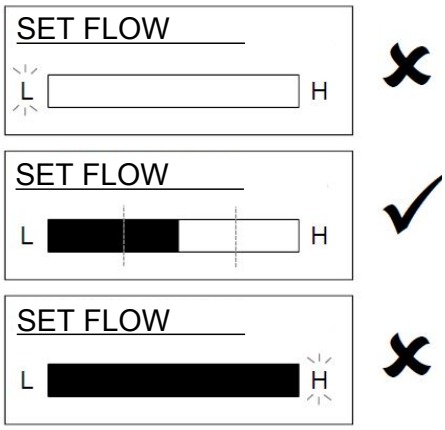


Fig. 20: Bar diagram of the flow

5.3.11 Language

The menu can be displayed in different languages. The available languages are:

- English
- German
- French
- Dutch
- Czech
- Spanish
- Italian
- Portuguese
- Polish
- Turkish

5.4 RS232 Communication

The BPM has a serial port for readout and configuration.

This requires a PC and a suitable terminal program or readout software. The sensor must be connected to a free COM port on a computer. A suitable communication cable for the serial connection between the sensor and computer/control unit is available on request. If the computer does not have a serial COM port, a USB to serial adapter can be used.

5.4.1 Interface Parameters

- Baudrate: 9600 (default)/19200/57600/115200
- Data bits: 8
- Parity None
- Stop bits: 1
- Flow control: None

5.4.2 Read Commands

#	Command format	Meaning	Return format
1	RVal[CR]	Read current measurement value	$Time:%.4f[h]; ISO4um:%d[-]; ISO6um:%d[-]; ISO14um:%d[-]; ISO21um:%d[-]; SAE4um:%c[-]; SAE6um:%c[-]; SAE14um:%c[-]; SAE21um:%c[-]; NAS:%c[-]; GOST:%c[-]; Conc4um:%.2f[p/ml]; Conc6um:%.2f[p/ml]; Conc14um:%.2f[p/ml]; Conc21um:%.2f[p/ml]; FIndex:%d[-]; MTime:%d[s]; ERC1:0x0000; ERC2:0x0000; ERC3:0x0000; ERC4:0x0300; CRC:z[CR][LF]
2	RID[CR]	Read ID	$BuehlerTechnologies;BPM100; SN:xxxxxx; SW:xx.xx.xx; CRC:z[CR][LF]
3	RCon[CR]	Read current configuration: Standard Operating mode Flow Analog output Alarm mode Filter setting Alarm value ISO/SAE 4µm Alarm value ISO/SAE 6µm Alarm value ISO/SAE 14µm Alarm value ISO/SAE 21µm Alarm value NAS Alarm value GOST Temperature alarm value Test time Pause time Checksum	 $Std:%d; StartMode:%d; Flow:%d; AO1:%d; Amode:%d; Mean:%d; Alarm4:%c; Alarm6:%c; Alarm14:%c; Alarm21:%c; AlarmNAS:%c; AlarmGOST:%c; AlarmT:%d[°C]; Mtime:%d[s]; Htime:%d[s]; CRC:z[CR][LF]
4	RMemS[CR]	Max. number of datasets in memory	MemS:%d[-];CRC:z[CR][LF]
5	RMemU[CR]	Number of current datasets in memory	MemU:%d[-];CRC:z[CR][LF]
6	RMemO[CR]	Memory organisation:	Time; ISO4um; ISO6um; ISO14um; ISO21um; SAE4um; SAE6um; SAE14um; SAE21um; NAS; GOST; Conc4um;

			Conc6um; Conc14um; Conc21um; FIndex; MTime; ERC1; ERC2; ERC3; ERC4[CR][LF]
7	RMem[CR]	Read all datasets in the memory with the prior memory organisation. Oldest dataset first. Cancel with enter key.	[Memory organisation] %f;%f; ... 0x0000[CR][LF] ... %f;%f; ... 0x0000[CR][LF] finished[CR][LF]
8	RMem-n[CR]	Read last n datasets in memory. Followed by checksum (CRC) per dataset. Oldest dataset first. Cancel with enter key.	$%f;%f; ... 0x0000;CRC:z[CR][LF] ... $%f;%f; ... 0x0000;CRC:z[CR][LF] finished[CR][LF]
9	RMemn;i[CR]	Read i datasets starting with dataset n in the memory. Oldest dataset = dataset 0 → n=0 Followed by checksum (CRC) per dataset. Oldest dataset first. Cancel with enter key.	$%f;%f; ... 0x0000;CRC:z[CR][LF] ... $%f;%f; ... 0x0000;CRC:z[CR][LF] finished[CR][LF]
10	RMemH-n[CR]	Read datasets for the last n hours in the memory. Oldest dataset first. Cancel with enter key.	$%f;%f; ... 0x0000;CRC:z[CR][LF] ... $%f;%f; ... 0x0000;CRC:z[CR][LF] finished[CR][LF]
11	CMem[CR]	Erase all datasets from memory. Erasing typically takes a few seconds. "Finished" appears when the process is complete.	CMem...finished[CR][LF]

Tab. 15: RS232 read commands

[CR] = Carriage Return

[LF] = Line Feed

%d / %c / %f = place holder

5.4.3 Configuration Commands

#	Command format		Specification	Return format
1	**Measurement time in seconds**			
	Write	WMtime%d [CR]	%d = 30...300 Default: 60	Mtime:%d[s];CRC:z[CR][LF]
	Read	RMtime[CR]	-	
2	**Pause in seconds**			
	Write	WHtime%d[CR]	%d = 1...86400 Default: 10	Htime:%d[s];CRC:z[CR][LF]
	Read	RHtime[CR]	-	
3	**Operating mode**			
	Write	SStartMode%d[CR]	%d = 0: Timed measurement (default) %d = 1: Digital I/O %d = 2: Key / RS232 %d = 3: Automatic	StartMode:%d;CRC:z[CR][LF]
	Read	RStartMode[CR]	-	
4	**Autoparts: Number of particles if operating mode = Auto**			
	Write	WAutoParts%d[CR]	%d = 200...5000000 Default: 200	AutoParts:%d[-];CRC:z[CR][LF]
	Read	RAutoParts[CR]	-	
5	**Start and stop measurement in operating mode "Key"**			
	Start	Start[CR]	-	Measuring[CR][LF]
	Stop	Stop[CR]	-	See return format to read command "RVal"
6	**Volume flow in ml/min**			
	Write	WFlow%d[CR]	%d = 0...400 0 = Automatic (default) 1...400 = Fixed value	Flow:%d[ml/min];CRC:z[CR][LF]
	Read	RFlow[CR]	-	
7	**Automatic measurement output via RS232**			
	Write	SAutoT%d[CR]	%d = 0: disabled (default) %d = 1: enabled	AutoT:%d;CRC:z[CR][LF]
	Read	-	-	
8	**Standard to display**			
	Write	SStd%d[CR]	%d = 0: ISO 4406:99 (default) %d = 1: SAE AS4059E %d = 2: NAS 1638 %d = 3: GOST 17216	Std:%d;CRC:z[CR][LF]
	Read	RCon[CR]	-	See response: "RCon"
9	**Alarm type**			
	Write	SAlarmD%d[CR]	%d = 0: Standard Alarm %d = 1: Filter Mode Default: 0	AlarmD:%d;CRC:z[CR][LF]
	Read	RCon[CR]	-	See response: "RCon"
10	**Alarm limit ISO/SAE 4µm (varies by configured standard)**			
	Write	WAlarm4%c[CR]	ISO: %c = 0...28 0 = Alarm disabled Default: 0 SAE: %c = 000...12 000 = Alarm disabled Default: 000	Alarm4:%c[-];CRC:z[CR][LF]
	Read	RAlarm4[CR]	-	
11	**Alarm limit ISO/SAE 6µm (varies by configured standard)**			

	Write	WAlarm6%c[CR]	ISO: SAE:	%c = 0...28 0 = Alarm disabled Default: 0 %c = 000...12 000 = Alarm disabled Default: 000	Alarm6:%c[-];CRC:z[CR][LF]
	Read	RAlarm6[CR]	-		
12	**Alarm limit ISO/SAE 14µm (varies by configured standard)**				
	Write	WAlarm14%c[CR]	ISO: SAE:	%c = 0...28 0 = Alarm disabled Default: 0 %c = 000...12 000 = Alarm disabled Default: 000	Alarm14:%c[-];CRC:z[CR][LF]
	Read	RAlarm14[CR]	-		
13	**Alarm limit ISO/SAE 21µm (varies by configured standard)**				
	Write	WAlarm21%c[CR]	ISO: SAE:	%c = 0...28 0 = Alarm disabled Default: 0 %c = 000...12 000 = Alarm disabled Default: 000	Alarm21:%c[-];CRC:z[CR][LF]
	Read	RAlarm21[CR]	-		
14	**NAS alarm limit**				
	Write	WAlarmNAS%c[CR]	%c = 00...12 00 = Alarm disabled Default: 00		AlarmNAS:%c[-];CRC:z[CR][LF]
	Read	RAlarmNAS[CR]	-		
15	**GOST alarm limit**				
	Write	WAlarmGOST%c[CR]	%c = 00...17 00 = Alarm disabled Default: 00		AlarmGOST:%c[-];CRC:z[CR][LF]
	Read	RAlarmGOST[CR]	-		
16	**Temperature alarm limit in °C**				
	Write	WAlarmT%d[CR]	%c = 0...85 0 = Alarm disabled Default: 0		AlarmT:%d[°C];CRC:z[CR][LF]
	Read	RAlarmT[CR]	-		
17	**Current output**				
	Write	SAO1%d[CR]]	%d = 0: disabled %d = 1: ISO/SAE 4µm %d = 2: ISO/SAE 6µm %d = 3: ISO/SAE 14µm %d = 4: ISO/SAE 21µm %d = 5: ISO/SAE sequential (default) %d = 6: NAS %d = 7: GOST		AO1:%d;CRC:z[CR][LF]
	Read	RCon[CR]	-		See response: "RCon"
18	**Low-pass filter**				
	Write	WMean%d[CR]	%d = 1...255 1 = No filter Default: 2		Mean:%d[-];CRC:z[CR][LF]
	Read	RMean[CR]	-		
19	**Communication type**				

	Write	SComMode%d[CR]	%d = 0: RS232 (default) %d = 1: CANopen %d = 2: Autodetect %d = 3: CAN J1939	ComMode:%d;CRC:z[CR][LF]
	Read	-	-	See response: "RCon"
20	**RS232 transfer rate**			
	Write	SRSBR%d[CR]	%d = 0: 9600 baud (default) %d = 1: 19200 baud %d = 2: 57600 baud %d = 3: 115200 baud	RSBR:%d;CRC:z[CR][LF]
	Read	-	-	
21	**CAN termination**			
	Write	SCTRM%d[CR]	%d = 0: disabled (default) %d = 1: enabled (120Ω)	CTRM:%d;CRC:z[CR][LF]
	Read	-	-	
22	**CAN transfer rate**			
	Write	SCOBR%d[CR]	%d = 3: 125K baud %d = 4: 250K baud (default) %d = 5: 500K baud %d = 6: 1000K baud	COBR:%d;CRC:z[CR][LF]
	Read	-	-	
23	**CAN Node-ID**			
	Write	WCOID%d[CR]	%d = 1...255 Default: 10	COID:%d[-];CRC:z[CR][LF]
	Read	RCOID[CR]	-	
24	**CAN Auto Default**			
	Write	WCAutoDef%d[CR]	Decide which protocol (CANopen or CAN J1939) to use if communication type = Autodetect %d = 0: CANopen (default) %d = 1: CAN J1939	CAutoDef:%d[-];CRC:z[CR][LF]
	Read	RCAutoDef[CR]	-	
25	**CAN J 1939 - interval in seconds for PDU 2**			
	Write	WCJInt%d[CR]	%d = 0...60 0 = send on value change Default: 10	CJInt:%d[s];CRC:z[CR][LF]
	Read	RCJInt[CR]	-	

Tab. 16: RS232 configuration commands

[CR] = Carriage Return

[LF] = Line Feed

%d / %c / %f = place holder

5.4.4 Checksum Calculation (CRC)

The checksum (CRC) can be used to verify the response to a command was transmitted properly.

The decimal value of each individual character (see ASCII table) transmitted in a string must be added up. Including line feed [LF] and carriage return [CR]. If the result is fully divisible by 256, transmission was error-free.

The following is an example of the BPM's response to the command "RMemS[CR]". (Memory map readout)

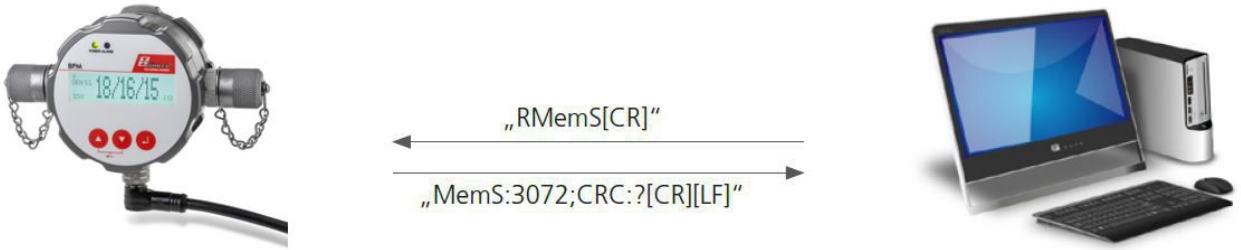


Fig. 21: Example RS 232 data transmission with checksum

Response	Value (decimal) per ASCII table
M	77
e	101
m	109
S	83
:	58
3	51
0	48
7	55
2	50
[	91
-	45
]	93
;	59
C	67
R	82
C	67
:	58
?	63
[CR]	13
[LF]	10
Sum	**1280 → 1280 / 256 = 5 Rest 0 → Error-free transmission**

Tab. 17: Checksum calculation (CRC) example

5.5 CAN Communication

The CAN interface corresponds to "CAN 2.0B Active Specification".

The sensor supports a limited number of transfer speeds on the CAN bus.

Data rate	Supported	CiA Draft 301	Bus length per CiA Draft Standard 301
1 Mbit/s	yes	yes	25 m
800 kbit/s	no	yes	50 m
500 kbit/s	yes	yes	100 m
250 kbit/s	yes	yes	250 m
125 kbit/s	yes	yes	500 m
100 kbit/s	no	no	750 m
50 kbit/s	no	yes	1000 m
20 kbit/s	no	yes	2500 m
10 kbit/s	no	yes	5000 m

Tab. 18: Supported bus rates for CANopen and corresponding cable lengths

5.5.1 CANOpen

The CANopen protocol defines what's described, not how it's described. The implemented procedure is a distributed control network which can connect very easy consumers to very complex control units without communication problems between consumers.

Parameter	Size	Unit
Typ. response time to SDO queries	<10	ms
Max. response time to SDO queries	150	ms
CAN-Transceiver supply voltage	3.3	V
Integrated termination	no	-

Tab. 19: Electrical parameter CANopen interface

The key concept of CANopen is the so-called Device Object Dictionary (OD), a concept also used in other fieldbus systems.

The following first explains Object Dictionary, then Communication Profile Area (CPA), and lastly the CANopen communication protocol.

The image is for illustration purposes only, implementation corresponds to CAN 2.0B specification.

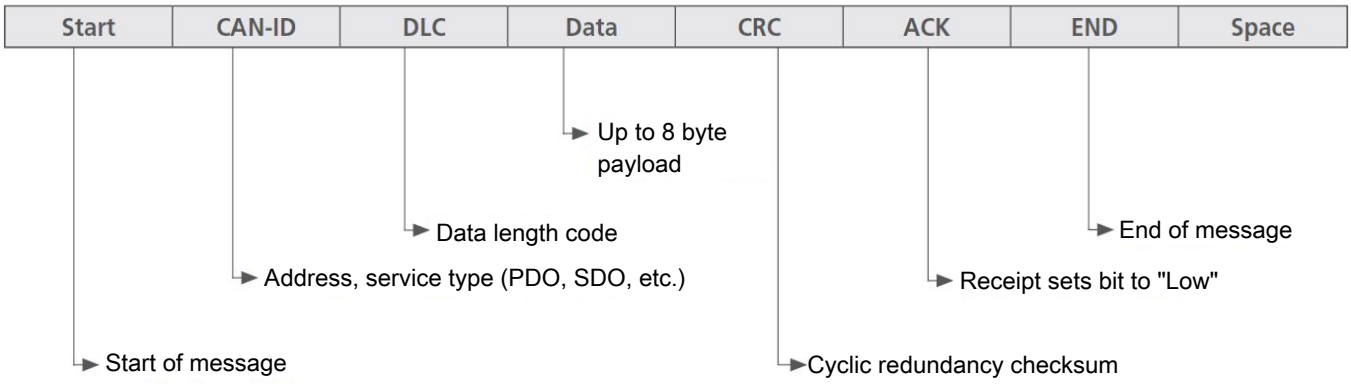


Fig. 22: CANopen message format

5.5.1.1 "CANopen Object Dictionary" In General

CANopen Object Dictionary (OD) is an object directory where each object can be addressed with a 16 bit index. Each object can consist of several data elements which can be addressed with an 8 bit subindex.

The principle layout of a CANopen object directory is shown below.

Index (hex)		Object
0000		-
0001	- 001F	Static data types (Boolean, Integer)
0020	- 003F	Complex data types (consisting of standard data types)
0040	- 005F	Complex data types, manufacturer specific
0060	- 007F	Static data types (device profile specific)
0080	- 009F	Complex data types (device profile specific)
00A0	- 0FFF	reserved
1000	- 1FFF	Communication Profile Area (e.g. device type, error register, supported PDOs, ..)
2000	- 2FFF	Communication Profile Area (manufacturer specific)
6000	- 9FFF	Device profile specific Device Profile Area (e.g. "DSP-401 Device Profile for I/O Modules")
A000	- FFFF	reserved

Tab. 20: General CANopen Object Dictionary structure

5.5.1.2 CANopen Communication Objects

Communication objects transmitted in CANopen are described by services and protocols and classified as follows:

- Network Management (NMT) is services and bus initialization, error handling, and node management
- Process Data Objects (PDOs) are used to transmit real-time process data
- Service Data Objects (SDOs) allow read and write access to the object directory of a node
- Special Function Object Protocol allows application-specific network synchronisation, timestamp transmission and emergency messages.

The following is an example for initializing the network with a CANopen Master and a sensor.

(A) Once powered, the sensor sends a boot-up message within approx. 5 seconds and once the preoperational state is reached. In this state the sensor only sends heartbeat messages when configured accordingly.

(B) The sensor can then be configured via SDOs, which is typically not required as the sensor automatically saves the configured communication parameters.

(C) To put the sensor in operational state, either the corresponding message can be sent to all CANopen consumers or specifically to the sensor. In operational state, the sensor sends the supported PDOs as configured, either periodically or triggered by sync messages.

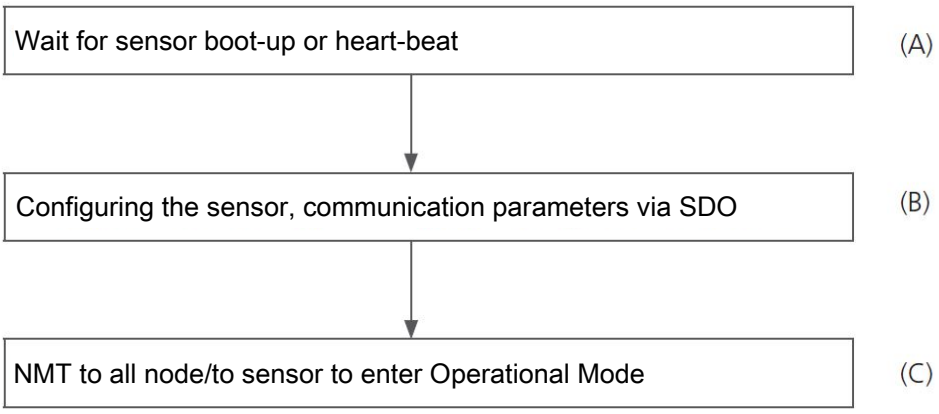


Fig. 23: CANopen bus initialization process

Different CANopen protocol services are available depending on the sensor state:

Com. Object	Initializing	Pre-Operational	Operational	Stopped
PDO			X	
SDO		X	X	
Synch		X	X	
BootUp	X			
NMT		X	X	X

Tab. 21: Available CANopen services in various sensor states

5.5.1.3 Service Data Object (SDO)

Service Data Objects enable write and read access to the sensor's object directory. Each SDO is acknowledged and transmission only takes place between two consumers, a so-called Client/Server model.

The sensor can only serve as server, so only responds to SDO messages and does not send requests to other consumers by itself. The SDO messages from the sensor to the client have the ID NodeID+0x580. When requests are sent from the client to the sensor (server), NodeID+0x600 is expected as the ID in the SDO message.

The standard protocol for SDO transfers requires 4 byte to encode the send direction, data type, the index and the subindex. This leaves 4 byte of the 8 byte of a CAN array for the data content. For objects with data contents greater than 4 byte there are two other protocols for so-called fragmented or segmented SDO transfer.

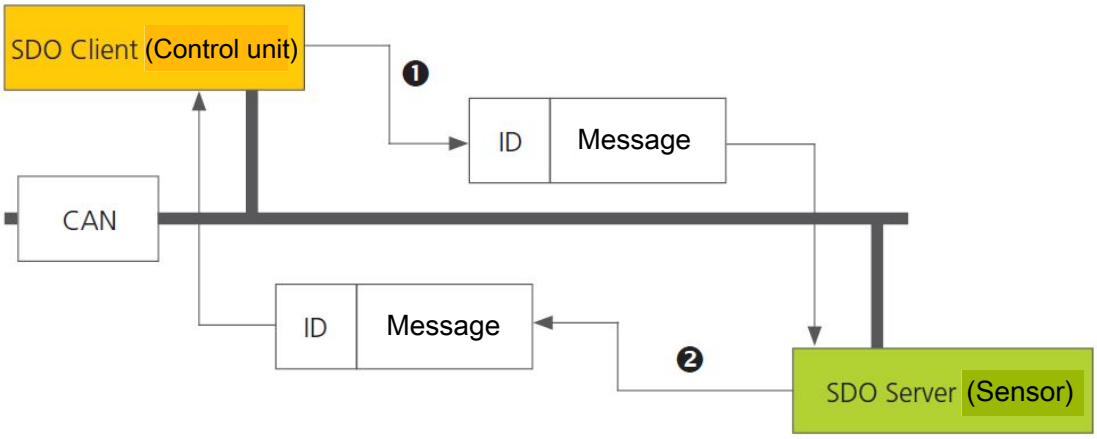


Fig. 24: SDO Client/Server relationship

SDOs are intended to configure the sensor by accessing the object directory, request rarely used data or configuration values or download large data volumes. SDO properties at a glance:

- All data in the object directory can be accessed
- Confirmed transmission
- Client/Server relationship during communication

The control data and payload of a non-segmented SDO standard message are spread across the CAN message as shown in the table below. The payload of an SDO message is up to 4 byte. The control data of an SDO message (cmd, index, subindex) is used to determine the access direction to the object directory and if applicable the transmitted data type. For detailed specifications of the SDO protocol, please refer to "CiA Draft Standard 301".

CAN	CAN-ID	DLC	CAN message payload							
			0	1	2	3	4	5	6	7
CANopen SDO	COB-ID 11 bit	DLC	Cmd	Index		Subindex	CANopen SDO message payload			

Tab. 22: Structure of an SDO message

The following is an example of an SDO query of the sensor serial number from the object directory to index 0x1018, subindex 4, with a data length of 32 bit. The client (control unit) sends a read request to the sensor with the ID "NodeID".

CAN	CAN-ID	DLC	CAN message payload							
			0	1	2	3	4	5	6	7
CANopen	COB-ID 11 bit	DLC	Cmd	Index		Subidx	SDO payload			
				1	0	0	3	2	1	0
Message from client to sensor	0x600 + NodeID	0x08	0x40	0x18	0x10	0x04	don't care	don't care	don't care	don't care

Tab. 23: SDO download request from the client to the server

The sensor responds with the corresponding SDO message encoded with the data type, index, subindex and the serial number of the sensor, in this case serial number 200123 (0x30DBB).

CAN	CAN-ID	DLC	CAN message payload							
			0	1	2	3	4	5	6	7
CANopen	COB-ID 11 bit	DLC	Cmd	Index		Subidx	SDO payload			
				1	0	0	3	2	1	0
Message from client to sensor	0x580 + NodeID	0x08	0x43	0x18	0x10	0x04	0xBB	0x0D	0x30	0x00

Tab. 24: SDO download response from the server to the client

The following is an example of a data upload (heartbeat time) via SDO to the object directory of the sensor to index 0x1017 with a data length of 16 bit. The client (control unit) sends a write request to the sensor with the ID "NodeID" to set the heartbeat time to 1000°ms (0x03E8).

CAN	CAN-ID	DLC	CAN message payload							
			0	1	2	3	4	5	6	7
CANopen	COB-ID 11 bit	DLC	Cmd	Index		Subidx	SDO payload			
				1	0	0	3	2	1	0
Message from client to sensor	0x600 + NodeID	0x08	0x2B	0x17	0x10	0x00	0xE8	0x03	0	0

Tab. 25: SDO upload request from the client to the server

The sensor responds with the corresponding SDO message confirming successful access and the index and subindex accessed are encoded.

CAN	CAN-ID	DLC	CAN message payload							
			0	1	2	3	4	5	6	7
CANopen	COB-ID 11 bit	DLC	Cmd	Index		Subidx	SDO payload			
				1	0	0	3	2	1	0
Message from client to sensor	0x580 + NodeID	0x08	0x60	0x17	0x10	0x00	0x00	0x00	0x00	0x00

Tab. 26: SDO upload response from server to client

5.5.1.4 Process Data Object (PDO)

PDOs are one or more datasets reflecting the object directory with up to 8 bytes of a CAN message to quickly transmit data and with the least possible expenditure of time from a "producer" to one or more “consumers".

Each PDO has a unique COB-ID (communication object identifier), is only sent from a single node but can be received by multiple nodes and does not need to be acknowledged/confirmed.

PDOs are ideal for sending data from sensors to the control unit or to send data from the control unit to actuators. PDO attributes of the sensor at a glance:

– Sensor supports three send PDOs (TPDOs), no receipt PDOs (RPDOs). Level sensors support four TPDOs.
– Data mapping in PDOs is fixed and cannot be edited.

The sensor supports two different PDO transfer methods.

1. With the event or timer triggered method, transmission is triggered by a timer inside the sensor or an event.

2. With the SYNCH triggered method, transmission is in response to a SYNCH message (CAN message from a SYNCH producer without payload). The response with PDO is either for every synch received or can be configured as every SYNCH messages received.

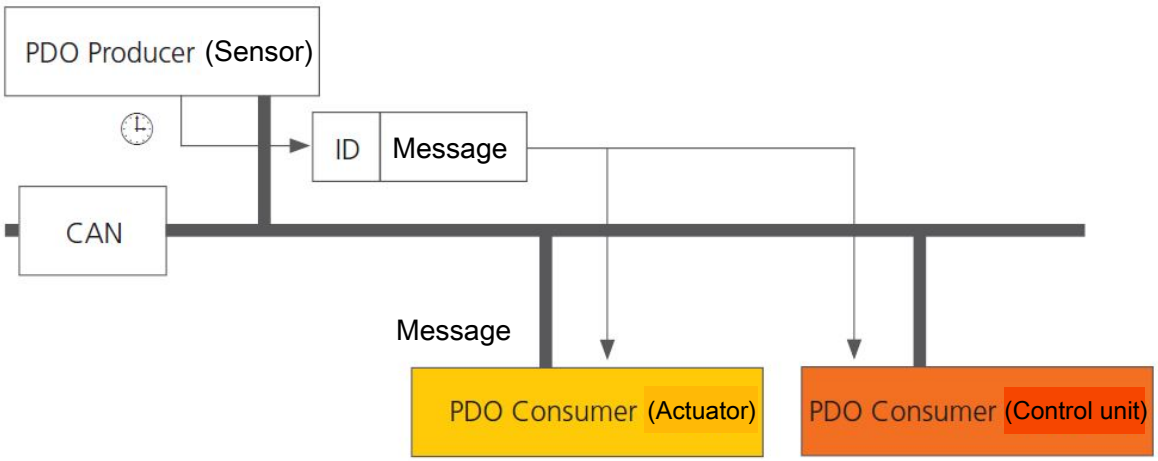


Fig. 25: PDO Consumer/Producer relationship

5.5.1.5 PDO Mapping

The sensor supports up to three to four transmit PDOs (TPDOs) for the most efficient CAN bus operation. The sensor does not support dynamic PDO mapping, so the mapping parameters in the OD are read-only, not writeable.

This shows the principle of mapping objects from the OD in a TPDO, corresponding with CiA DS-301. Which objects are mapped in TPDO 1 to 4 can be determined in the OD, index 0x1A00 to 0x1A03. This also shows the structure of the PDO mapping entry. Furthermore, every TPDO has a description of the communication parameters, so transmission type, COB-ID and event timer, if applicable. The communication parameters for TPDO 1 to 4 are documented in the OD, index 0x1800 to 0x1803.

Byte		LSB
Index (16 bit)	Subindex (8 bit)	Object length in bit (8 bit)

Tab. 27: Basic structure of a PDO mapping entry

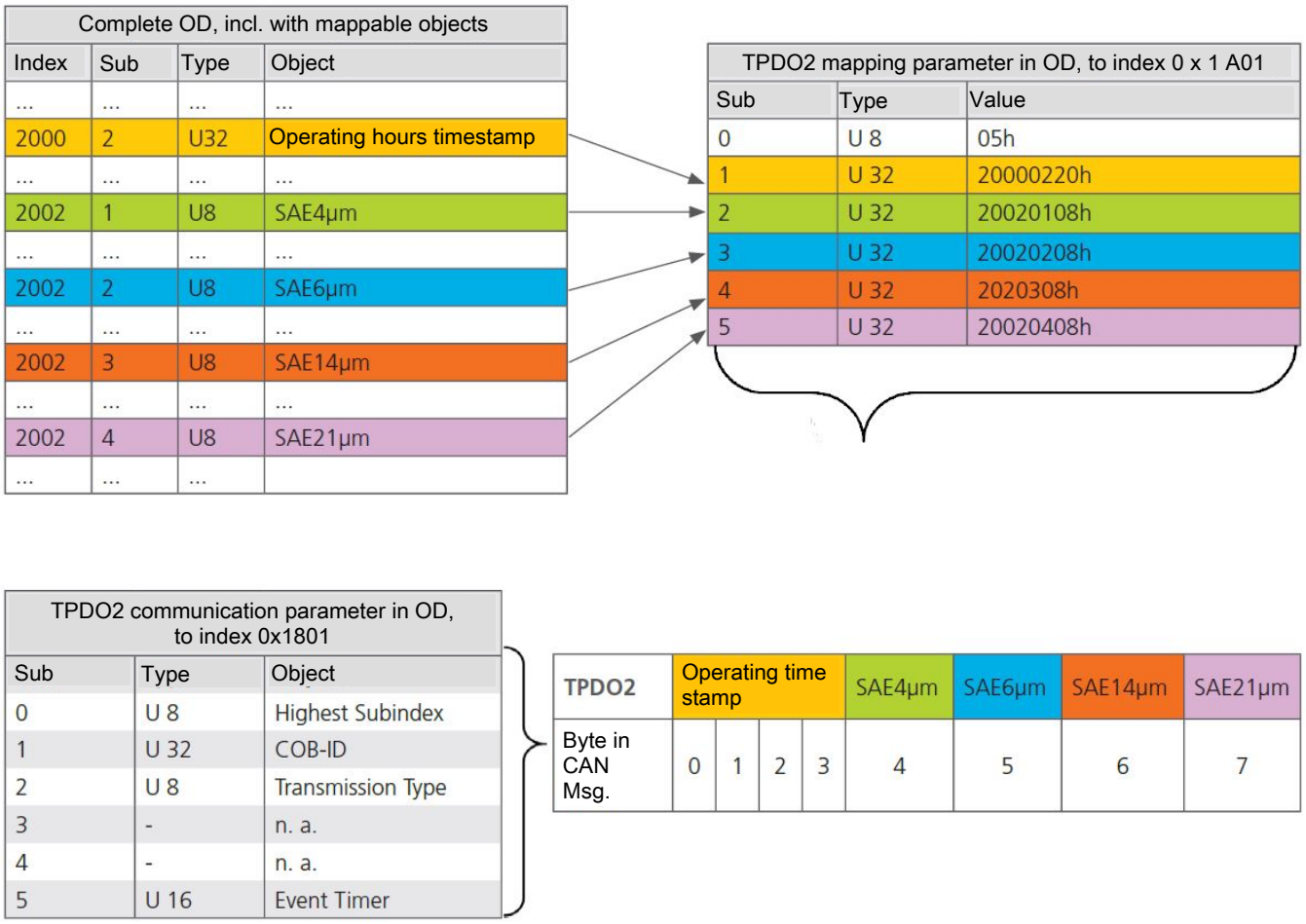


Fig. 26: Principle of mapping multiple OD objects in a TPDO

The sensor supports certain types of TPDO, which can be entered for the respective communication parameters of the TPDOs.

Type	supported	cyclic	non-cyclic	synchronous	asynchronous
0	yes		x	x	
1-240	yes	x		x	
241-253	no				
254	yes				x
255	yes				x

Tab. 28: Description of TPDO types

5.5.1.6 "CANopen Object Dictionary" Details

The following table lists the object directory for the sensor. Apart from a few exceptions, these settings correspond to the CAN-open standard as described in DS 301.

Idx	SIdx	name	type	Attr.	mapped on PDO	default	notes
1000h	**0**	**device type**	**unsigned 32**	**ro**		**194h**	**sensor, see DS 404**
1001h	**0**	**error register**	**unsigned 8**	**ro**		**00h**	**mandatory see DS301**
1017h	**0**	**producer heartbeat time**	**unsigned 16**	**rw**		**1338h**	**heartbeat time in ms, range: 0..65535**
1018h		**identity object**	**record**	**ro**			
	0	number of entries	unsigned 8	ro		04h	largest sub index
	1	vendor ID	unsigned 32	ro		000000E6h	
	2	product code	unsigned 32	ro		5B31F668	BPM100
	3	revision number	unsigned 32	ro		1000	device dependent
	4	serial number	unsigned 32	ro			device dependent
1800h		**transmit PDO1 parameter**	**record**				
	0	number of entries	unsigned 8	ro		05h	largest sub index
	1	COB-ID	unsigned 32	rw		180h+ NodeID	COB-ID used by PDO, range: 181h..1FFh, can be changed while not operational
	2	transmission type	unsigned 8	rw		FFh	cyclic + synchronous, asynchronous values: 1-240, 254, 255
	5	event time	unsigned 16	rw		1F4h	event timer in ms for asynchronous TPDO1, value has to be a multiple of 50 and max 12700
1801h		**transmit PDO2 parameter**	**record**				
	0	number of entries	unsigned 8	ro		05h	largest sub index
	1	COB-ID	unsigned 32	rw		280h+ NodeID	COB-ID used by PDO, range: 281h..2FFh, can be changed while not operational
	2	transmission type	unsigned 8	re		FFh	cyclic + synchronous, asynchronous values: 1-240, 254, 255
	5	event time	unsigned 16	rw		1F4h	event timer in ms for asynchronous TPDO2 range: 0..65000
1802h		**transmit PDO3 parameter**	**record**				
	0	Number of entries	unsigned 8	ro		05h	largest sub index
	1	COB-ID	unsigned 32	rw		380h+ NodeID	COB-ID used by PDO, range: 381h..3FFh, can be changed while not operational
	2	transmission type	unsigned 8	rw		FFh	cyclic + synchronous, asynchronous values: 1-240, 254, 255
	5	event timer	unsigned 16	rw		1F4h	event timer in ms for asynchronous TPDO3 range: 0..65000
1803h		**transmit PDO4 parameter**	**record**				
	0	number of entries	unsigned 8	ro		05h	largest sub index
	1	COB-ID	unsigned 32	rw		480h+ NodeID	COB-ID used by PDO, range: 481h..4FFh, can be changed while not operational
	2	transmission type	unsigned 8	rw		FFh	cyclic + synchronous, asynchronous values: 1-240, 254, 255
	5	event time	unsigned 16	rw		1F4h	event timer in ms for asynchronous TPDO3 range: 0..65000
1A00h		**TPDO1 mapping parameter**	**record**				
	0	Number of entries	unsigned 8	ro		05h	largest sub index
	1	PDO mapping for 1st app obj. to be mapped	unsigned 32	co		20000220h	20000220h
	2	PDO mapping for 2nd app obj. to be mapped	unsigned 32	co		20010108h	ISO4µm, 1 byte in 2001h, sub 01

	3	PDO mapping for 3rd app obj. to be mapped	unsigned 32	co		20010208h	ISO6µm, 1 byte in 2001h, sub 02
	4	PDO mapping for 4th app obj. to be mapped	unsigned 32	co		20010308h	ISO14µm, 1 byte in 2001h, sub 03
	5	PDO mapping for 5th app obj. to be mapped	unsigned 32	co		20010408h	ISO21µm, 1 byte in 2001h, sub 04
1A01h		**TPDO2 mapping parameter**	**record**				
	0	Number of entries	unsigned 8	ro		05h	largest sub index
	1	PDO mapping for 1st app obj. to be mapped	unsigned 32	co		20000220h	timestamp of the measurement, 4 byte
	2	PDO mapping for 2nd app obj. to be mapped	unsigned 32	co		20020108h	SAE4µm, 1 byte in 2002h, sub 01
	3	PDO mapping for 3rd app obj. to be mapped	unsigned 32	co		20020208h	SAE6µm, 1 byte in 2002h, sub 02
	4	PDO mapping for 4th app obj. to be mapped	unsigned 32	co		20020308h	SAE14µm, 1 byte in 2002h, sub 03
	5	PDO mapping for 5th app obj. to be mapped	unsigned 32	co		20020408h	SAE21µm, 1 byte in 2002h, sub 04
1A02h		**TPDO3 mapping parameter**	**record**				
	0	number of entries	unsigned 8	ro		05h	largest sub index
	1	PDO mapping for 1st app obj. to be mapped	unsigned 32	co		20000120h	operating hours, 4 byte
	2	PDO mapping for 2nd app obj. to be mapped	unsigned 32	co		20030108h	oil condition bits, 1 byte
	3	PDO mapping for 3rd app obj. to be mapped	unsigned 32	co		20030708h	measurement bits, 1 byte
	4	PDO mapping for 4th app obj. to be mapped	unsigned 32	co		20030808h	sensor status bits, 1 byte
	5	PDO mapping for 5th app obj. to be mapped	unsigned 32	co		20040008h	temperature, 1 byte
1A03h		**TPDO4 mapping parameter**	**record**				
	0	Number of entries	unsigned 8	ro		03h	largest sub index
	1	PDO mapping for 1st app obj. to be mapped	unsigned 32	co		20000220h	timestamp of the measurement, 4 byte
	2	PDO mapping for 2nd app obj. to be mapped	unsigned 32	co		20060108h	NAS, 1 byte in 2006h, sub 01
	3	PDO mapping for 3rd app obj. to be mapped	unsigned 32	co		20070108h	GOST, 1 byte in 2007h, sub 01
2000h		**time related parameters of the sensor**	**record**				
	0	number of entries	unsigned 8	ro		04h	largest sub index
	1	operating hours	unsigned 32	ro	y		sensor up time in seconds
	2	timestamp of the last measurement	unsigned 32	ro	y		timestamp of the last measurement
	3	laser operation hours in hours	unsigned 32	ro			laser operation hours
	4	time to calibration note S1 in hours	unsigned 32	ro			time to calibration note S1
2001h		**ISO measurement**	**record**				
	0	number of entries	unsigned 8	ro		04h	largest sub index
	1	ISO4µm	unsigned 8	ro	y		
	2	ISO6µm	unsigned 8	ro	y		
	3	ISO14µm	unsigned 8	ro	y		
	4	ISO21µm	unsigned 8	ro	y		
2002h		**SAE measurement**	**record**				
	0	number of entries	unsigned 8	ro		04h	largest sub index

	1	SAE4µm	unsigned 8	ro	y		offset of two to display 000, 00 and 0, valid for all classes 0 == SAE 000 1 == SAE 00 2 == SAE 0 3 == SAE 1 ... 14 == SAE 12 (maximum value)
	2	SAE6µm	unsigned 8	ro	y		
	3	SAE14µm	unsigned 8	ro	y		
	4	SAE 21µm	unsigned 8	ro	y		
2003h		**condition monitoring bits**	**array**				
	0	number of entries	unsigned 8	ro		08h	largest sub index
	1	oil specific bits	unsigned 8	ro	y		concentration limit exceeded flow high flow low measurement not plausible (air...)
	2	reserved	unsigned 8	ro			
	3	reserved	unsigned 8	ro			Bit 0: calibration limit S1 reached bit 1: calibration limit S5 reached
	4	reserved	unsigned 8	ro			
	5	reserved	unsigned 8	ro			
	6	reserved	unsigned 8	ro			
	7	measurement info	unsigned 8	ro	y		Bit0: measurement is running Bit1: operating mode: time Bit2: operating mode: Digital I/O Bit3: operating mode: Button Bit4: alarm type: (1)filter/(0)standard Bit5: power-up Bit6: concentration alarm Bit7: temperature alarm
	8	sensor alarm	unsigned 8	ro	y		Bit0: laser current high Bit1: laser current low Bit2: voltage high Bit3: voltage low Bit4: temperature high Bit5: temperature low Bit6: - Bit7: operating mode: auto
2004h	**0**	**sensor temperature**	**signed 8**	**ro**	**y**		**temperature in °C**
2005h	**0**	**flow index**	**unsigned 16**	**ro**			**Flow index (0..500)**
2006h		**NAS measurement**	**record**				
	0	number of entries	unsigned 8	ro		01h	largest sub index
	1	NAS	unsigned 8	ro	y		offset of one to display 00 and 0 0 == NAS 00 1 == NAS 0 2 == NAS 1 ... 13 == NAS 12 (maximum value)
2007h		**GOST measurement**	**record**				
	0	number of entries	unsigned 8	ro		01h	largest sub index
	1	GOST 17216	unsigned 8	ro	y		offset of one to display 00 and 0 0 == GOST 00 1 == GOST 0 2 == GOST 1

							..... 17 == GOST 16 (maximum value)
2020h		**command**	**unsigned 8**	**wo**			**1 = start of a measurement** **2 = stop of a measurement** **3 = result between**
2030h		**measurement related settings**	**record**				
	0	number of entries	unsigned 8	ro		4h	largest sub index
	1	measurement time	unsigned 32	rw			Measurement time in s
	2	hold time	unsigned 32	rw			Time between measurements
	3	operation mode	unsigned 16	rw			0 = time control 1 = digital I/O 2 = button 3 = automatic
	4	history disable	unsigned 16	rw		0h	0 = history enabled 1 = history disabled
2031h		**startup settings**	**record**				
	0	number or entries	unsigned 8	ro		4h	largest sub index
	1	startmode	unsigned 16	rw		0h	0 = Network with NMT Master (Init => PreOp => Start_Remote_Node => Operational) >0 = Network without NMT Master (Init => Operational)
	2	communication type	unsigned 16	rw			enabled communication interface: 0: RS232 1: CANopen 2: auto 3: J1939
	3	CAN baudrate	unsigned 16	rw			baudrate CAN: 3: 125k 4: 250k 5: 500k 6: 1000k
	4	RS232 baudrate	unsigned 16	rw			baudrate RS232: 0: 9600 1: 19200 2: 57600 3: 115200
2032h		**standard & alarm related settings**	**record**				
	0	number of entries	unsigned 8	ro		9h	largest sub index
	1	display & alarm standard	unsigned 16	rw			displayed standard and alarm trigger bit setting 0 = ISO 1 = SAE 2 = NAS 3 = GOST
	2	alarm type	unsigned 16	rw			0 = standard alarm 1 = filter mode
	3	alarm value temperature	unsigned 8	rw			range: 0..85 °C 0 = disabled
	4	alarm value ISO/SAE4µm	unsigned 8	rw			alarm threshold 4µm (note the offset)
	5	alarm value ISO/SAE6µm	unsigned 8	rw			alarm threshold 4µm (note the offset)
	6	alarm value ISO/SAE14µm	unsigned 8	rw			alarm threshold 4µm (note the offset)
	7	alarm value ISO/SAE21µm	unsigned 8	rw			alarm threshold 4µm (note the offset)
	8	alarm value NAS	unsigned 8	rw			alarm threshold NAS (note the offset)

	9	alarm value GOST	unsigned 8	rw			alarm threshold GOST (note the offset)
2100h		**readmem control functions**	**record**				
	0	number of entries	unsigned 8	ro		4h	largest sub index
	1	size of history memory	unsigned 32	ro		device de-pendent	size of memory in datasets
	2	used history mem	unsigned 32	ro			used datasets within memory (corresponds internally to write pointer)
	3	reading pointer, dataset	unsigned 32	rw			autoincrementing read pointer to a dataset for history memory reading; can be between 0 and current write pointer
	4	clear history memory	unsigned 16	wo			1 = clear memory
2101h	**0**	**readmem Initiate segmen-ted SDO data upload**	**unsigned 32**	**ro**			**Appropriate Pointer has to be set (with 2100sub3) before start reading, Size of the record will be sent back on reading**

Tab. 29: Communication-related object directory

5.6 Classification Systems

The automatic particle counter (APC) used to calibrate the BPM is primary calibrated according to ISO 11171.

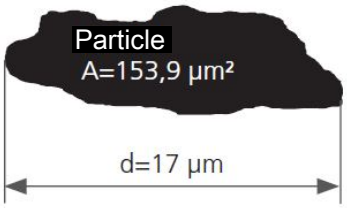
The ordinal numbers of the BPM are displayed according to ISO 4406. These are determined by the detected particle concentrations for 4, 6, 14 and 21 µm(c).

The successor of the NAS, the SAE AS and even the GOST protocol are based on different size ranges. The particle sizes can be converted into one another with a minimal loss of accuracy.

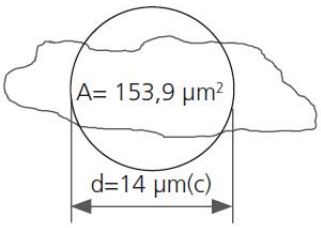
5.6.1 Particle Size Definition

In industrial hydraulics, the particle counts are coded according to ISO 4406:1999. When the test dust ACFTD was replaced by ISO MTD, the particle sizes were also redefined.

ACFTD particle sizes definition (ISO 4402:1991)



ISO MTD particle sizes definition (ISO 11171)



Tab. 30: Particle Size Definition

The size specified in µm(c) is the diameter of a circle of the same area as the projected area of the detected particle.

The sizes can be converted between ISO-MTD and ACFTD. See table below.

ISO-MTD	> 4 µm(c)	> 6 µm(c)	> 14 µm(c)	> 21 µm(c)	> 38 µm(c)	> 70 µm(c)
ACFTD	> 2 µm	> 5 µm	> 15 µm	> 25 µm	> 50 µm	> 100 µm

Tab. 31: Particle size comparison ISO-MTD - ACFTD

5.6.1.1 ISO 4406:99 Cleanliness Classes

The values are totalled in cumulative form (all particles >4 µm, all particles > 6 µm, ...).

Concentration in particles/m		ISO 4406:99	BPM display
From	through		
2,500,000.00		> 28	28
1,300,000.00	2,500,000.00	28	28
640,000.00	1,300,000.00	27	27
320,000.00	640,000.00	26	26
160,000.00	320,000.00	25	25
80,000.00	160,000.00	24	24
40,000.00	80,000.00	23	23
20,000.00	40,000.00	22	22
10,000.00	20,000.00	21	21
5,000.00	10,000.00	20	20
2,500.00	5,000.00	19	19
1,300.00	2,500.00	18	18
640.00	1,300.00	17	17
320.00	640.00	169	16
160.00	320.00	15	15
80.00	160.00	14	14
40.00	80.00	13	13
20.00	40.00	12	12
10.00	20.00	11	11
5.00	10.00	10	10
2.50	5.00	9	9
1.30	2.50	8	8
0.64	1.30	7	7
0.32	0.64	6	≤ 6
0.16	0.32	5	≤ 6
0.08	0.16	4	≤ 6
0.04	0.08	3	≤ 6
0.02	0.04	2	≤ 6
0.01	0.02	1	≤ 6
0.00	0.01	0	0

Tab. 32: Particle size comparison ISO-MTD - ACFTD

5.6.1.2 Cleanliness classes according to SAE AS 4059E

As with ISO, the values are totalled in cumulative form (all particles >4 µm, all particles >6 µm, ...).

All data in µm (c)

Concentration in particles/ml (ISO MTD)				SAE AS 4059E	BPM display
> 4 µm (A)	> 6 µm (B)	> 14 µm (C)	> 21 µm (D)		
1.95	0.76	0.14	0.03	000	000
3.90	1.52	0.27	0.05	00	00
7.80	3.04	0.54	0.10	0	0
15.60	6.09	1.09	0.20	1	1
31.20	12.20	2.17	0.39	2	2
65.20	24.30	4.32	0.76	3	3
125.00	48.60	8.64	1.52	4	4
250.00	97.30	17.30	3.06	5	5
500.00	195.00	34.60	6.12	6	6
1,000.00	389.00	69.20	12.20	7	7
2,000.00	779.00	139.00	24.50	8	8
4,000.00	1,560.00	277.00	49.00	9	9
8,000.00	3,110.00	554.00	98.00	10	10
16,000.00	6,230.00	1,110.00	196.00	11	11
32,000.00	12,500.00	2,220.00	392.00	12	12

Tab. 33: Determination of cleanliness classes according to SAE AS 4059E

5.6.1.3 NAS 1638 Cleanliness Classes

NAS 1638 is broken down into different size classes. 5-15 µm, 15-25 µm, 25-50 µm, ... The particles are further counted differentially, not cumulatively as with ISO 4406.

NOTICE! The BPM can only measure the sizes 4, 6, 14 and 21 µm, so the cleanliness class is only determined based on NAS 1638.

NAS cannot be converted back directly into ISO.

The concentrations are calculated using the following formula:

- Concentration NAS(5-15µm) = concentration ISO6µm – concentration ISO14µm
- Concentration NAS(15-25µm) = concentration ISO14µm – concentration ISO21µm
- Concentration NAS(25-50µm) = concentration ISO21µm

The respective NAS ordinal number is determined from the following table. The largest of the three NAS ordinal numbers determined is the final result.

Concentration in particles/ml			NAS 1638 BPM display
5-15µm	15-25µm	25-50µm	
1.25	0.22	0.01	00
2.50	0.44	0.08	0
5.00	0.89	0.16	1
10.00	1.78	0.32	2
20.00	3.56	0.63	3
40.00	7.12	1.26	4
80.00	14.25	2.53	5
160.00	28.50	5.06	6
320.00	57.00	10.12	7
640.00	114.00	20.25	8
1,280.00	228.00	40.50	9
2,560.00	456.00	81.00	10
5,120.00	910.00	162.00	11
10,240.00	1,824.00	324.00	12

Tab. 34: Determining cleanliness classes based on NAS 1638

Even if there is no direct correlation between ISO 4406 and NAS 1638, the following table can serve as a reference.

NAS	ISO	NAS	ISO
3	- / 12 / 9	8	- / 17 / 14
4	- / 13 / 10	9	- / 18 / 15
5	- / 14 / 11	10	- / 19 / 16
6	- / 15 / 12	11	- / 20 / 17
7	- / 16 / 13		

Tab. 35: ISO 4406 and NAS 1638 comparison (approximate)

5.6.1.4 GOST 17216 Cleanliness Classes

GOST 17216 is broken down into different size ranges. 5-10 µm, 10-25 µm, 25-50 µm, ... The particles are further counted differentially, not cumulatively as with ISO 4406.

NOTICE! The BPM can only measure the sizes 4, 6, 14 and 21 µm, so the cleanliness class is only determined based on GOST 17216.

The GOST ordinal number displayed is derived from the ISO 4406 ordinal numbers.

The following table shows how to determine the GOST ordinal number. If an ordinal number determined (ISO 4, 6 or 14 µm) exceeds the respective value in the table, use the next bigger GOST ordinal number.

GOST cannot be converted back directly into ISO.

ISO 4406:99			GOST 17216 BPM display
4 µm	6 µm	14 µm	
6	5	3	00
7	5	3	0
8	6	4	1
9	7	5	2
-	8	6	3
-	9	7	4
-	10	8	5
-	11	9	6
-	12	9	7
-	13	10	8
-	14	12	9
-	15	13	10
-	16	13	11
-	17	14	12
-	18	16	13
-	19	16	14
-	20	18	15
-	21	19	16
-	22	20	17

Tab. 36: Determining the cleanliness classes based on GOST 17216

6 Cleaning And Maintenance

CAUTION

Ingress dirt and liquids cause malfunctions

Early wear, malfunctions! Risk of damage! Property damage
The safe function of the particle monitor is then no longer guaranteed.
Ensure utmost cleanliness when working on the hydraulic system.
Do not use pressure washers.

Surface damage from solvents and aggressive cleaners

Aggressive cleaners can damage the seals on the particle monitor, causing premature aging.
Never use solvents or aggressive cleaners.
Do not clean with pressure washers.

Damage to hydraulics and seals

The water pressure of a pressure washer can damage the hydraulics and the seals of the particle monitor.
The water will display the oil from the hydraulics and seals.
Do not clean with pressure washers.

- Seal all openings with suitable protective caps/guards.
- Verify all seals and fasteners on plug connections are tight to ensure moisture cannot enter the device.
- Only clean the device with a dry, lint-free cloth.

Maintenance

This device is maintenance-free when used properly.

NOTICE

Please note, the device requires an annual calibration by the manufacturer.
Failure to have this calibration carried out will void the warranty.

Repair

Repairs to the device must be carried out by the manufacturer or its authorised dealers and subsidiaries. We assume no warranty for unauthorised repairs.

7 Service and repair

This chapter contains information on troubleshooting and correction should an error occur during operation.

Repairs to the unit must be performed by Bühler authorised personnel.

Please contact our Service Department with any questions:

Tel.: +49-(0)2102-498955 or your agent

If the equipment is not functioning properly after correcting any malfunctions and switching on the power, it must be inspected by the manufacturer. Please send the equipment inside suitable packaging to:

Bühler Technologies GmbH

- Reparatur/Service -

Harkortstraße 29

40880 Ratingen

Germany

Please also attach the completed and signed RMA decontamination statement to the packaging. We will otherwise be unable to process your repair order.

You will find the form in the appendix of these instructions, or simply request it by e-mail:

service@buehler-technologies.com.

7.1 Removal information

WARNING	**Improper removal**
	Removing the particle monitor improperly during pressurisation presents a risk of media escaping at high pressure a) Switch off the pressure to the particle monitor and supply lines. b) Check the established state. c) Secure the system against restarting. d) Remove the particle monitor.

7.2 Troubleshooting

Error	Possible cause	Recommended actions
– Unable to communicate via RS232 or CAN bus. – Current output < 4 mA.	Cable not properly connected.	– First check the electrical connection of the sensor and verify the data cable and power cable are properly connected. – Please note the prescribed pin assignment.
	Operating voltage outside the prescribed range.	– Always operate the device in ranges between 9 and 33 VDC.
	Communication bus configured incorrectly	– Check the configuration in the menu under "Communication"
– All size channels show identical values.	Air inside the oil	– Increase the operating pressure to inside the specified range. – Increase the distance to the next pump/gearbox/cylinder.
– All size channels show 0/0/0/0.	No volume flow	– Verify the supply and discharge lines are installed properly. – Increase the operating pressure to inside the specified range.
	No valid measurement result	– Check the configuration and measuring mode. – Ensure a measurement is started and completed.
	Dirty measuring cell ([▶] symbol flashing in display)	– Clean the device with clean oil or solvent (e.g. isopropyl alcohol). – Flush with clean oil in the opposite direction.
	Measuring cell failure ([▶] symbol flashing in display)	– Please contact Bühler Technologies GmbH Service.
– High laser current. – Low photovoltage.	Air inside the oil	– Increase the operating pressure to inside the specified range. – Increase the distance to the next pump/gearbox/cylinder.
	Dirty measuring cell	– Clean the device with clean oil or solvent (e.g. isopropyl alcohol). Flush with clean oil in the opposite direction.
– The display continuously shows "no valid application". – The device keeps restarting.	Basic system malfunction. (All communication lines are automatically disabled.)	– Please contact Bühler Technologies GmbH Service.
– No serial communication.	Interface configuration incorrect	– Check and if necessary correct the interface parameter settings (e.g. 9600, 8.1, N, N). – Test communication with a terminal program.
	Incorrect communication port selected	– Check and if necessary correct the selected communication port (e.g. COM1).
	Incorrect sensor command syntax	– Check the syntax of the sensor commands. Particularly note capitalisation.
	Num Lock key off	– Turn on the Num Lock key.
	Caps Lock is on (all caps)	– Turn off the Caps Lock.
	Cable connected incorrectly or defective	– If possible, use original data cables.

Tab. 37: Troubleshooting

7.3 Accessories

Item no.	Description
1590001006	Recalibration
1590001001	RS232 data cable
1590001002	USB/RS232 adapter
1590001003	Power supply
1590001004	Minimess connection with flow regulator

8 Disposal

Dispose of the packaging materials according to the relevant regulations.

Improper disposal of the device and the hydraulic fluid can pollute the environment.

Therefore dispose of the device and the hydraulic fluid according to the regulations in your country.

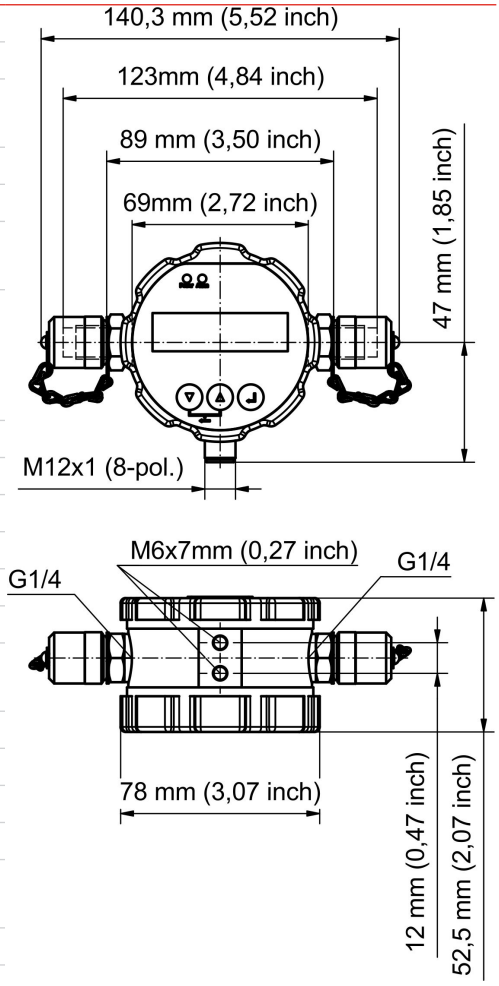
Dispose of leftover hydraulic fluid according to the relevant safety data sheets for these hydraulic fluids.

9 Appendices

9.1 Technical Data

BPM-100-000-1DC2S1A	1DC2S1A
Version:	Compact unit with Minimess adapter
Process connection:	G 1/4" and M16x2 Minimess adapter
Material in contact with media:	stainless steel, sapphire, chromium, NBR, Minimess coupling: zinc/nickel
Medium temperature:	-20 °C to +85 °C
Ambient temperature:	-20 °C to +85 °C
Pressure resistance:	420 bar dynamic 600 bar static
Compatible fluids:	mineral oils (H, HL, HLP, HLPD, HVLP), synthetic esters (HETG, HEPG, HEES, HEPR), polyalkylene glycol (PAG), zinc- and ash-free oils (ZAF), poly-alpha-olefins (PAO)
Weight:	720 g
Input value	
Flow range:	50...400 ml/min
Operating voltage (U_B):	9 – 33 V DC
Power input:	max. 0.3 A
Measuring range	[Ordinal number]
ISO4409:99:	0...28 display 10...22 calibrated
SAE AS 4059E:	0...12 display
Following NAS 1638:	0...12 display
Following GOST 17216:	0...17 display
Size channels:	4, 6, 14, 21 µm
Measuring accuracy in calibrated measuring range	±1 Ordinal number
Additional secondary measurands:	temperature, volume flow, operating hours
1DC output:	RS232/CANopen/SAE J1939
Input/output 2S:	high/low, open collector
1A output:	4-20 mA clocked

Dimensions



9.2 Standard pin assignment

Plug connection	M12 (base)
Number of pins	8-pin
Voltage	max. 33 V DC
IP rating with IP67 cable box attached	IP67
Version	1DC2S1A
Connection schematic	
1	L+
2	L-
3	TxD, CAN low [OUT]
4	RxD, CAN high [IN]
5	Switching input [high/low]
6	Analog output 4...20 mA
7	Switching output [high/low]
8	Signal earth
Shield	-

9.3 Cable Lengths

The tables lists the maximum cable lengths for various transfer rates.

Baudrate	Max. cable length
9600	150 m
19200	15 m
57600	5 m
115200	<2 m

Tab. 38: RS 232 cable lengths

9.4 Particle Contamination

The necessary oil cleanliness in the system depends on the components most sensitive to contamination. If the component manufacturer does not specify the oil cleanliness or filter fineness, we recommend using the tables below to determine the oil cleanliness.

The reference values listed for standard components refer to a base pressure range of 160 ... 210 bar.

System component	Required cleanliness class according to ISO 4406	
Pumps	Axial piston pumps	21 / 18 / 15
	Radial piston pumps	21 / 18 / 15
	Gear pumps	21 / 18 / 15
	Vane pumps	20 / 17 / 14
Motors	Axial piston motors	21 / 18 / 15
	Radial piston motors	21 / 18 / 15
	Geared motors	21 / 18 / 15
	Multi-disc motors	20 / 17 / 14
Valves	Directional valves	21 / 18 / 15
	Pressure control valves	21 / 18 / 15
	Flow control valves	21 / 18 / 15
	Check valves	21 / 18 / 15
	Proportional valves	20 / 17 / 14

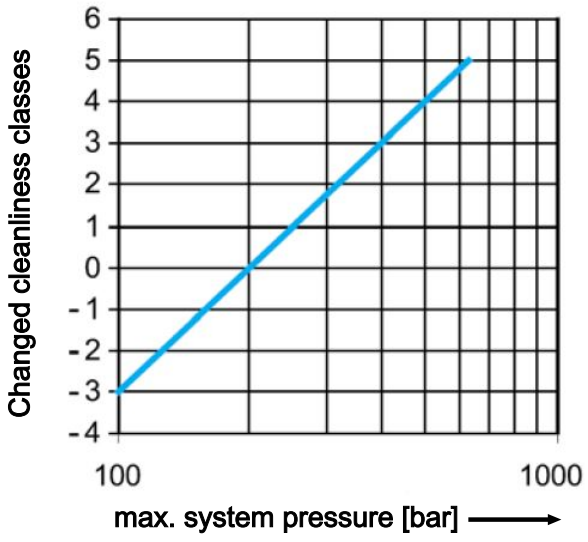
Tab. 39: Cleanliness classes for system components

If the operating pressure in a system is high, it's important to improve the oil cleanliness to ensure the components have the same wear resistances as under normal pressure.

The following table shows the necessary change in oil cleanliness if the operating pressure changes from the basic pressure range of 160 ... 210 bar.

Operating pressure in bar	Change in oil cleanliness
< 100	3 classes lower
100 . . . 160	1 class lower
160 ... 210	Okay
210 ...250	1 class better
250 ... 315	2 classes better
315 ... 420	3 classes better
420 ... 500	4 classes better
500 ... 630	5 classes better

Tab. 40: Change in cleanliness classes for modified operating pressure



Example:
A system with gear pump and proportional valves requires an oil cleanliness of 20/17/14 according to ISO 4406 for an operating pressure of 210 bar. If the operating pressure is increased to 250 bar, the table shows the oil cleanliness must be reduced 1 class to 19/16/13.
The necessary oil cleanliness is also determined by other factors:

- Expected machine life.
- Cost of repairs/spare parts.
- Costs of downtimes and interruptions.
- Safety requirements of the system (these are not only affected by the cleanliness of the oil).

If one of these aspects is particularly important, the necessary oil cleanliness should be improved one class. If two or more criteria apply, the necessary oil cleanliness should be improved two classes.

10 Attached documents

- Declaration of Conformity KX150002
- RMA - Decontamination Statement

EU-Konformitätserklärung
EU-declaration of conformity

Hiermit erklärt Bühler Technologies GmbH, dass die nachfolgenden Produkte den wesentlichen Anforderungen der Richtlinie

Herewith declares Bühler Technologies GmbH that the following products correspond to the essential requirements of Directive

2014/30/EU
(Elektromagnetische Verträglichkeit / *electromagnetic compatibility)*

in ihrer aktuellen Fassung entsprechen.

in its actual version.

Produkt / products: Bühler Partikel Monitor / *Bühler Particle Monitor*
Typ / type: BPM-100

Das Betriebsmittel dient zur Überwachung der Partikel innerhalb von Öl.
The equipment is intended for monitoring the particles within the oil.

Das oben beschriebene Produkt der Erklärung erfüllt die einschlägigen Harmonisierungsrechtsvorschriften der Union:
The object of the declaration described above is in conformity with the relevant Union harmonisation legislation:

EN 61000-6-2:2005/AC:2005

EN 61000-6-4:2007/A1:2011

Die alleinige Verantwortung für die Ausstellung dieser Konformitätserklärung trägt der Hersteller.
This declaration of conformity is issued under the sole responsibility of the manufacturer.

Dokumentationsverantwortlicher für diese Konformitätserklärung ist Herr Stefan Eschweiler mit Anschrift am Firmensitz.
The person authorised to compile the technical file is Mr. Stefan Eschweiler located at the company's address.

Ratingen, den 16.04.2021

Stefan Eschweiler
Geschäftsführer – *Managing Director*

Frank Pospiech
Geschäftsführer – *Managing Director*

Bühler Technologies GmbH, Harkortstr. 29, D-40880 Ratingen,
Tel. +49 (0) 21 02 / 49 89-0, Fax. +49 (0) 21 02 / 49 89-20
Internet: www.buehler-technologies.com

RMA-Formular und Erklärung über Dekontaminierung
RMA-Form and explanation for decontamination

RMA-Nr./ RMA-No.

Die RMA-Nummer bekommen Sie von Ihrem Ansprechpartner im Vertrieb oder Service./ You may obtain the RMA number from your sales or service representative.

Zu diesem Rücksendeschein gehört eine Dekontaminierungserklärung. Die gesetzlichen Vorschriften schreiben vor, dass Sie uns diese Dekontaminierungserklärung ausgefüllt und unterschrieben zurücksenden müssen. Bitte füllen Sie auch diese im Sinne der Gesundheit unserer Mitarbeiter vollständig aus./ This return form includes a decontamination statement. The law requires you to submit this completed and signed decontamination statement to us. Please complete the entire form, also in the interest of our employee health.

Firma/ Company

Firma/ Company
Straße/ Street
PLZ, Ort/ Zip, City
Land/ Country

Ansprechpartner/ Person in charge

Name/ Name
Abt./ Dept.
Tel./ Phone
E-Mail

Gerät/ Device
Anzahl/ Quantity
Auftragsnr./ Order No.

Serien-Nr./ Serial No.
Artikel-Nr./ Item No.

Grund der Rücksendung/ Reason for return

- ☐ Kalibrierung/ Calibration
- ☐ Modifikation/ Modification
- ☐ Reklamation/ Claim
- ☐ Reparatur/ Repair
- ☐ andere/ other

bitte spezifizieren/ please specify

Ist das Gerät möglicherweise kontaminiert?/ Could the equipment be contaminated?

☐ Nein, da das Gerät nicht mit gesundheitsgefährdenden Stoffen betrieben wurde./ No, because the device was not operated with hazardous substances.

☐ Nein, da das Gerät ordnungsgemäß gereinigt und dekontaminiert wurde./ No, because the device has been properly cleaned and decontaminated.

☐ Ja, kontaminiert mit:/ Yes, contaminated with:

☐ explosiv/ explosive	☐ entzündlich/ flammable	☐ brandfördernd/ oxidizing	☐ komprimierte Gase/ compressed gases	☐ ätzend/ caustic	☐ giftig, Lebensgefahr/ poisonous, risk of death	☐ gesundheitsgefährdend/ harmful to health	☐ gesundheitsschädlich/ health hazard	☐ umweltgefährdend/ environmental hazard

Bitte Sicherheitsdatenblatt beilegen!/ Please enclose safety data sheet!

Das Gerät wurde gespült mit:/ The equipment was purged with:

Diese Erklärung wurde korrekt und vollständig ausgefüllt und von einer dazu befugten Person unterschrieben. Der Versand der (dekontaminierten) Geräte und Komponenten erfolgt gemäß den gesetzlichen Bestimmungen.

This declaration has been filled out correctly and completely, and signed by an authorized person. The dispatch of the (decontaminated) devices and components takes place according to the legal regulations.

Falls die Ware nicht gereinigt, also kontaminiert bei uns eintrifft, muss die Firma Bühler sich vorbehalten, diese durch einen externen Dienstleister reinigen zu lassen und Ihnen dies in Rechnung zu stellen.

Should the goods not arrive clean, but contaminated, Bühler reserves the right, to comission an external service provider to clean the goods and invoice it to your account.

Firmenstempel/ Company Sign

Datum/ Date

Bühler Technologies GmbH, Harkortstr. 29, D-40880 Ratingen
Tel. +49 (0) 21 02 / 49 89-0, Fax: +49 (0) 21 02 / 49 89-20
E-Mail: service@buehler-technologies.com
Internet: www.buehler-technologies.com

rechtsverbindliche Unterschrift/ Legally binding signature

Die Analyse defekter Baugruppen ist ein wesentlicher Bestandteil der Qualitätssicherung der Firma Bühler Technologies.

Um eine aussagekräftige Analyse zu gewährleisten muss die Ware möglichst unverändert untersucht werden. Es dürfen keine Veränderungen oder weitere Beschädigungen auftreten, die Ursachen verdecken oder eine Analyse unmöglich machen.

Bei elektronischen Baugruppen kann es sich um elektrostatisch sensible Baugruppen handeln. Es ist darauf zu achten, diese Baugruppen ESD-gerecht zu behandeln. Nach Möglichkeit sollten die Baugruppen an einem ESD-gerechten Arbeitsplatz getauscht werden. Ist dies nicht möglich sollten ESD-gerechte Maßnahmen beim Austausch getroffen werden. Der Transport darf nur in ESD-gerechten Behältnissen durchgeführt werden. Die Verpackung der Baugruppen muss ESD-konform sein. Verwenden Sie nach Möglichkeit die Verpackung des Ersatzteils oder wählen Sie selber eine ESD-gerechte Verpackung.

Beachten Sie beim Einbau des Ersatzteils die gleichen Vorgaben wie oben beschrieben. Achten Sie auf die ordnungsgemäße Montage des Bauteils und aller Komponenten. Versetzen Sie vor der Inbetriebnahme die Verkabelung wieder in den ursprünglichen Zustand. Fragen Sie im Zweifel beim Hersteller nach weiteren Informationen.

Analysing defective assemblies is an essential part of quality assurance at Bühler Technologies.

To ensure conclusive analysis the goods must be inspected unaltered, if possible. Modifications or other damages which may hide the cause or render it impossible to analyse are prohibited.

Electronic assemblies may be sensitive to static electricity. Be sure to handle these assemblies in an ESD-safe manner. Where possible, the assembles should be replaced in an ESD-safe location. If unable to do so, take ESD-safe precautions when replacing these. Must be transported in ESD-safe containers. The packaging of the assemblies must be ESD-safe. If possible, use the packaging of the spare part or use ESD-safe packaging.

Observe the above specifications when installing the spare part. Ensure the part and all components are properly installed. Return the cables to the original state before putting into service. When in doubt, contact the manufacturer for additional information.

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