Fluidcontrol

Bühler Condition Monitor

BCM-MS, BCM-LS

Installation and Operation Instructions

Original instructions

BE150104
03/2021

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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

The BCM-MS200 and BCM-LS200 are used to measure and document changes in the properties of hydraulic and lubricating media and simultaneously measure the humidity and temperature. The respective measured values used to detect changes in the properties as well as the temperature and humidity are detected continuously, saved and can be read out at any time using a serial port. If the measured values deviate from a saved reference, this indicates changes which should be interpreted and investigated further.

Measured changes in the oil parameters can provide information about condition changes, e.g. oil aging, refreshing, changes or water ingress. Damages can then potentially be detected early or even avoided. This allows taking suitable measures to avoid serious machine malfunctions and prolong maintenance and oil change intervals. Furthermore, measured parameters and changes in these can be used to derive and document information related to system maintenance carried out or the use of the prescribed lubricant type.

The following chapters explain which situations changes in the condition can be detected. The sensor records the following physical oil parameters and their time curve:

- temperature
- relative humidity
- conductivity
- relative fluid permittivity
- Liquid level (BCM-LS200 only)

Since the conductivity and relative permittivity in particularly greatly depend on the temperature, the sensor is able to convert these parameters to a fixed reference temperature. The sensor continuously measures at various temperatures for this conversion and uses this data to determine the temperature gradients of the parameters.

Determining the temperature gradient requires several temperature cycles when commissioning the sensor. During operation, the temperature gradient is also continuously adjusted when oil is changed or ages.

1.2 Functionality

1.2.1 Temperature Measurement

A PT1000 platinum resistance sensor measures the oil temperature. The measuring range spans from -20 °C to 120 °C. Since the resistance sensor is located directly in the oil, the conductivity of the surrounding medium should not exceed 3 µSm (-1).

1.2.2 Moisture Measurement

The relative humidity (formula symbol: φ) is measured using a capacitive transducer. The capacitive moisture detector detects the relative humidity within a measuring range of 0 % to 100 %. If free water or emulsions are present, the sensor shows 100 %. Since the moisture detector is located directly in the oil, the conductivity of the surrounding medium should not exceed 3 µSm (-1).

1.2.3 Relative Humidity

Relative humidity φ means the ratio between the actual amount of free water in the oil (ρ_W) compared to the maximum possible free water at the saturation limit ($\rho_{W,max}$).

$$\varphi = \frac{\rho_W}{\rho_{W\,max}} \cdot 100\ \% \quad (3\text{-}1)$$

Since the saturation limit, i.e. the maximum amount of water it can hold $\rho_{W,max}$, greatly depends on the temperature, the relative humidity changes with the temperature even if the absolute water content remains constant. As a rule, oil can hold more water as the temperature rises before reaching the saturation limit.

1.2.4 Conductivity Measurement

Fresh oils have a characteristic conductivity. Since the conductivity is oil-specific due to manufacturing variations, it already serves as a criterion for distinguishing oils. To be able to distinguish between oils based on conductivity, the conductivity at a specific temperature or the change in conductivity above the temperature must be significantly distinct.

The introduction of impurities (solid/liquid) can also be detected provided this changes the conductivity at a specific temperature or the conductivity above the temperature.

Oil changes, oil mixing and contaminations can therefore be detected under the above conditions based on the conductivity.

Please also keep in mind that batch variances and oil aging can also affect conductivity.

Conductivity can change due to various aging processes, so in this case the aging process can also be tracked with conductivity. The measuring range of conductivity ranges from <100 to approx. 800,000 pS/m.

Since conductivity greatly depends on the temperature (a higher oil conductivity has a negative effect on the accuracy of the measurement), the sensor internally converts to a reference temperature of 40 °C. Another parameter for this conversion is the temperature gradient of the parameter, which can also be used to define oil as specified above.

1.2.5 Measuring Relative Permittivity

The relative permittivity ϵ_{Oil} of the fluid is a measure of its polarity. Base oils and additive packages with a different chemistry and from different manufacturers can have different polarities. The polarity and the polarity trend of the fluid above the temperature are therefore properties which under certain circumstances, e.g. taking into account batch variances, can be used to determine oils being confused, mixed or refreshed.

Oils typically change their polarity throughout the aging process. If this causes a significant change in polarity, the aging process can also be monitored. The measuring range for relative permittivity is 1...7.

Since the relative permittivity depends on the temperature, the sensor internally converts to a reference temperature of 40 °C. Another parameter for this conversion is the temperature gradient of the parameter, which - as specified above - can also be used to define oil.

NOTICE! When used in highly conductive fluids, measuring the relative permittivity can be subject to cross-influence despite the built-in compensation.

1.2.6 Level Measurement

The sensor features capacitive level detection. The liquid level is measured using the same principle as the dielectric constant. The reference used for measurement is the dielectric constant determined by the sensor. This process allows capacitive detection of the liquid level without specifying the type of fluid.

NOTICE! When used in highly conductive fluids, the liquid level can be subject to cross-influence despite the built-in compensation.

1.2.7 Operating Hours Counter

The sensor has a built-in operating hours counter in which the values are retained after a power interruption. After the interruption, the counter continues from the last value prior to the interruption.

1.2.8 Data Logger

The built-in operating hours counter which starts as soon as the sensor is connected to power, allows allocating the measured characteristics to a point in the operating hours. The timestamp, the four factors temperature, oil moisture, conductivity and relative dielectric constant as well as the other derived characteristics are saved to the sensor ring buffer. Over 6000 datasets total can be saved to the buffer.

1.2.9 Oil Condition

Oil aging generally refers to any change in parameters and properties of the oil over its life. The goal is to use the changes to derive significant aging processes in the oil using the parameters measured with the sensor. The automatic oil condition analysis, however, goes beyond this. The goal here is to not only determine aging, but also other changes in the condition. Possible condition changes are:

– oil aging (e.g. oil oxidation)
– contamination with foreign fluids
– water ingress (e.g. high water content or free water)
– oil changes, including changing to the wrong type of oil
– Oil refreshing
– oils being mixed

The goal of automatic analysis is to help the user interpret the characteristics and determine various conditions and changes in the condition from the current measurement data and the saved data history. Detecting conditions and changes in the condition as part of the rule base used, however, is only reliable if the measurements and their quality generally permit this interpretation.

A detailed description of all detectable condition changes and how to query, save and configure parameters can be found in the appendix.

1.2.10 Determining The Remaining Useful Lifetime (RUL)

In addition to classifying various conditions or condition changes, another sensor function is to determine the remaining useful lifetime (RUL) based on available data.

Here we distinguish between two different approaches.

The following illustration is an example trend of a aging parameter over the operating time.

After an oil change, the oil parameters do not (significantly) change over a long period. After the so-called incubation period (phase I), once certain additives (antioxidants) are depleted, oil aging then accelerates, often progressively (phase II).

Phase II is characterised by an accelerated aging process, thus change in the aging parameters. In this area the signal trend of the various measured parameters can be used to extrapolate a predetermined aging limit, thus is the remaining useful lifetime (RUL).

A default parameter for the aging limit is factory preset. For specific information on setting the aging limits, please contact Bühler Technologies GmbH Service.

NOTICE! The limits should be adjusted to the specific application. The remaining useful lifetime determined is a guideline determined through linear extrapolation. Please note, aging processes can also be non-linear.

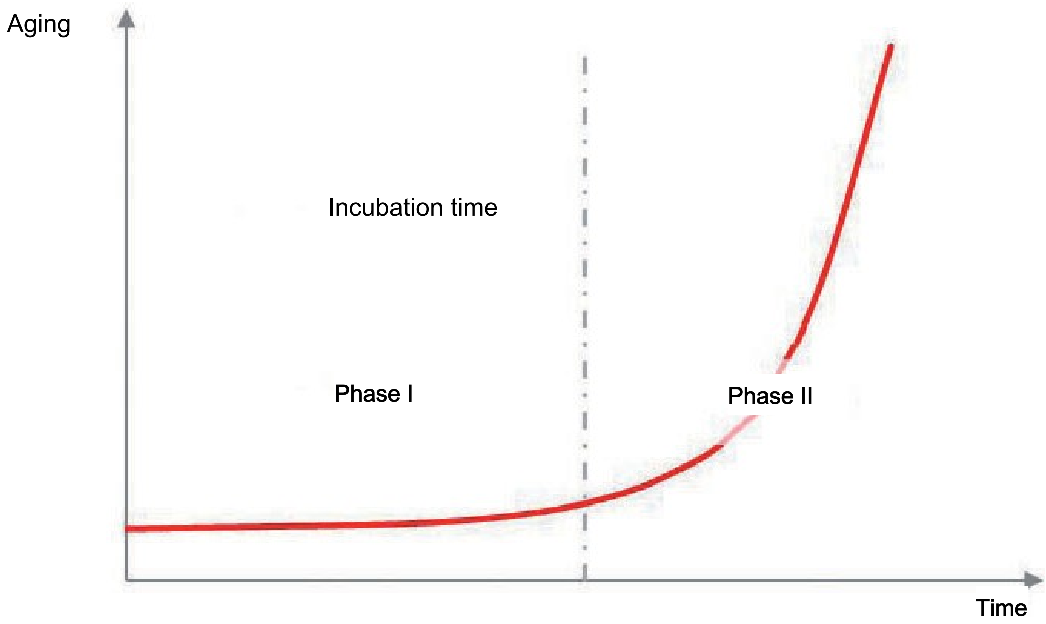


Fig. 1: Theoretical aging

Since the characteristics measured in phase I do not change, the RUL also cannot be determined based on characteristics. During this phase, however, the RUL can be estimated based on the thermal stress at the measuring point. This is permissible so long as the temperature is the decisive stress factor for the oil and decisive in the aging rate (Arrhenius law). The sensor continuously detects a temperature histogram for this purpose. Furthermore, data can only be transmitted for comparable applications and the same types of oil.

NOTICE! We will gladly assist you with the necessary parameter settings for calculating the RUL based on thermal stress (Phase I). Please contact Bühler Technologies GmbH Service.

1.2.11 Scope And Basic Parameters For Automatic Condition Analysis And RUL Calculation

Some basic parameters must be taken into account for the automatic condition analysis:

– Changes in the condition can only be determined if the information is included in the measured parameters. For example, the measured parameters typically do not provide any information about the depletion of antioxidants.
– Individual critical changes in the oil can overlap in extreme cases so the resulting overall change does not reflect this condition.
– The respective conditions or condition changes have detection limits where the underlying signal changes or change gradients are not detected.
– The automatic condition analysis can be distorted due to cross-influences.
– The RUL calculation is only a rough estimate. In open systems with uncontrollable contamination and systems with strongly varied operating conditions the uncertainty of the characteristics information increases. The parameter settings further greatly affect the results.
– A purely mathematical estimate of the RUL based on measured burden factors cannot predict spontaneous condition changes.

Overall, a sufficient data volume and purposeful parameter settings will typically yield a satisfactory accuracy and prediction of the aging process.

1.2.12 List Of All Measured And Derived Parameters

The 5 original characteristics above are measured to define the oil condition. These parameters and their meaning are again listed in the table below.

#	Parameter	Abbreviation	Unit	Explanation
1	Operating hours	Time	h	runs when powered
2	Temperature	T	°C	Oil temperature
3	Relative permittivity (rel. DK)	P	-	Fluid polarity. Fresh oils differ in P and can therefore be distinguished. Furthermore, P changes with oil aging.
4	Conductivity	C	pS/m	Fresh oils differ in C and can therefore be distinguished. Furthermore, C changes with oil aging.
5	rel. oil humidity	RH	%	Rel. humidity between 0 and 100 %
61	Liquid level	L	%	Liquid level between 0 and 100

Tab. 1: Original characteristics determined

The parameters depend on the temperature, which is compensated by the sensor. This compensation involves two additional temperature gradients used to assess the condition.

#	Original parameter	Derived characteristic Abbreviation	Unit	Explanation
1	P	PTG	1/K	rel. DK - temperature gradient
2	C	CTG	(pS/m)/K	Conductivity - temperature gradient
3	RH	HTG	%/K	rel. oil humidity - temperature gradient

Tab. 2: Derived temperature gradients

The sensor uses the original parameters P, C and RH as well as the determined temperature gradients PTG, CTG and HTG to calculate the temperature-compensated parameters P40 and C40 and H20, H40 in the same unit as the respective original parameter.

NOTICE! The accuracy of determining PTG, CTG and HTG as well as the quality of the temperature compensation depend on the fluid.

#	Original parameter	Derived characteristic Abbreviation	Explanation
1	P	P40	rel. DK at reference temperature of 40 °C
2	C	C40	Conductivity at reference temperature of 40 °C
3	RH	RH202 [1]	rel. oil humidity compensated to 20 °C oil temperature

Tab. 3: Temperature-compensated characteristics

[1] Compensation of relative humidity to 20 °C greatly depends on the fluid, temperature profile and other factors

The sensor in turn uses original parameters, the temperature gradients and the compensated characteristics to determine time gradients. The time gradients particularly provide information about the type of change in state.

#	Original parameter	Derived characteristic Abbreviation	Unit	Explanation
1	P40	LGP40	1/h	Long-term gradient of P40
2	P40	MGP40	1/h	P40 gradient over mean period
3	P40	SGP40	1/h	Short-term gradient of P40
4	C40	LGC40	(pS/m)/h	Long-term gradient C40
5	C40	MGC40	(pS/m)/h	C40 gradient over mean period
6	C40	SGC40	(pS/m)/h	Short-term gradient of C40
7	T	LGT	K/h	Long-term gradient of oil temperature
8	T	SGT	K/h	Short-term gradient of oil temperature
9	H20	SGH20	%/h	Short-term gradient of H_2O

Tab. 4: Time gradients

Rapid changes indicate e.g. oil being added, but depending on the extent, slow gradients can indicate contamination with a foreign fluid or oil aging. Here the sensor determines short-term gradients with an averaging period of a few hours and long-term gradients with an averaging period of several hundred to several thousand hours.

Please refer to chapter Error Bits Key [> page 45] for a list of all parameters used in the assessment.

1.2.13 Calibration And Sensor Function Test

The sensor is developed to be exposed to the specified loads over prolonged periods.

For fluids or applications where there is no experiential base related to the long-term stability of the sensor, the sensor should be inspected and calibrated at a laboratory at least every 2 years.

1.2.14 List Of Parameter Outputs For Specific Commands

The sensors support a series of commands to output the measured, deduced and calculated oil parameters. The following tables list the responses to individual commands. Depending on the sensor firmware version, the order or even the contents of the output may vary.

#	Parameter name	Unit	Explanation
1	Time	h	Sensor operating hours counter
2	T	°C	Fluid temperature
3	L	%	Oil level in relation to measuring range (for level sensors only)
4	P	-	Relative fluid permittivity
5	P40	-	Relative fluid permittivity compensated to 40 °C fluid temperature
6	C	pS/m	Fluid conductivity
7	C40	pS/m	Fluid conductivity compensated to 40 °C fluid temperature
8	RH	%	Relative fluid humidity
9	RH20	%	Relative fluid humidity compensated to 20 °C (room temperature) fluid temperature (only output if sensor not configured to AH output)
10	AH	ppm	Absolute water content of the fluid (only output if sensor calibrated accordingly for this oil)
11	TMean	°C	Average fluid temperature since starting teach-in, or indicates oil refilling
12	PCBT	°C	Temperature of electronics or sensor
13	RULT	h	Temperature-based remaining useful lifetime (RUL) of the oil
14	RULLG	h	Long-term gradient- and limit-based RUL of the oil
15	RUL	h	Combined and weighted RUL
16	APP40	%	Aging progress (AP) based on P40 and set limits
17	APC40	%	AP based on C40 and set limits
18	AP:	%	Combined and weighted AP
19	fB	-	Temperature load factor since starting teach-in, or indicates oil refilling
20	OAge	h	Oil age, time since starting teach-in, or indicates oil refilling
21	ERC	-	Summary auto-detected oil conditions

Tab. 5: Response to command "RVal"

#	Parameter name	Unit	Explanation
1	Time	h	Sensor operating hours counter
2	PTG	1/k	Temperature gradient of relative permittivity
3	CTG	ln(pS/m)/K	Temperature gradient of the natural logarithm of conductivity
4	HTG	%/K	Temperature gradient of relative humidity
5	LGP40	1/h	Long-term gradient of P40
6	LGC40	(pS/m)/h	Long-term gradient of C40
7	LGT	K/h	Long-term gradient of oil temperature
8	MGP40	1/h	P40 gradient over mean period
9	MGC40	(pS/m)/h	C40 gradient over mean period
10	SGP40	1/h	Short-term gradient of P40
11	SGC40	(pS/m)/h	Short-term gradient of C40
12	SGT	K/h	Short-term gradient of oil temperature
13	SGH20	%/h	Short-term gradient of H_20

Tab. 6: Response to command "RGrad"

#	Parameter name	Unit	Explanation
1	AO1	-	Configuration for analog output 1
2	AO2	-	Configuration for analog output 2
3	ETrig	-	Error-triggered save to history (1 = on, 0 = off)
4	TrAu	min	Periodic dataset transfer as output for RVal command with an interval of the minutes specified (range 1..60 minutes, if set to 0, automatic transfer is off)
5	ORef	-	Automatic teach-in status (0: completed, 1..30: in progress, > 30: not started)
6	COEN	-	CANopen communication (0: off, 1: on)
7	MemInt	min	Interval at which data is saved to history (default: 20 minutes)
8	COSpd	kBit/s	CAN bus speed
9	COID	-	Sensor nodeID
10	COHBeat	ms	Sensor CANopen heart beat
11	TPDO1ID	-	TPDO 1COB-ID for CANopen
12	TPDO2ID	-	TPDO 2 COB-ID for CANopen
13	TPDO1Type	-	TPDO 1 type for CANopen
14	TPDO2Type	-	TPDO 2 type for CANopen
15	TPDO1Timer	ms	TPDO 1 timer for CANopen
16	TPDO2Timer	ms	TPDO 2 timer for CANopen
17	RULowr	h	Timer for overwriting the RUL calculation (if a system sensor fails, the replacement sensor can have the RUL value of the previous sensor the RUL counts down from)

Tab. 7: Response to command "RCon"

#	Parameter name	Unit	Explanation
1	LimP40%	5	Oil aging limit for P40 in % from fresh oil value (default: 5 %)
2	LimC40%	%	Oil aging limit for C40 in % from fresh oil value up (default: 300 %), permissible downward deviation is automatically calculated from this specification
3	LimT	°C	Maximum permissible oil temperature (if exceeded, the corresponding bit is set in ERC, default: 85 °C)
4	LimTMean	°C	Average maximum permissible oil temperature (if exceeded, the corresponding bit is set in ERC, default: 65 °C)
5	RULh	h	Reference value for the oil lifetime in hours (specified by machine manufacturer)
17	RULfB	-	Oil life reference value (specified by machine manufacturer)

Tab. 8: Response to command "RLim"

#	Parameter name	Unit	Explanation
1	RefStat	-	Automatic teach-in status (0: completed, 1..30: in progress, > 30: not started)
2	RefC40	pS/m	Taught-in fresh oil conductivity reference value at 40 °C
3	RefP40	-	Taught-in fresh oil relative permittivity reference value at 40 °C
4	RefCTG	(pS/m)/K	Taught-in conductivity temperature gradient reference value
17	RefPTG	1/K	Taught-in relative permittivity temperature gradient reference value

Tab. 9: Response to command "RORef"

1.3 BCM-MS model key

BCM - MS200 - 1DC2A

Type designation
BCM Bühler Condition Monitor

M Multisensor

S Sensor

Process connection
0 G3/4"

Outputs
1DC2A 1x CANopen/2x analog

Item no.	Model
1550001000	BCM-MS200-1DC2A

1.4 BCM-LS model key

BCM - LS200 - 1DC2A / xxx

Type designation
BCM Bühler Condition Monitor

L Multisensor incl. liquid level measurement

S Sensor

Process connection
0 G3/4"

Length
200 mm
375 mm
615 mm

Outputs
1DC2A 1x CANopen/2x analog

Item no.	Model
1550002200	BCM-LS200-1DC2A/200
1550002375	BCM-LS200-1DC2A/375
1550002615	BCM-LS200-1DC2A/615

1.5 Scope Of Delivery

- Bühler Condition Monitor BCM
- Product Documentation

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

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.

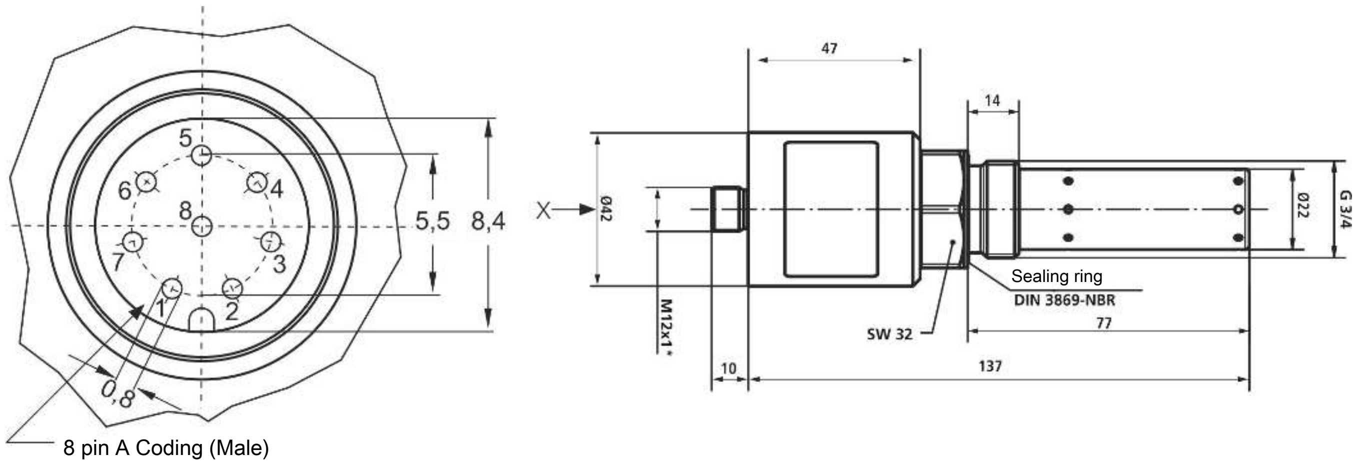
Always observe the applicable safety and operating regulations in the respective country of use when performing any type of maintenance.

The method for cleaning the devices must be adapted to the IP protection class of the devices. Do not use cleaners which could damage the device materials.

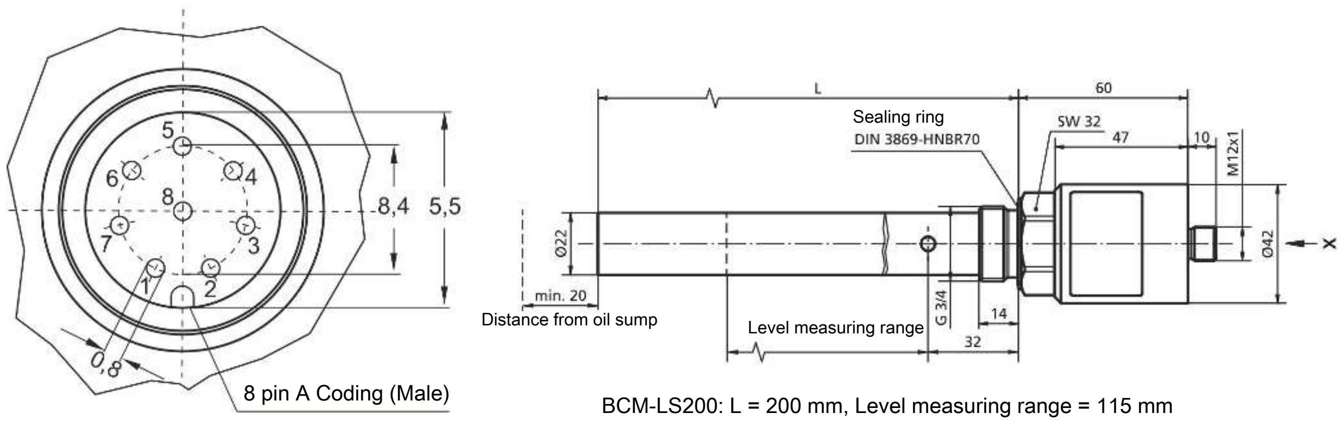
3 Installation and connection

3.1 Dimensions

Connection dimensions BCM-MS200



Connection dimensions BCM-LS200



BCM-LS200: L = 200 mm, Level measuring range = 115 mm

3.2 Installation

The sensor is a screw-in sensor with ¾" thread. The level sensor must be screwed vertically into application tank from above, the BCM-MS200 can either be installed sideways in the tank or in a flow pipe using a line adapter.

Condition monitoring requires the bottom 5 cm of the sensor to be bathed in oil for Level 200/375/615. The probe head of the BCM-MS200 should always be in oil. Maximum pressure and temperature ratings should generally be observed in the sensor placement.

Screw the sensor into a prepared mount inside the tank. A profiled sealing ring seals this from the oil side. To ensure proper sealing, the seal face of the sensor mount should be specially prepared and have a maximum roughness value of R_{max} = 16. The tightening torque for the sensor is 45 Nm ±4.5 Nm.

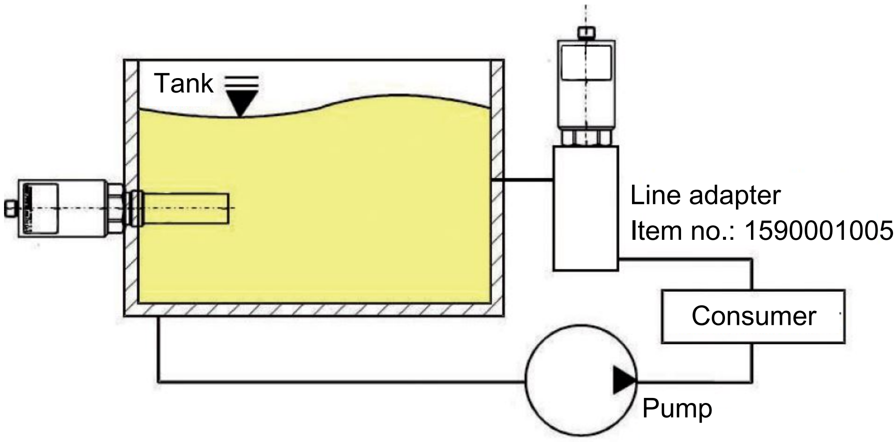


Fig. 2: Installation options

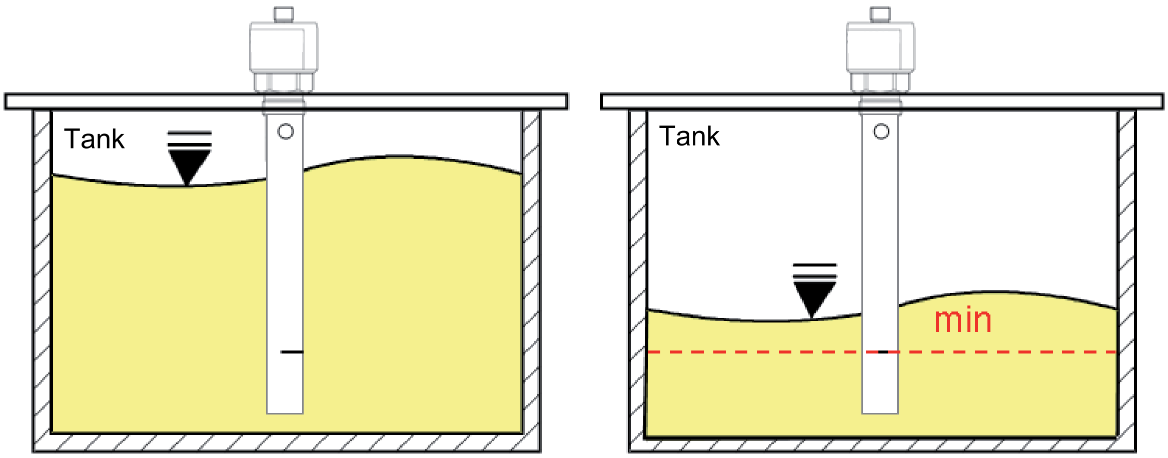


Fig. 3: Installation options

To ensure proper function, please observe the following guidelines related to sensor mounting position and location.

- To analyse an oil volume characteristic of the oil condition, the sensor should not be immediately in the oil sump of the tank.
- For tank top installation, it will preferably be mounted near the return or flushing pipe.
- Ensure the sensor is fully covered in oil regardless of the system operating situation. Particularly note the varying oil volume of the tank or potential inclination. Avoid foam in the tank.
- When installing the return or flushing pipe, please note the flushing pipe must not run dry in any operating situation.
- To avoid thermal factors as much as possible, the sensor should not be installed in the immediate vicinity of hot components and parts (e.g. motor).
- Varying oil temperatures are required to enable converting the characteristics to a reference temperature. The greater the temperature fluctuations, the quicker the temperature gradient can be determined.

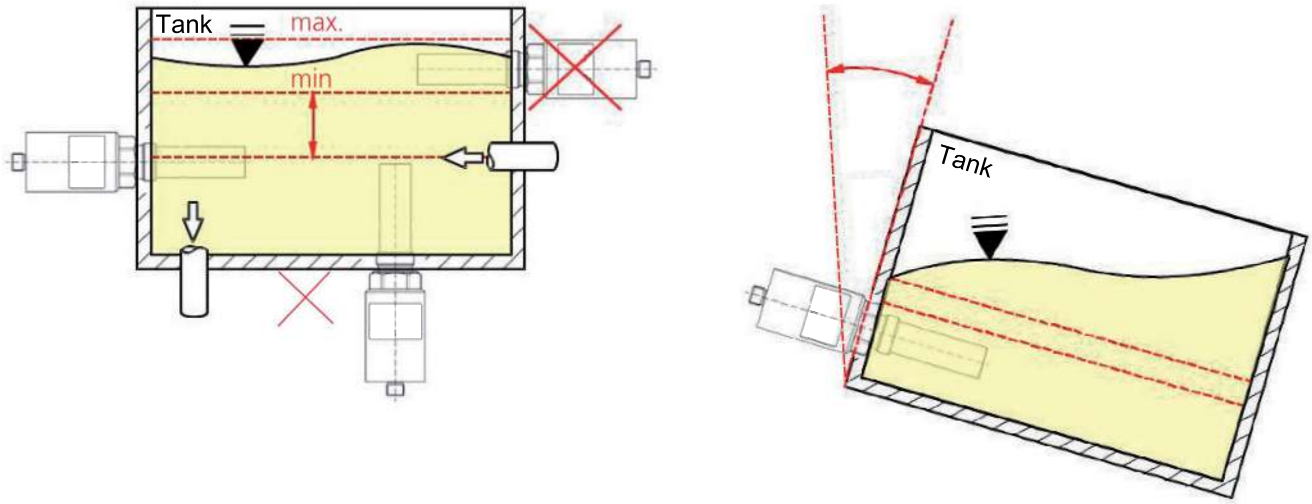


Fig. 4: Installation recommendations

3.3 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.

To install, switch off the machine and connect the device as follows:

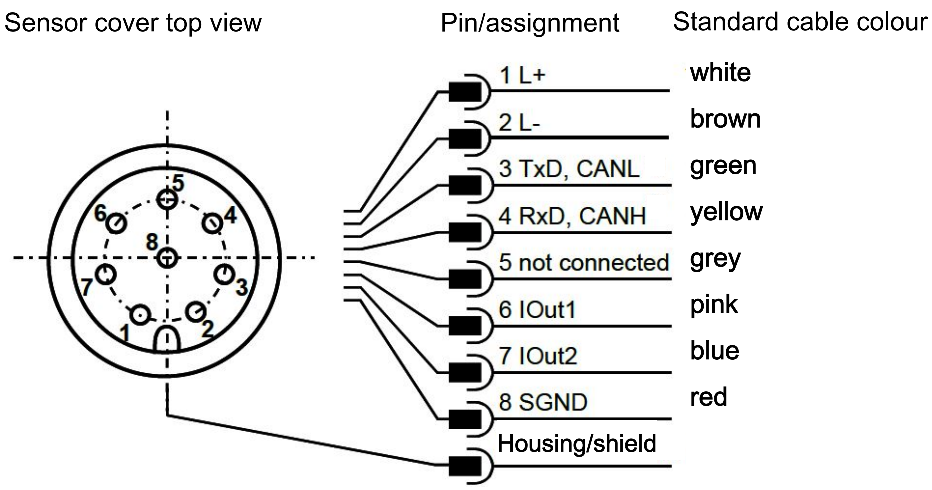


Fig. 5: Sensor plug pin assignment

The permitted operating voltage is between 9 V and 33 V DC. 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.

3.3.1 Analog Current Outputs (4..20 mA) - Measurement Without Load Resistor

The current should be measured with a suitable ammeter as shown below.

Sensor cover top view

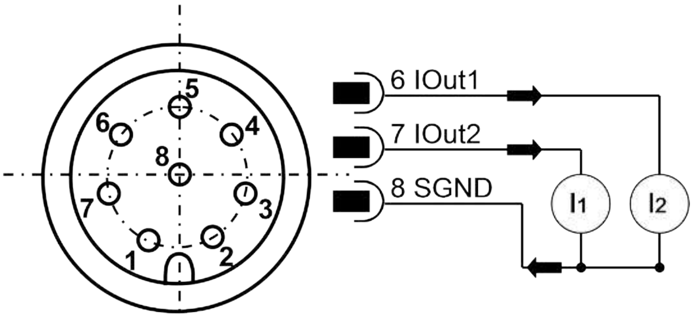


Fig. 6: Measuring the analog 4...20 mA outputs without load resistances

Please refer to chapter Calibration [> page 17] for how to allocate the measured current to the parameter.

3.3.2 Analog Current Outputs (4..20 mA) - Measurement With Load Resistor

To measure the currents of the analog current outputs, a load resistor must be connected to each output as shown below. Depending on the supply voltage, the load resistance should be between 25 Ohm and 200 Ohm. A voltmeter can now be used to measure the voltage which drops over the respective resistance.

Sensor cover top view

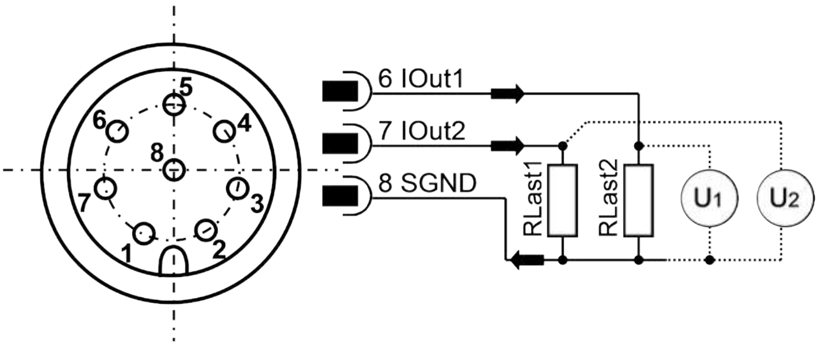


Fig. 7: Connecting the load resistances to measure the analog 4..20 mA outputs

The default configuration is intended for oil temperature on channel 1 and relative humidity on channel 2.

The channel assignment can be changed and is described in chapter Setting Analog Current Outputs [> page 23].

3.3.3 Load Resistor Size

The load resistance cannot be selected arbitrarily. It must be adjusted to the supply voltage of the sensor. The maximum load resistance can be calculated using the formula (6 -1). Or you can alternatively use the table here.

R_{max} / Ω=U_{Supply} / V · 25 (Ω/V) – 200 Ω   25 Ω ≤ R_{max} Ω 200 Ω   (6-1)

R_{max} in Ω	U_{supply} in V
25	9
50	10
100	12
150	14
200	16

Tab. 10: Determining the load resistance based on the supply voltage

3.3.4 Calibration

Output quantity X	Output range	Quantity equation	Formula
T in °C	-20°C...120°C	$X/°C = \frac{U/V}{R/\Omega} \cdot 8750\,(°C/A) - 55°C$	(6-2)
RH in %	0%...100%	$X/\% = \frac{U/V}{R/\Omega} \cdot 6250\,(\%/A) - 25\%$	(6-3)
H20; H40 in %	0%...100%	$X/\% = \frac{U/V}{R/\Omega} \cdot 6666{,}67\,(\%/A) - 33{,}33\%$	(6-4)
AH in ppm	0ppm...AHScl	$X/ppm = \frac{U/V}{R/\Omega} \cdot \frac{AHScl/ppm}{16 \cdot 10^{-3} A} - \frac{AHScl/ppm}{4}$	(6-5)
P; P40	1...5	$X = \frac{U/V}{R/\Omega} \cdot 266{,}67 \left(\frac{1}{A}\right) - 0{,}3333$ < 5 mA: Teaching in or sensor partially exposed to air	(6-6)
C; C40 in pS/m	100pS/m... 1000100 pS/m	$X/^{pS}/_{m} = \frac{U/V}{R/\Omega} \cdot 6{,}667 \cdot 10^{7} \left(\frac{pS}{A}\right) - 333233\,\frac{pS}{m}$ < 5 mA: Teach-in	(6-7)
AP in %	0%...100%	$X = \frac{U/V}{R/\Omega} \cdot 6250 \left(\frac{\%}{A}\right) - 25\,\%$	(6-8)
L in %	0%...100%	$X = \frac{U/V}{R/\Omega} \cdot 6250 \left(\frac{\%}{A}\right) - 25\,\%$	(6-9)1
log(C); log(C40) in pS/m	1pS/m...1000000 pS/m	$X/^{pS}/_{m} = 10^{\left(\frac{U/V}{R/\Omega} \cdot 375 \left(\frac{pS}{A}\right) - 1{,}5 \log\left(\frac{pS}{m}\right)\right)}$	(6-10)2

Tab. 11: Calculating the output parameter for the analog current outputs

By default, the current outputs show the temperature between -20 °C and 120 °C and the relative humidity between 0 and 100 %. The upper limit for the absolute humidity (AHScl) is required to scale the analog current outputs. This is freely programmable. However, the limit is oil-specific and must be determined at a laboratory along with the other parameters required to measure the absolute humidity.

Please contact Bühler Technologies GmbH Service in this regard. The current outputs are scaled linear.

Iout in mA	4	5	12	20
T in °C	-20	-11.25	50	120
RH, H20, H40 in %	0	6.25	50	100
AH in ppm	0	0.0625*AHScl	0.5*AHScl	AHScl
P; P40	Teach-in mode enabled	1	2.867	5
C; C40 ibn pS/m	Teach-in mode enabled	100	466807	1000100
log(C); log(40) in pS/m	1	2.37	1000	1000000
AP:	0	6.26	50	100
L	0	6.25	50	100

Tab. 12: Scaling the analog current outputs

4 Operation and Control

NOTICE

The device must not be operated beyond its specifications.

4.1 RS232 Communication

Communication with the sensor takes place either via serial RS232 port, CANopen or via two analog 4...20 mA outputs.

The sensors come standard with RS232 port enabled. In this mode it's quite easy to configure the analog interface and to configure the CANopen communication parameters. If necessary, a RS232 command can then be used to switch to CANopen interface (see chapter Write Commands [> page 20], command WCOEN), which will be applied after restarting the sensor.

We recommend the software ("CMSensorDataViewer" and "CMSensorConfig") available for download at www.buehler-technologies.com to configure and/or operate the sensor via PC. The software provides easy access to sensor data and configuring the sensor without the use of terminal programs when operating the sensor via PC.

If the sensor is in CANopen mode, the RS232 port can be permanently switched to Index 0x2020, Subindex 3, which will be applied after restarting the sensor.

If the sensor is in CANopen mode, the RS232 port can also be changed temporarily. In this case, connect the sensor to the RS232 port configured accordingly and whilst booting, press the pound key (#) until the sensor responds with its ID. If the sensor does not respond within 10 seconds after connecting power, repeat the process.

4.1.1 Serial Port (RS232)

The sensor has a serial port which can be used to read and configure it. This requires a PC and the corresponding terminal program or a readout software. Both are detailed in the following chapters.

First you will need to select an existing free COM port on your PC to connect the sensor to. A suitable communication cable for the serial connection between the sensor and PC/control unit is available under Item no. 1590001001. If the PC does not have a standard COM port, you can also use serial port cards or USB to serial adapter, Item no. 1590001002.

When starting the sensor in CAN mode, it must first be changed to RS232 mode. After connecting the sensor to power, the sensor checks the line to determine whether it's connected to a serial port and if a defined character ("#") is sent, which must be set during start-up. If the character is not sent, the sensor switches to CANopen mode. If it understands the sent character, it switches to communication via RS232. Here the command for RS232 mode can be permanently enabled.

When restarting the sensor, it will then automatically start in RS232 mode and the above steps can be skipped.

4.1.1.1 Interface Parameters

- Baudrate: 9600
- Data bits: 8
- Parity none
- Stop bits: 1
- Flow control: No

4.1.2 Command List

The following lists all interface commands for communication with the sensor.

These can be sent to the sensor via terminal program, e.g. Microsoft Windows HyperTerminal.

4.1.2.1 Read Commands

#	Command format	Meaning	Return format
1	RVal[CR]	Read all measurements followed by checksum (CRC)	$ Time:x.xxx[h];T:xx.x[°C]; ....;CRC:x[CR][LF]
2	RID[CR]	Read identification followed by checksum (CRC)	$BuehlerTechnologies;BCM-MS200 SN:xxxxx;...;CRC:x[CR][LF]
3	RCon[CR]	Read configuration parameters and CAN configuration followed by checksum (CRC)	$AO1:x;AO2:x;...; CRC:x[CR][LF]
4	RGrad[CR]	Read parameter gradients followed by checksum (CRC)	$Time:x.xxx[h]; PTG:x.xxx[1/K]; CTG:x. xxxx[pS/m/K];...; CRC:x[CR][LF]
5	RMemO[CR]	Read memory organisation, parameters and data units are output	Time [h]; T [°C]; P [-];P40 [-];PTG [1/K];C [pS/m];... [CR][LF]
6	RMemS[CR]	Read number of storable datasets	MemS: xxxx[CR][LF]
7	RMemU[CR]	Read number of saved datasets	MemU: xxxx[CR][LF]
8	RMem[CR]	Read entire memory, incl. organisation, datasets are [CR][LF] separated, press any key to interrupt	Time [h]; T [°C]; P [-];P40 [-];PTG [1/K];... [CR][LF] x.xxx;x.xxxx;x.xxxx;x.xxxx; x.xxxx;... [CR][LF]
9	RMem-n[CR]	Read last n datasets in memory followed by checksum (CRC) per dataset, semicolon separated data, datasets [CR][LF] separated, starting with oldest dataset, press any key to interrupt	$x.xxx;x.xxxx;x.xxxx;x.xxxx; x.xxxx;... ;CRC:x[CR][LF] ... $x.xxx;x.xxxx;x.xxxx;x.xxxx; x.xxxx;... ;CRC:x[CR][LF]
10	RMem-n;i[CR]	Read i datasets in memory, starting with (current dataset)- (n datasets) followed by checksum (CRC) per dataset, data semicolon separated, datasets [CR][LF] separated, starting with the oldest dataset, press any key to interrupt	$x.xxx;x.xxxx;x.xxxx;x.xxxx; x.xxxx;... ;CRC:x[CR][LF] ... $x.xxx;x.xxxx;x.xxxx;x.xxxx; x.xxxx;... ;CRC:x[CR][LF]
11	RMemH-n[CR]	Read datasets in memory of the last n hours followed by checksum (CRC) per dataset, data semicolon separated, datasets [CR][LF] separated, starting with the oldest dataset, press any key to interrupt	$x.xxx;x.xxxx;x.xxxx;x.xxxx; x.xxxx;... ;CRC:x[CR][LF] ... $x.xxx;x.xxxx;x.xxxx;x.xxxx; x.xxxx;... ;CRC:x[CR][LF]
12	RORef[CR]	Read saved reference values RefStat (teach-in progress: 255 not initiated, 30..1 teach-in in progress, 0 teach-in completed), RefC40, RefP40, RefCTG, RefPTG	$RefStat:x[-];RefC40:x[pS/m];... ;CRC:x[CR][LF]
13	RLim[CR]	Read set limits for alarms and calculate Aging-Progress value and RUL Defaults: LimitP40%: 5.0 % LimitC40%: 400 % MaxT: 80 °C MaxTMean: 50 °C RULh: 0h (not set) RULfB: 0 (not set) LMax: 90 %[1] LMin: 20 %[1]	$LimitP40%:x.x[%]; LimitC40%:x[%]; MaxT:x[°C]; MaxTMean:x.x[°C];... ;CRC:x[CR][LF]

Tab. 13: Serial communication - read commands

[1] only for level sensors

4.1.2.2 Write Commands

#	Command format	Meaning	Return format
1	SONew[CR]	Saves current state as fresh oil. All parameters are erased gradients, reference values, taught-in values), oil age is set to 0 h, teach-in is initialised (Duration: approx. 250 operating hours), data in memory is retained	ok[CR][LF]
2	WAHSclxxxx[CR]	Set limit for absolute humidity. This value is critical for scaling when output via 4..20 mA interface.	AHScl:xxxxx[CR][LF]
3	SAO1x[CR]	Assigns a corresponding measurement value to the first current output. Default relative humidity	SAO1:x[CR][LF]
4	SAO2x[CR]	Assigns a corresponding measurement value to the second current output. Default: Temperature	SAO2:x[CR][LF]
5	CTime[CR]	Erases the operating hours counter	ok[CR][LF]
6	CMem[CR]	Erases all data from history	ok[CR][LF]
7	WMemInt*n*[CR]	Set save interval to *n* minutes Range n: 1..1440 minutes	MemInt:*n* [min] [CR][LF]
8	SMemD[CR]	Save current data to memory as a new dataset	ok[CR][LF]
9	WCOENx[CR]	Enable or disable CANopen mode. x = 0: CAN disabled, x = 1: CAN enabled Applied after restart	COEN:x[CR][LF]
10	WCOSpdx[CR]	Sets baudrate of CAN interface x = Baudrate in kBit/s supported baudrates (all in kBit/s): 10, 20, 50, 100, 125, 250, 500, applied after restarting	COSpd:x[CR][LF]
11	WCOIDx[CR]	Set node ID for CANopen mode. Range x: 0..127 COB-ID of TPDOs is automatically set to defaults TPDO1 COB-ID: 0x180+node ID TPDO2 COB-ID: 0x280+node ID TPDO3 COB-ID: 0x380+node ID TPDO4 COB-ID: 0x480+node ID Applied after restart	COID:xxx[CR][LF]
12	WCOHBeat*n*[CR]	Set heart beat time for CANopen mode. Range x: 0..10000ms, resolution: 50ms If n = 0, heart beat off Corresponds to SDO entry Index: 0x1017 Applied after restart	COHBeat:n[ms] [CR][LF]
13	WTPDOy*n*[CR]	Set TPDOy-COB-ID for CANopen mode. Range y: 1..2 Range *n*: 384..1279 (0x180..0x4FF) Corresponds to SDO entry Index: 0x180y, Sub: 1 TPDO3-COB-ID cannot be changed and is always set to 0x380+Node-ID TPDO4-COB-ID1 cannot be changed and is always set to 0x480+Node-ID Applied after restart	TPDOy:n[CR][LF]
14	WTPDO*y*Types [CR]	Set TPDO*y* type for CANopen mode. Range y: 1..2 Range n: 1..240, 254, 255 Corresponds to SDO entry Index: 0x180y, Sub 2 TPDO3 type cannot be changed and always corresponds to the TPDO2 type, applied after restarting	TPDOyType:n [CR][LF]
15	WTPDO*y*Timer*n* [CR]	Set TPDO*y* Timer for CANopen mode. Range *y*: 1..2 Range n: 0..10000ms, resolution: 50ms If *n* = 0, heart beat off Corresponds to SDO entry Index: 0x1017 TPDO3- and TPDO4[1] timer cannot be changed and always corresponds to the TPDO2 timer, applied after restarting	TPDOyTimer:n[ms] [CR][LF]

16	WLimP40%*n* [CR]	Set limit for permitted P40 change from taught-in reference value in % When near or over the current P40 deviation of this value, warnings and alarms are set Range *n*: 1.0..100.0% Default *n*: 5 %	LimP40%:*n*[%] [CR][LF]
17	WLimC40%*n* [CR]	Set limit for permitted C40 change from taught-in reference value in % When near or over the current C40 deviation of this value, warnings and alarms are set Range *n*: 1.0..1000.0% Default *n*: 300 %	LimC40%:*n*[%] [CR][LF]
18	WLimT*n* [CR]	Set limit for permitted maximum temperature Alarm is set if exceeded Range *n*: 20.0..120.0 °C Default *n*: 80 °C	LimT: *n.n*[°C][CR][LF]
19	WLimTmean*n* [CR]	Set limit for permitted maximum average temperature Alarm set if limit exceeded Range *n*: 20.0..120.0 °C Default *n*: 60 °C	LimT:*n.nn*[°C][CR][LF]
20	SETrig*n* [CR]	Disables (n = 0) or enables (n = 1) event-triggered save of measurements Range *n*: 0..1 Default *n*: 0	MemETrig:*n*[CR][LF]
21	WRULh*n* [CR]	Enter reference lifetime of current oil for temperature-based RUL calculation	RULh:*n*[CR][LF]
22	WRULfB*n* [CR]	Enter reference load factors of current oil for temperature-based RUL calculation	RULfB:*n*[CR][LF]
23	STrAu*n*[CR]	Disables (n = 0) or enables (n = 1..60) automatic transmission of measurements, every n minutes, transmission corresponds to response to command RVal Range *n*: 0..60 Default *n*: 0	TrAu:*n*[min][CR][LF]
24	WLMax*n*1	Set maximum permitted liquid level in % Alarm set if limit exceeded Range *n*: 0 ...100 % Default *n*: 90 %	LMax: *n*[%] [CR][LF]
25	WLMin*n*1	Set minimal permitted liquid level in % Alarm set if below this limit Range n: 0 ...100 % Default n: 20 %	LMin:*n*[%] [CR][LF]

Tab. 14: Serial communication - write commands

[1] only for level sensors

[CR] = [Carriage Return (0xD)]

[LF] = [Linefeed (0xA)]

4.1.2.3 CRC Calculation

Every character sent in the string (incl. linefeed and carriage return) must be added up, based on a range of 8 bit (0→255). If the result is ZERO, there is no error.

Example of sent string: RH:31[%];CRC:Ù[CR][LF]

Character	Value
R	82
H	72
:	58
3	51
1	49
[	91
%	37
]	93
;	59
X	67
P	82
X	67
:	58
Ù	217
[CR]	13
[LF]	10
Sum	0→OK

Tab. 15: Example of checksum calculation (CRC)

4.1.3 Setting Analog Current Outputs

The two analog current outputs are factory preset. Channel 1 (Pin 6) is the temperature output, channel 2 (Pin 7) the relative humidity. However, the sensor allows changing the preset output parameter. The command is: "SAO1x[CR]" and "SAO2x[CR]" with the corresponding numerical code x. The following table shows the possible parameters for configuring the analog outputs.

Numerical code x	Parameter
0	Temperature (T)
1	Relative humidity (RH)
2	Absolute humidity (AH)[1]
3	Aging progress (AP)
4	Relative permittivity (P)
5	Relative permittivity at 40 °C (P40)
6	Conductivity (C)
7	Conductivity at 40 °C (C40)
8	Relative humidity at 20 °C (H20)
9	Relative humidity at 40 °C (H40)
10	Liquid level[2]
11	log(conductivity) (log(C)) (Version 1.21.12 and up)
12	log(conductivity at 40 °C) (log(C40)) (Version 1.21.12 and up)
30	Alarm 4mA = no alarm 20mA = oil level low (sensor in air or if level sensor oil level < set minimum) or free water (>95 %) or very high water content (>75 %) or maximum oil temperature setting exceeded
40	Sequential output of T, rel. H, P, C, P40, C40, AP and L[2]
100	Output fixed to 4 mA
101	Output fixed to 12 mA
102	Output fixed to 20 mA

Tab. 16: Numerical code for output parameters of the analog current outputs

[1] This setting requires special calibration.

[2] Only available for level sensors.

4.1.3.1 Sequential Output Of Values

Key parameters can be output sequentially via the analog interfaces. In this case the sensor is configured as specified in chapter Setting Analog Current Outputs [> page 23]. The correspondingly configured sensor outputs the key parameters as shown below.

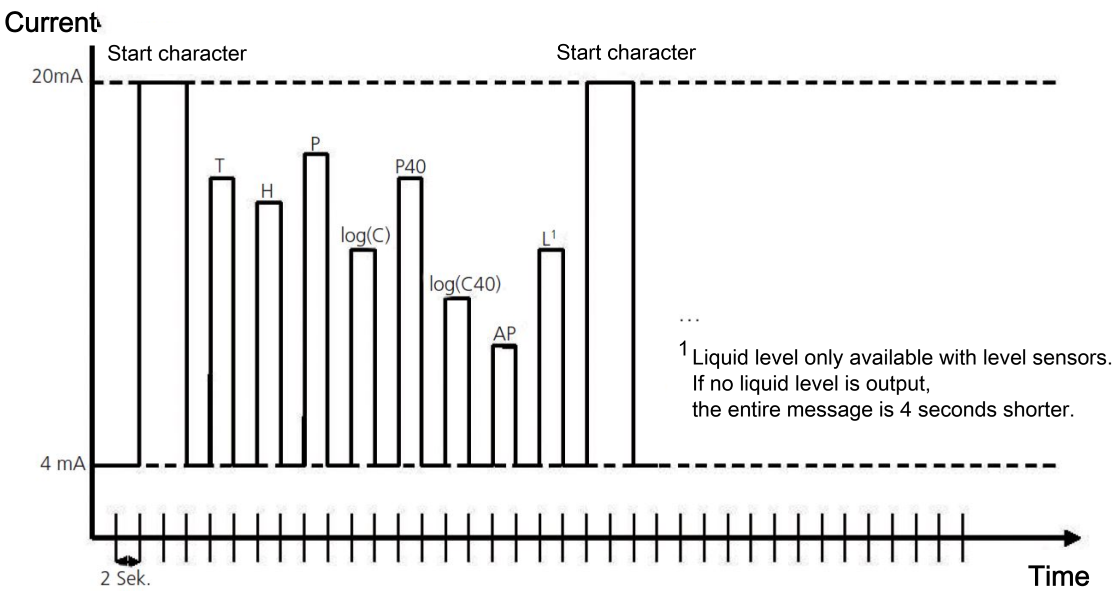


Fig. 8: Sequential output of values via analog interface

4.1.4 Output Triggering

On principle there are two different options to output measurements via the RS232 port, time-triggered or command-triggered.

The command list for querying characteristics can be found in chapter Command List and in the appendix. There are both commands to query the current characteristics as well as to query recent characteristics (time may vary depending on the settings).

4.1.5 Save Triggering

To minimise the input and programming efforts for the user, the sensor features automatic analysis of sensor characteristics. The data generated are saved to the data and error memory on an event-, time- or command-triggered basis. Event refers to a change in the status code of the statuses summarised in chapter Error Bits Key. Even-based saving can be enabled with the command "SETrig".

4.1.6 Configuration For Automatic Condition Analysis

The sensor is preconfigured with default values for automatic condition analysis. When changing individual configuration values, we recommend proceeding per the following table (example for default configuration).

Step		Parameter
1	Set save interval to 20 minutes	WSaveInt20.0[ENTER]
2	Write aging values	WLimP40%5.0[ENTER] WLimV40%20[ENTER]
3	Write temperature limits	WLimT80.0[ENTER] WLimTMean50.0[ENTER]
4	Set oil reference lifetime, if known	WRULhxxxx[ENTER]
5	Set oil reference load factor, if known	WRULfBxxxx[ENTER]
6	Erase memory as needed	CMem[ENTER]
7	Mark current oil as fresh oil	SONew[ENTER]

Tab. 17: Process for default sensor configuration

After changing the oil, these steps must be repeated with adjusted parameters if the oil type has changed. If the oil type is the same as before the oil change, step 7 will suffice (mark current oil as fresh oil). The sensor will reset internally taught-in values, gradients, oil age etc. and initialise a new teach-in cycle which can be up to 250 hours. During this time, the condition analyses relying on taught-in values and gradients cannot be detected.

Status detection for high temperature and water ingress will still work.

The 64Bit hex code is represented by 16 hex numbers.

For the valence and meaning of the individual bits, please refer to the table in chapter Error Bits Key.

Timed output can be enabled or disabled via command.

4.2 CAN Communication

4.2.1 CAN Interface

The CAN interface corresponds to "CAN 2.0B Active Specification". The data packets have the format shown below. This illustration is for illustration purposes only, it is implemented according to the CAN 2.0B specification.

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

Data rates recommended by CiA and supported by the sensor

Data rate	Supported	CiA Draft 301	Bus length (per CiA Draft Standard 301)
1 Mbit/s	no	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	yes	no	750 m
50 kbit/s	yes	yes	1000 m
20 kbit/s	yes	yes	2500 m
10 kbit/s	yes	yes	5000 m

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

The electrical parameters of the CAN interface are shown in this table:

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: CAN interface electrical parameters

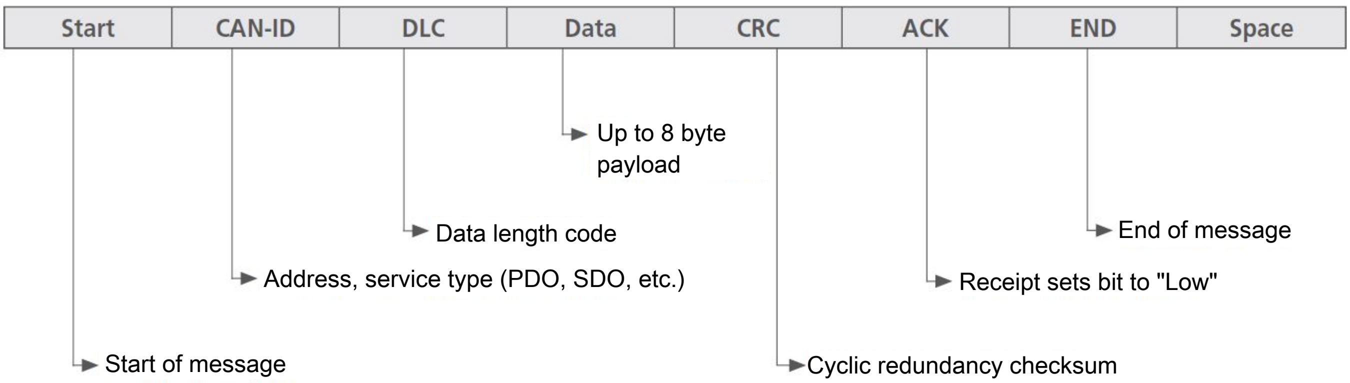


Fig. 9: CAN message format

4.2.2 CANopen

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

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.

4.2.2.1 "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

4.2.2.2 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.

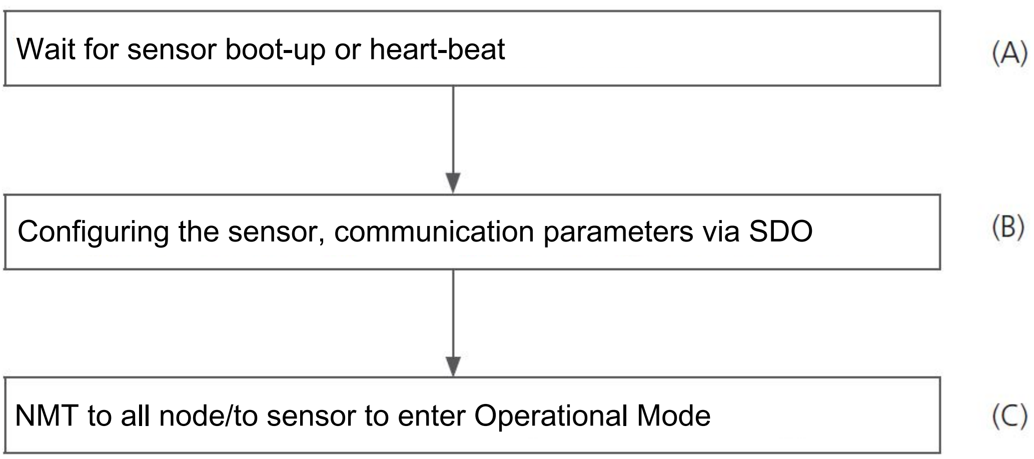


Fig. 10: CANopen bus initialization process

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

4.2.2.3 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.

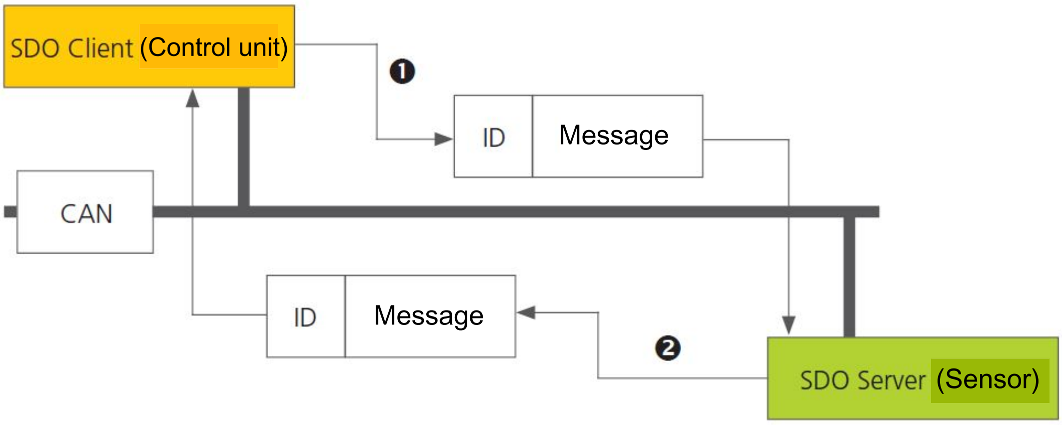


Fig. 11: SDO Client/Server relationship

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

4.2.2.4 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 TPDOs, no RPDOs (level sensors support four TPDOs).
- Data mapping in PDOs is fixed and cannot be edited.
- COB-IDs for TPDO1 and TPDO2 can be freely selected, TPDO3 always has the COB ID 0x380+NodeID.
- TPDO1 and TPDO2 can be transmitted on SYNCH event/timer triggered or cycle triggered and is can each be set individually for the two TPDOs, TPDO3 (and TPDO4 for level sensors) handles the TPDO2 settings.

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.

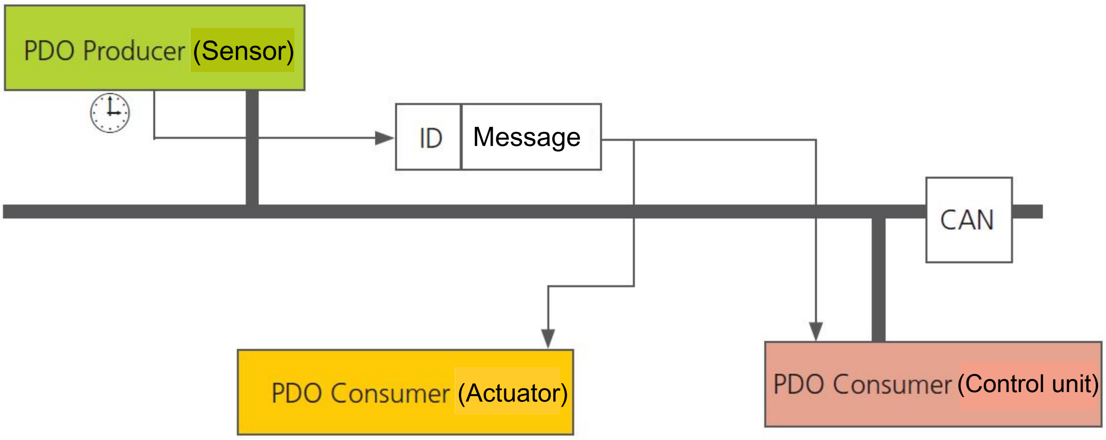


Fig. 12: PDO Consumer/Producer relationship

4.2.2.5 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

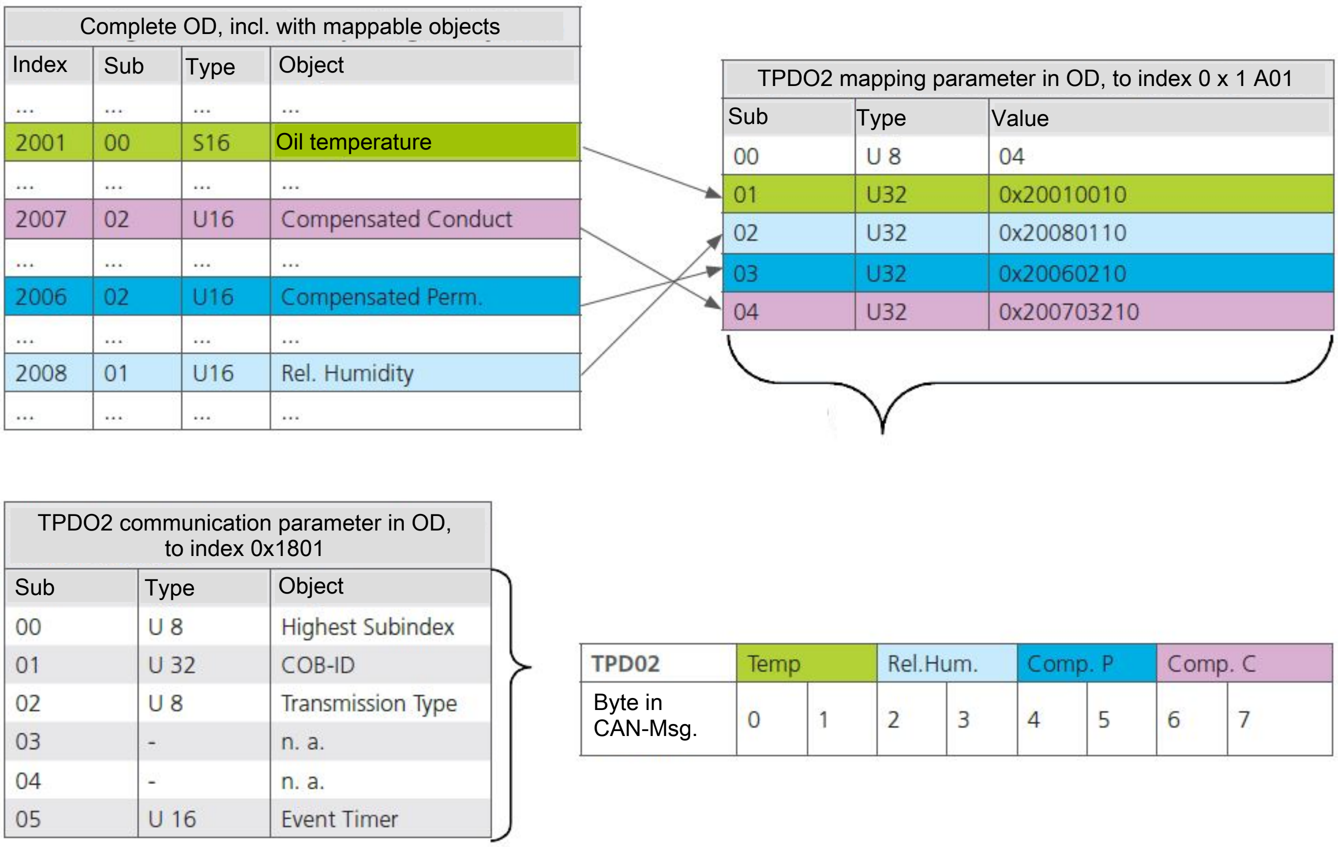


Fig. 13: Principle of mapping multiple OD objects in a TPDO

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

4.2.2.6 "CANopen Object Dictionary" Details

The following tables show the full object directory for the sensor. The first table shows the communication portion of the object directory. Apart from a few exceptions, these settings correspond to the CANopen standard as described in DS 301. There are some communication limitations based on the hardware platform used. The configuration steps for "heartbeat time" (Index 1017h), "TPDO1 event timer" (Index 1800h, Subindex 5), "TPDO2 event timer" (Index 1801h, Subindex 5), "TPDO3 event timer" (Index 1802h, Subindex 5) are limited to 50 ms in place of the 1 ms envisaged. This means that these objects can be configured to 0 ms, 50 ms, 250 ms, but not 35 ms, 125 ms, etc.

Communication Profile Area

Idx (hex)	Sub	Name	Type	Attr.	Default	Notes
1000	0	Device type	U32	ro	194h	Sensor, see DS 404
1001	0	Error register	U8	ro	00h	mandatory, see DS 301
100A	0	Manufacturer Software Version	string	ro	depends current firmware	e.g.: "1.01"
1017	0	Producer heartbeat time	U16	rw	3E8h	heartbeat time in ms, granularity of 50ms (instead of 1ms, e.g. can be set to 0, 50, 150, but not to 20) range: 0..10000
1018		**identity object**	**record**	**ro**		
	0	Number of entries	U8	ro	04h	largest sub index
	1	Vendor ID	U32	ro	000000E6h	
	2	Product code	U32	ro	Device dependant	
	3	Revision number	U32	ro	Device dependant	
	4	Serial number	U32	ro		Device dependant lower 3 bytes contain the serial number, the top byte is reserved for future use
1800		**Transmit PDOs Parameter**	**record**			
	0	Number of entries	U8	ro	05h	largest sub index
	1	COB-ID	U32	rw	180h + NodeID	COB-ID used by PDO, range: 181h..1FFh, can be changed while not operational
	2	Transmission type	U8	rw	FFh	cyclic+synchronous, asynchronous values: 1-240, 254, 255
	5	Event timer	U16	rw	1388h	event timer in ms for asynchronous TPDO1, value has to be a multiple of 50 and max 12700
1801		**Transmit PDO2 Parameter**	**record**			
	0	Number on entries	U8	ro	05h	largest sub index
	1	COB-ID	U32	rw	280h + NodeID	COB-ID used by PDO, range: 281h..2FFh, can be changed while not operational
	2	Transmission type	U8	re	FFh	cyclic+synchronous, asynchronous values: 1-240, 254, 255
	5	Event timer	U16	rw	1388h	event timer in ms for asynchronous TPDO2, value has to be a multiple of 50 and max 12700
1802		**Transmit PDO3 Parameter**	**record**			
	0	Number on entries	U8	ro	05h	largest sub index
	1	COB-ID	U32	ro	380h + NodeID	COB-ID used by PDO, cannot be changed
	2	Transmission type	U8	ro	Copy of TPDO2 Transmission Type	cyclic+synchronous, asynchronous, copy TPDO2 Transmission Type
	5	Event timer	U16	ro	copy of TPDO2 event timer	event timer in ms for asynchronous TPDO3, copy of TPDO2 event timer
1803		**Transmit PDO4 Parameter**	**record**		**only for level sensors**	
	0	Number of entries	U8	ro	05h	largest sub index
	1	COB-ID	U32	ro	480h + NodeID	COB-ID used by PDO, cannot be changed
	2	Transmission type	U8	ro	Copy of TPDO2 Transmission Type	cyclic+synchronous, asynchronous, copy TPDO2 Transmission Type

	5	Event timer	U16	ro	copy of TPDO2 event timer	event timer in ms for asynchronous TPDO4, copy of TPDO2 event timer
1A00		**TPDO1 Mapping Parameter**	**record**			
	0	Number of entries	U8	ro	04h	largest sub index
	1	1st app obj. to be mapped	U32	co	20000410h	Alarms
	2	2nd app obj. to be mapped	U32	co	20000310h	Information
	3	3rd app obj. to be mapped	U32	co	20000210h	Status
	4	4th app obj. to be mapped	U32	co	20000110h	Sensor Status
1A01		**TPDO2 Mapping Parameter**	**record**			
	0	Number of entries	U8	ro	04h	largest sub index
	1	1st app obj. to be mapped	U32	co	20010010h	Temperature
	2	2nd app obj. to be mapped	U32	co	20080110h	Humidity
	3	3rd app obj. to be mapped	U32	co	20060210h	Permittivity @ 40 °C
	4	4th app obj. to be mapped	U32	co	20070210h	Conductivity @ 40 °C
1A02		**TPDO3 Mapping Parameter**	**record**			
	0	Number of entries	U8	ro	03h	largest sub index
	1	1st app obj. to be mapped	U32	co	20050510h	RUL in h
	2	2nd app obj. to be mapped	U32	co	20050210h	Oil Age in h
	3	3rd app obj. to be mapped	U32	co	10180420h	Sensor serial number
1A03		**TPDO4 Mapping Parameter**	**record**		**only for level sensors**	
	0	Number of entries	U8	ro	01h	largest sub index
	1	1st app obj. to be mapped	U32	co	200B0108h	Oil level in %

Tab. 29: "Communication Profile Area", communication object directory

All oil and sensor objects are always located in the object directory from index 2000h and listed in the following. This part of the object directory is sensor-specific and represents the oil parameters measured and derived by the sensor. Furthermore, some configuration options are supported to for example set the maximum temperature values or configure the settings required to calculate the RUL.

Manufacturer-specific profile area						
Idx (hex)	**Sub**	**Name**	**Type**	**Attr.**	**Default**	**Notes**
2000		**Condition Monitoring Bitfield**	**array**			
	0	Number of entries	U8	ro	04h	largest sub index
	1	Sensor status bits	U16	ro		
	2	Oil status bits	U16	ro		
	3	Oil information bits	U16	ro		
	4	Oil alarm bits	000u16	ro		
2001						
	0	Oil Temperature	S16	ro		Oil temperature in °C multiplied by 10
2005		**Time related parameters**	**record**			
	0	Number of entries	U8	ro	08h	largest sub index
	1	Sensor up time	U32	ro		Operating time in seconds
	2	Oil age	U16	ro		Time since last oil change in hours
	3	Save interval	U16	rw	20	Save interval in minutes
	4	Sensor total up time	U32	ro		Total sensor operating time in hours
	5	Remaining Useful Lifetime	U16	ro		Remaining Lifetime of the oil in hours
	6	Remaining Useful Lifetime, temperature based	U16	ro		Temperature component of RUL
	7	Remaining Useful Lifetime, oil characteristics based	U16	ro		Oil characteristics component of RUL
	8	Remaining Useful Lifetime overwrite function	U16	wo		RUL overwrite function
	9	Status of oil age counter	U8	rw		Oil age counter, running after boot up (value > 0), to stop counter write a 0, no saving, always 1 after reboot

2006		**Permittivity related parameters of the oil**	**record**			
	0	Number of entries	U8	ro	06h	largest sub index
	1	Permittivity	U16	ro		Permittivity, multiplied by 1000
	2	Permittivity, temperature compensated to 40 °C	U16	ro		P @ 40 °C, multiplied by 1000
	3	Permittivity, deviation from fresh oil value in %	S16	ro		deviation of P @ 40 °C from teached value in %, multiplied by 100
	4	Threshold for permittivity, deviation from fresh oil value in %	S16	rw		LimitP40%, threshold for deviation of P @ 40 °C from teached value in %, multiplied by 100
	5	Aging Progress of Permittivity in %	U16	ro		P @ 40 °C Aging Progress in %, multiplied by 10
	6	Permittivity fresh oil value	U16	rw		Permittivity of the oil, compensated to 40 °C, multiplied by 1000
2007		**Conductivity related parameters of the oil**	**record**			
	0	Number of entries	U8	ro	06h	largest sub index
	1	Conductivity	U16	ro		Conductivity, divided by 100, 0..1000000pS/m
	2	Conductivity, temperature compensated to 40 °C	U16	ro		Conductivity @ 40 °C, divided by 100, 0..1000000pS/m
	3	Conductivity, deviation from fresh oil value in %	S16	ro		Deviation of C @ 40 °C from taught value in %, multiplied by 10
	4	Threshold for Conductivity, deviation from fresh oil value in %	S16	rw		LimitC40 %, threshold for deviation of C @ 40 °C from taught value in %, multiplied by 100
	5	Aging Progress of Conductivity in %	U16	rw		C @ 40 °C Aging Progress in %, multiplied by 10
	6	Conductivity, fresh oil value	U16	ro		Conductivity of the oil, compensated to 40 °C, divided by 100, 0..1.000.000pS/m
2008		**Humidity related parameters of the oil**	**record**			
	0	Number of entries	U8	ro	03h	largest sub index
	1	rel. humidity	S16	ro		rel. humidity of the oil, multiplied by 10, range: 0.0..100.0%
	2	rel. humidity, temperature compensated to 40 °C	S16	ro		rel. humidity of the oil in % multiplied by 10, compensated to 40 °C, range: 0.0..100.0 %
	3	Condensation temperature	S16	ro		Temperature where the water in oil would condensate to free water, value in °C, range: 0..100°C
2009		**Temperature related parameters of the oil**	**record**			
	0	Number of entries	U8	ro	07h	largest sub index
	1	Current Oil Temperature	S16	ro		Oil temperature of the oil in °C, multiplied by 10
	2	Current Sensor Temperature	S16	ro		Sensor temperature in °C, multiplied by 10
	3	Mean Temperature	S16	ro		Mean temperature of the oil since last oil change in °C multiplied by 10
	4	Threshold for Oil Temperature	S16	rw	85	Temperature where an alarm bit is set multiplied by 10, range: 100..1000
	5	Threshold for Mean Temperature	S16	rw	65	Temperature where an alarm bit is set multiplied by 10, range: 100..1000
200A		**Temperature Histogram**	**array**			
	0	Number of entries	U8	ro	1Eh	largest sub index
	1	Temperature class <0 °C	U16	ro		counts in class <0°C
	2	Temperature class 0 °C..<5 °C	U16	ro		counts in class 0°C..<5 °C
	....		U16	ro		....
	30	Temperature class >140 °C	U16	ro		counts in class >140 °C
200C		**Aging Progress**	**U16**	**ro**		**Aging Progress in % multiplied by 10**
200B		**Level related parameters**	**record**		**Only for level sensors**	

	0	Number of entries	U8	ro	3 h	largest sub index
	1	Level	U8	ro		Level in %
	2	Threshold for max. oil level	U8	rw	90	Level where an alarm bit is set, range: 0..100
	3	Threshold for im. oil level	U8	rw	20	Level where an alarm bit is set, range: 0..100
2020		**Commands**	**record**			
	0	Number of entries	U8	ro	3 h	largest sub index
	1	New oil	U8	wo		New oil commands 0x01 = new oil, same as RS232 command "SONew"
	2	Rule Base settings	U8	wo		rule base commands 0x00 = error triggered saving off 0x01 = error triggered saving on
	3	CANopen Enable	U8	wo		CAN enable status on next reboot, CANopen can be disabled, need RS232 to be activated again! 0x00 = off 0x01 = on
2021		**Node ID**	**U8**	**rw**		**NodeID of the sensor, will be used on next reboot**
2030		**RUlfB and RULh settings**	**record**			
	0	Number of entries	U8	ro	2h	largest sub index
	1	RUL Reference Load Factor fB * 1000	U16	rw		reference load factor fB multiplied by 1000
	2	RUL Reference Lifetime in Hours	U16	rw		100..30000 h, reference life time for this oil in this application
2100		**Readmem control functions**	**record**			
	0	Number of entries	U8	ro	3 h	largest sub index
	1	Size of history memory, data sets	U16	ro		size of mem in datasets, device dependent
	2	Used history memory (write pointer)	U16	ro		used datasets in mem
	3	Reading pointer, dataset	U16	rw		autoincrementing read pointer for history memory reading expressed as datasets, can be between 0 and current write pointer
2101		**Readmem Initiate segmented SDO data download**	**U16**	**ro**		**Appropriate Pointer has to be set (with 2100sub3) before start reading, Size of the record will be sent back on reading**

Tab. 30: Manufacturer-specific Profile Area", sensor portion of the CANopen communication profile

4.3 Before Initial Use

The following describes the steps required on the PC for initial sensor operation. This requires the following components:

- PC/laptop with RS232 port or alternatively USB port serving as measuring computer
- Sensor
- Sensor cable (Item no.: 1590001001)
- Power supply incl. IEC connector (Item no.: 1590001003)
- Software "CMSensorDataViewer" and "CMSensorConfig"
- Plus for connection via USB: USB to RS232 adapter plus driver software (Item no.: 1590001002). The software "CM-SensorDataViewer" and "CMSensorConfig" can be downloaded from www.buehler-technologies.com.

Prepare the components as follows:

A) Software installation "CMSensorDataViewer"

- Extract the .zip file on your computer.

B) Install driver for the USB to RS232 adapter for data acquisition via USB (when not using an adapter, skip to step D)

- Now connect your USB to RS232 adapter to your PC/laptop.
- If the PC does not recognise the USB to RS232 adapter, install the corresponding driver. In this case, follow the installation instructions for the operating system or the included driver CD.

C) Connecting the sensor for data acquisition via USB

- Connect the M12 plug of the sensor cable to the sensor.
- Connect the 9pin D-sub connector of the cable to the corresponding serial port of the USB to RS232 adapter.
- Connect the power supply and the sensor cable.
- Now properly connect your power supply to the mains with the IEC connector. Your sensor is now ready for use.

D) Connecting the sensor for data acquisition via RS232

- Connect the M12 plug of the sensor cable to the sensor.
- Connect the 9pin Connect the D-sub plug of the cable to the corresponding serial port on your PC/laptop.
- Connect the power supply and the sensor cable.
- Now properly connect your power supply to the mains with the IEC connector. Your sensor is now ready for use.

E) Start the software

- "CMSensorDataViewer" and "CMSensorConfig" can be launched by double-clicking CMSensorDataViewer.exe or CMSensor-Config.exe.
- Select the serial port (COM) where the sensor is connected to the PC. When not using a USB to RS232 adapter, this is typically COM 1.
- When using a USB to RS232 adapter, a new virtual COM port will be added. Select this. If necessary, open the Windows device manager to check the assignment of the virtual COM port.
- The incoming data and the sensor identification will appear on the left side of the screen. The right side of the screen can be used to show the data as a diagram.

4.4 Initial Operation

The following explains how initial sensor operation for both the RS232 and CAN interface.

Verify the device is installed properly and safely and connected to power. The basic conditions specified in these instructions must be met to ensure proper sensor function.

4.4.1 Initial Operation With RS232 Port

After connecting the sensor to power, the sensor will automatically communicate its sensor ID via RS232.

The sensor is now ready and can be read out using the analog outputs or digital interface. For a list of supported commands, please refer to chapter Command List. For quick startup, please observe the information in chapter Before Initial Use.

4.4.2 Initial Operation With CAN Interface

The sensor comes standard with the RS232 enabled and CAN interface disabled. To permanently enable the CAN interface, the sensor must be configured via RS232 port (command "WCOEN"). You can alternatively contact Bühler Technologies GmbH Service.

On delivery, the CANopen interface of the sensor is configured as shown in this table:

CANopen interface default configuration		
Parameter	**Set value**	**RS232 command**
Node-ID	0x64 (dec: 100)	WCOID
CAN baudrate	250 kbit/s	WCOSpd
Heart beat timer	1000 ms	WHBeat
TPDO1 ID	Node ID + 0x180 = 0x1E4 (dec: 484)	WTPDO1
TPDO2 ID	Node ID + 0x280 = 0x2E4 (dec: 740)	WTPDO2
TPDO3 ID	Node ID + 0x380 = 0x3E4 (dec: 996)	-
TPDO1 Type	255	WTPDO1Type
TPDO2 Type	255	WTPDO2Type
TPDO3 Type	= TPDO2 Type	-
TPDO1 Timer	5000 ms	WTPDO1Timer
TPDO2 Timer	5000 ms	WTPDO2Timer
TPDO3 Timer	= TPDO2 Timer	-
TPDO4 Timer (level sensors only)	= TPDO2 Timer	-
CAN enabled	0	WCOEN

Tab. 31: CANopen default configuration

After configuring the CAN interface for the available CANopen network, the CAN interface of the sensor can be enabled and the sensor can be connected to the CANopen network.

The process for communicating with the sensor via RS232 port with the CAN communication enabled, please refer to Operation and Control [> page 18].

4.4.3 Function Range Depending On Configuration

Depending on the desired functional range, the sensor can be configured with additional information to use the corresponding functions. The table shown here contains a list of the necessary sensor configurations for the respective functional range. For information about configuring the sensor, please see chapter Configuration For Automatic Condition Analysis [> page 24].

Configurations necessary for function range	
Function range/scenario	**Required system information/required configuration**
– Basic parameters: Temperature, humidity, P, C, P40, C40 – Average temperature, load factor since starting sensor – Short-term gradients – Water content alarms, "Oil level low"	– No additional system information required
– High temperature alarms	– Limits for maximum and average temperature must be adjusted for the application
– Detect contamination with other oils/fluids – Long-term gradients	– Teach-in process must always be initialized with fresh oil
– Aging progress of characteristics (P40 and C40) – Alarms for aging progress of limits	– Teach-in process must always be initialized with fresh oil – Limits for P40 and C40 must be configured (if default configuration insufficient)
– Predicted oil "Remaining Useful Lifetime"	– Teach-in process must always be initialized with fresh oil – Limits for P40 and C40 must be configured (more information available than specified by default configuration) – System load factor and the associated oil lifetime must be known

Tab. 32: Function range depending on configuration

4.5 Application Example

The oil condition is a factor formed from various parameters. Limits for specific oil parameters vary by the respective application, e.g. the components and materials used. The type and speed of oil parameter change in turn varies by application, specific system load and the fluid medium or lubricant used.

Universal limits therefore cannot be defined for individual parameters. The following shows some example characteristics of condition changes for fluid media or lubricants. The values specified are merely guidelines. Adjusting the standard values specifically for the system requires laboratory analyses.

Condition/condition change	Criterion
1. Oil refreshing/change	The sensor characteristics changing quickly is typical for refreshing small amounts of oil refreshing. Depending on the temperature, media viscosity, flow conditions and mixing in the system, oil being refilled can already be detected within a few hours. The same applies to oil being changed. If the sensor is running during the oil change, the oil change can already be detected when the oil is drained and the measurement temporarily dropping to the respective air value. Whether oil refreshing can be detected greatly depends on the amount of oil refilled, the difference in oil characteristics and the sensor resolution. **Relative permittivity (DK):** When refilling with a higher or lower relative DK - compared to the medium currently in the system - the value rises or drops after homogeneous mixing. This change in condition arises when refilling with a different type of oil or if the oil in the system has already changed due to aging. Adding the exact same relative DK as the oil in the system cannot be detected from this parameter. However, oil refreshing can be detected through other parameters described below.
2. Using the correct oil	Whether the prescribed lubricants is used can be determined by the conductivity and the relative DK. The respective parameters must be stored in the system for fresh oil. The theoretical and actual values can then be compared.
3. Oil aging	Oxidative aging of fluid media or lubricants typically produces polar aging products. It typically produces aldehydes and ketones and subsequently acidic and higher-molecular aging products. Analysis laboratories often use the acid number TAN as the characteristic marker for determining free acid in the oil. Since oils already have different acid numbers when fresh, the TAN trend is typically monitored. A change in the TAN by 2 mg KOH/g, for example in hydraulic fluids, is considered an indicator for an oil change. **Relative permittivity (DK):** The sensor can track a rise in polar oil components using the relative DK. As with monitoring the TAN, the trend and less so the absolute parameter are key. Oxidation typically causes a rise in the relative DK. The change is typically slow. If the relative DK has changed over 10 to 20 % from the fresh oil value, the oil should be further analysed. Closer analysis is also advisable if the speed at which the signal changes increases considerably and a progressive signal sequence can be detected. **Conductivity:** The conductivity and the relative DK change in the aging process. In many cases the number of charge carriers in the oil increases and the conductivity increases. The sensor saves the fresh oil values for conductivity and relative DK. Oil aging can then be detected e.g. by comparing fresh oil values and current characteristics. The sensor automatically performs this analysis and deduces the so-called aging progress (AP) from this.

5 Cleaning And Maintenance

This device is maintenance-free when used properly.

The method for cleaning the devices must be adapted to the IP protection class of the devices. Do not use cleaners which could damage the device materials.

6 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.

6.1 Troubleshooting

Error	Possible Cause	Action
– No sensor communication with HyperTerminal	Cable not properly connected	First check the electrical connection of the sensor and verify the data and power cable are properly connected. Please note the prescribed pint assignment.
	Operating voltage outside the prescribed range.	Please operate the sensor within a range between 9 V and 33 V DC.
	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, if necessary with an interface tester.
	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. If the commands are invalid, the sensor will return the string with a question mark in front of it.
	Incorrect or defective cable	If possible, use original data cables
	RS-232 interface not enabled	Temporarily or permanently enable the RS232 port with CM-SensorConfig or a terminal program as described in chapter Operation and Control [> page 18].
– Measurements implausible or measurements fluctuate	Sensor measuring air due to highly fluctuating tank volume	Verify the sensor is installed properly per the installation instructions.
	Sensor measuring air in the oil or polar deposits in the oil sump	Verify the sensor is installed properly per the installation instructions.
	The oil is very foamy	Verify the sensor is installed properly per the installation instructions. Foam can particularly be expected with gearboxes and unfavourable installation positions.
	Measurements outside the specification	Observe the technical data and operate the sensor within the specified measurement ranges.
– No analog output	Cable not properly connected	First check the electrical connection of the sensor and verify the data and power cable are properly connected. Please note the prescribed pint assignment.
	Operating voltage outside the prescribed range.	Please operate the sensor within a range between 9 V and 33 V DC.
	Interface configuration incorrect	Check and if necessary correct the settings of the analog outputs.

	Analog outputs wired incorrectly	Observe the information on measuring the analog outputs
– No sensor communication via CAN	Cable not properly connected	First check the electrical connection of the sensor and verify the data and power cable are properly connected. Please note the prescribed pint assignment.
	Operating voltage outside the prescribed range.	Please operate the sensor within a range between 9 V and 33 V DC.
	Interface configuration incorrect	Check and if necessary correct the settings for the interface parameters. The correct setting depends on the sensor configuration.
	CAN interface not enabled	enable the CAN interface with the RS232 port, CMSensorConfig or a terminal program as described in chapter Operation and Control [> page 18].
– Absolute humidity measurement incorrect	Calibrating parameter settings incorrect	The calibrating parameters are specific to the oil and must be programmed. Please contact Bühler Technologies GmbH Service.
	Measuring range setting incorrect	The measuring range is specific to the oil and must be programmed. Please contact Bühler Technologies GmbH Service.

Tab. 33: Error: No sensor communication with HyperTerminal

6.2 BCM-MS accessories

Item no.	Description
1590001005	Line adapter
1590001001	RS232 data cable
1590001002	USB/RS232 adapter
1590001003	Power supply

6.3 Accessories BCM-LS

Item no.	Description
1590001001	RS232 data cable
1590001002	USB/RS232 adapter
1590001003	Power supply

7 Disposal

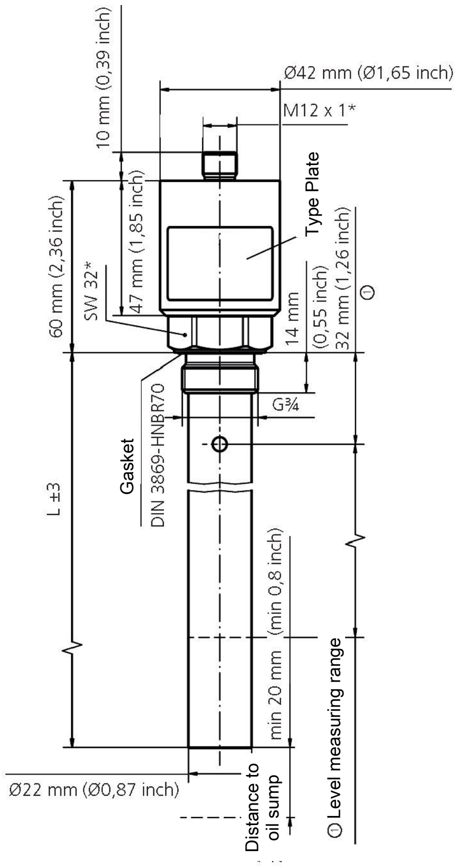
Dispose of parts so as not to endanger the health or environment. Follow the laws in the country of use for disposing of electronic components and devices during disposal.

8 Appendices

8.1 BCM-LS Technical Data

BCM-LS200–1DC2A/xxx	1DC2A
Version:	Compact unit
Process connection:	G3/4
Material in contact with media:	aluminium, HNBR, polyurethane resin, epoxy resin, electroless nickel immersion gold (ENIG), solder, aluminium oxide, glass, gold, silver palladium
Medium temperature:	-20 °C to +85 °C
Ambient temperature:	-20 °C to +85 °C
Pressure resistance:	50 bar
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:	170 g for 200 mm version 210 g for 375 mm version 250 g for 615 mm version
Operating voltage (U_B):	9 – 33 V DC
Power input:	max. 0.2 A
Measuring range	
Temperature:	-20 °C...85 °C
Rel. humidity:	0...100 %
Rel. permittivity:	1...7
Conductivity:	100...800,000 pS/m
Liquid Level	115 mm for 200 mm version 288 mm for 375 mm version 515 mm for 615 mm version see scale drawing
Measuring accuracy	
Temperature:	±2 K
Rel. humidity:	±3 %
Rel. permittivity:	±0.015
Conductivity (100...2,000 pS/m):	±200 pS/m
Conductivity (2,000...800,000 pS/m):	<±10 %
Liquid Level	<±5 %
1DC output:	RS232/CANopen/SAE J1939
2A output:	2x 4-20 mA (assigned to one measurand or sequential output of all values)

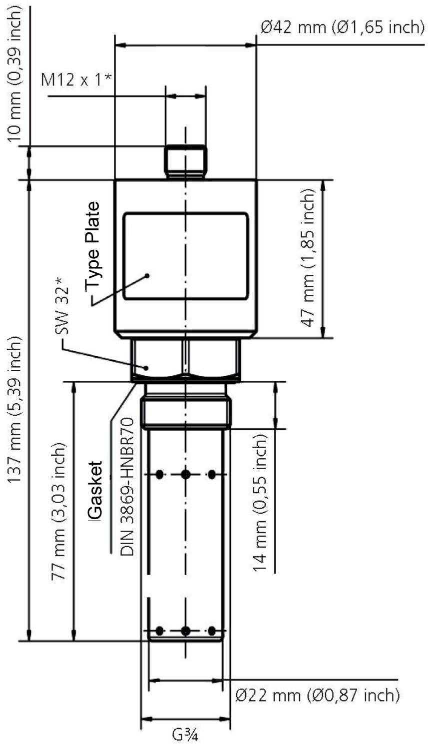
Dimensions



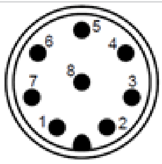
8.2 BCM-MS Technical Data

BCM-MS200–1DC2A	1DC2A
Version:	Compact unit
Process connection:	G3/4
Material in contact with media:	aluminium, HNBR, polyurethane resin, epoxy resin, electroless nickel immersion gold (ENIG), solder, aluminium oxide, glass, gold, silver palladium
Medium temperature:	-20 °C to +85 °C
Ambient temperature:	-20 °C to +85 °C
Pressure resistance:	50 bar
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:	140 g
Operating voltage (U_B):	9 – 33 V DC
Power input:	max. 0.2 A
Measuring range	
Temperature:	-20 °C...85 °C
Rel. humidity:	0...100 %
Rel. permittivity:	1...7
Conductivity:	100...800,000 pS/m
Measuring accuracy	
Temperature:	±2 K
Rel. humidity:	±3 %
Rel. permittivity:	±0.015
Conductivity (100...2,000 pS/m):	±200 pS/m
Conductivity (2,000...800,000 pS/m):	<±10 %
1DC output:	RS232/CANopen/SAE J1939
2A output:	2x 4-20 mA (assigned to one fixed measurand or sequential output of all values)

Dimensions



8.3 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	1DC2A
Connection schematic	
1	L+
2	L-
3	TxD, CAN low [OUT]
4	RxD, CAN high [IN]
5	-
6	Analog output, 4...20 mA
7	Analog output, 4...20 mA
8	Signal earth
Shield	-

8.4 Permissible Mechanical Loads

The following table lists the permissible mechanical loads for the sensors. When exceeding the vibration resistance of the level sensors, additional mechanical stabilisation is required at the bottom end of the sensor.

Load	**Size**	**Unit**
max. longitudinal vibration BCM-MS und BCM-LS Test based on DIN EN 60068-2-6	f: 5 – 9 A:+-15 f: 9 – 200 a: 10	HZ mm HZ g
max. transverse vibration BCM-MS Testing based on DIN EN 60068-2-6	f: 5 – 9 A: +- 15 f: 9 – 200 a: 10	HZ mm HZ g
max. transverse vibration BCM-LS	Not specified[1]	-

Tab. 34: Permissible Mechanical Loads

[1] If transverse stress can be assumed, the sensor must be stabilised mechanically to minimise the leverage.

8.5 Error Bits Key

Block	#	Bit	Type	Description	Recommen-ded light status
1	0	0	Alarm	Low oil level summary	RED
1	1	1	Alarm	Sensor exposed to air	RED
1	2	2	Alarm	Oil level dropping (delayed response)	RED
1	3	3	Alarm	Sensor partly exposed to air	RED
1	4	4	Alarm	Reserved	-
1	5	5	Alarm	Reserved	-
1	6	6	Alarm	Current temperature exceeds limit	RED
1	7	7	Alarm	Mean value in temperature history exceeds limit	-
1	8	8	Alarm	Oil aging*, parameters exceed set limits	RED
1	9	9	Alarm	Reserved	-
1	10	10	Alarm	Reserved	-
1	11	11	Alarm	Aged gradients	RED
1	12	12	Alarm	Oil change recommended*	RED
1	13	13	Alarm	Slow contamination with other fluid*	-
1	14	14	Alarm	Reserved	-
1	15	15	Alarm	Reserved	-
2	16	0	Info/warning	Reserved	-
2	17	1	Info/warning	Reserved	-
2	18	2	Info/warning	Reserved	-
2	19	3	Info/warning	Reserved	-
2	20	4	Info/warning	Reserved	-
2	21	5	Info/warning	Refresh oil* **	-
2	22	6	Info/warning	Change oil* **	-
2	23	7	Info/warning	Oil aging alert*, parameters reach 2/3 of set limits	YELLOW
2	24	8	Info/warning	Viscosity: Measuring range exceeded	-
2	25	9	Info/warning	Temperature: Measuring range exceeded	-
2	26	10	Info/warning	Reserved	-
2	27	11	Info/warning	Reserved	-
2	28	12	Info/warning	rel. DZ: Measuring range exceeded	-
2	29	13	Info/warning	Oil does not correspond to specified reference oil (characteristics of the oil deviate significantly from the values of the taught-in fresh oil)	-
2	30	14	Info/warning	Reserved	-
2	31	15	Info/warning	Reserved	-
3	32	0	Info/warning	Teach-in not completed, will be set after marking the current oil as fresh oil	-
3	33	1	Info/warning	Reserved	-
3	34	2	Info/warning	Reference value changed (reference values / limits were changed externally, remains active for approx. 15s)	-
3	35	3	Info/warning	Oil change completed	-
3	36	4	Info/warning	Reserved	-
3	37	5	Info/warning	Change oil soon*	YELLOW
3	38	6	Info/warning	The counter for oil aging was stopped externally and will be reset on next sensor restart or via command	-
3	39	7	Info/warning	PowerUp (sensor was restarted, remains active for approx. 15s)	-
3	40	8	Info/warning	Change oil with different type	-
3	41	9	Info/warning	Change oil with same type	-
3	42	10	Info/warning	Refresh oil with different oil	-

3	43	11	Info/warning	Refresh oil with same oil	-
3	44	12	Info/warning	Bit 44/45: Oil type detection** 44: HLP 45: HEPR 44+45: HEES/HETG	-
3	45	13	Info/warning		-
3	46	14	Info/warning	Gradient teach-in enabled	-
3	47	15	Info/warning	Event-based saving enabled	-
4	48	0	Error	Reserved	-
4	49	1	Error	Sensor defective (summary of self-diagnosis, partial sensor failure or specified measuring range greatly exceeded)	-
4	50	2	Error	Aging projection not plausible*	-
4	51	3	Error	Electronics temperature outside the permitted range	-
4	52	4	Error	Reserved	-
4	53	5	Error	Temperature: Sensor failure	-
4	54	6	Error	Reserved	-
4	55	7	Error	rel. DZ: Sensor failure	-
4	56	8	Error	Viscosity: Sensor failure	-
4	57	9	Error	Reserved	-
4	58	10	Error	Reserved	-
4	59	11	Error	Reserved	-
4	60	12	Error	Reserved	-
4	61	13	Error	Reserved	-
4	62	14	Error	Reserved	-
4	63	15	Error	Reserved	-

Tab. 35: Detectable change in condition and assigned bit code

* After an oil change, these parameters will only be available after completing the teach-in phase, depending on the system after 10 to 250 operating hours and several load conditions, as the required grants can only be detected with adequate precision after some teach-in time.

** This condition analysis is currently in the test phase.

8.6 Load Factor Of A System

Calculating a system's load factor requires a typical temperature curve or temperature histogram at the sensor's measuring point. The formula (15-1) can be used to calculate the load factor from a temperature histogram. H_n is the number of counts in the temperature class of the histogram currently being viewed, N is the total number of counts in the histogram, T_{Class} is the average temperature of the class currently being viewed and T_{Class} must be set to 95 °C.

$$ß = \sum_{n=0}^{n=N} \left[\frac{H_n}{N} \cdot 1{,}5^{\frac{T_{klasse} - T_{max}}{D}} \right] \qquad (15\text{-}1)$$

The sensor autonomously detects the load factor at the site. Alternatively, this load factor can be used as a reference if the machine can be considered a representative device with average load.

9 Attached documents

– Declarations of Conformity KX150004, KX150005
– 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 Condition Monitor / *Bühler Condition Monitor*
Typ / type: BCM-MS

Das Betriebsmittel dient zur Überwachung der relativen Feuchte, Temperatur, Permittivität und der Leitfähigkeit innerhalb von Öl.
The equipment is intended for monitoring the relative humidity, temperature, permittivity and conductivity 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 13309:2010
ISO 13766:2006

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 22.03.2021

Stefan Eschweiler
Geschäftsführer – *Managing Director*

Frank Pospiech
Geschäftsführer – *Managing Director*

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Tel. +49 (0) 21 02 / 49 89-0, Fax. +49 (0) 21 02 / 49 89-20
Internet: www.buehler-technologies.com

EU-Konformitätserklärung
EU-declaration of conformity

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

in ihrer aktuellen Fassung entsprechen.

in its actual version.

Produkt / products: Bühler Condition Monitor / *Bühler Condition Monitor*
Typ / type: BCM-LS

Das Betriebsmittel dient zur kontinuierlichen Überwachung der relativen Feuchte, Temperatur, Permittivität, Leitfähigkeit sowie den Füllstand in Ölbehältern.
The equipment is intended for continuous monitoring of the relative humidity, temperature, permittivity, conductivity and the fill level in oil tanks.

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 13309:2010
ISO 13766:2006

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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 ______

______
rechtsverbindliche Unterschrift/ Legally binding signature

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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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