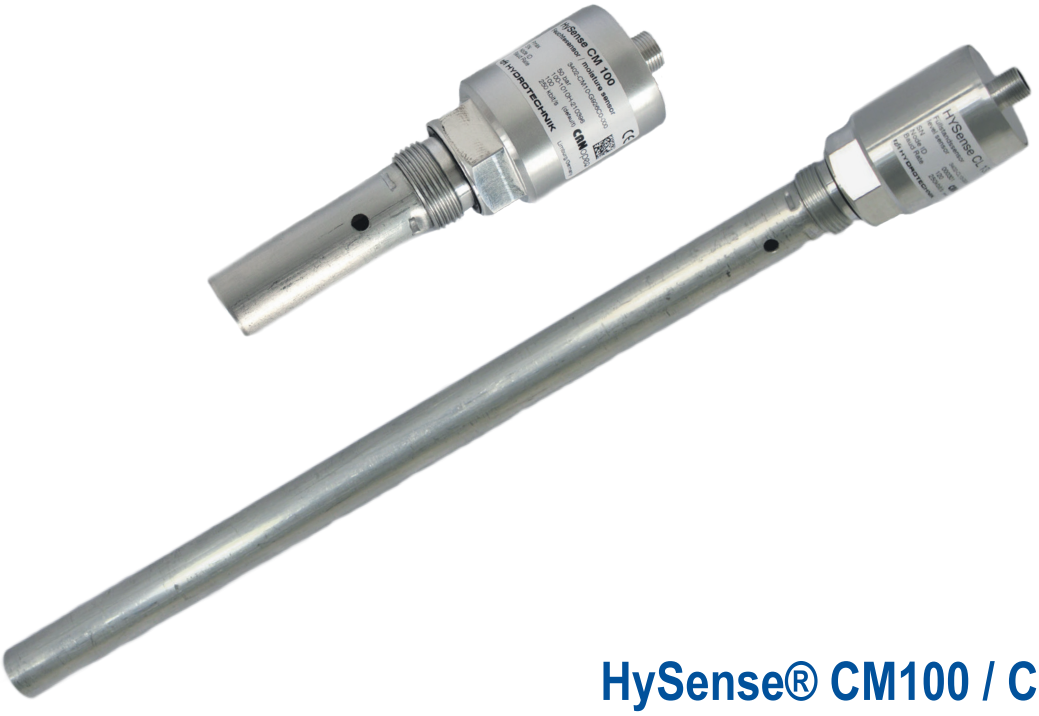
HYDROTECHNIK

EN



HySense® CM100 / CL1xx
Oil condition sensors

Manual

Version 1.0 EN

MANUAL

Read safety and operating instructions before commissioning!

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Our products are subject to a natural wear and aging process.

1. PERFORMANCE AND MEASUREMENT PRINCIPLES

1.1 General

The HySense® CM 100 / HySense® CL 120 / CL 130 / CL 160, hereinafter referred to as CM 100 / CL 120 / CL 130 / CL 160 serves to measure and document changes in the properties of the hydraulic and lubricating media and for simultaneous humidity and temperature measurement. The corresponding measured values, serving as a basis for the detection of changes in properties, as well as the temperature and humidity, are continuously recorded, saved and can be read at any time via a serial interface or CAN bus. The deviation of the measured values from a stored reference indicates changes, which should be interpreted and analyzed in detail.

From measured oil parameters, indications on status changes as e.g. oil aging, refreshment or water ingress can be derived. As a result, incipient damage can be detected at an early stage or completely avoided. This offers the possibility, to prevent serious machine faults by suitable measures as well as to prolong maintenance and oil change intervals. Information regarding a performed plant maintenance or the use of the prescribed lubricant can also be derived from the measured oil parameters and their property changes and then be documented.

Under which conditions state changes are to be detected is described in the following chapters.

The sensor detects the following physical characteristics as well as their time course:

› temperature
› relative humidity
› conductivity
› relative permittivity of the fluid
› filling level[1]

Since the conductivity and the relative permittivity show a strong temperature dependence, the sensor offers the possibility to convert these parameters to a fixed reference temperature. For this conversion, the sensor continuously measures at different temperatures, and thereby determines the temperature gradient of the parameters.

To determine the temperature gradient, a few temperature cycles are required when starting up the sensor. During operation, the temperature gradient is continuously updated even with an oil change or oil aging.

The individual measured values as well as other sensor functions are described below in more detail:

1.2 Temperature measurement

For measuring the oil temperature, a PT1000 platinum resistance sensor is used. The measuring range extends 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 a value of 3 µSm (-1).

1.3 Humidity measurement

The measurement of the relative humidity (symbol: φ) is effected by using a capacitive transducer. The capacitive humidity sensor detects the relative humidity in the measuring range between 0 % and 100 %. In case of free water or emulsions, the sensor indicates 100 %. Since the humidity sensor is located directly in the oil, the conductivity of the surrounding medium should not exceed a value of 3 µSm (-1).

1.3.1 Relative humidity

Relative humidity φ is understood to be the ratio of the actually in the oil contained (ρ_w) to the maximum possible amount of dissolved water at the saturation limit ($\rho_{w,max}$).

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

Since the saturation limit, i.e. the maximum absorbable absolute humidity $\rho_{w,max}$[1] is strongly temperature dependent, the relative humidity varies with the temperature, even when the absolute humidity remains constant. Usually, oils absorb more water with increasing temperature, before the saturation limit has been reached.

[1] Only with CL 120, CL 130 and CL 160

1.3.2 Absolute humidity

The absolute humidity is no physically measured value. It is determined by the relative humidity φ and the saturation limit $\rho_{w,max}$ according to the following formula (2).

$$\rho_W = \frac{\varphi \cdot \rho_{Wmax}}{100\%} \qquad (2)$$

The saturation limit $\rho_{w,max}$ depends on the oil type and the temperature and must be determined in the laboratory.

1.4 Conductivity measurement

Oils in the fresh state show a characteristic conductivity. Since the conductivity is oil specific in the context of manufacturing variations, it already constitutes a criterion for distinguishing oils. In order to distinguish oil based on the conductivity, the conductivity at a certain temperature or the change in the conductivity above this temperature must be significantly distinguishable.

Also an entry of foreign matter (solid / liquid) can be detected, so far as this results in a change in conductivity at certain temperature or of the conductivity above this temperature.

Oil change, oil mixtures and contaminations can thus be detected on the basis of conductivity under the given boundary conditions.

It should be considered that even batch variations and oil aging have an influence on the conductivity.

The conductivity may change due to various aging processes, so that by means of conductivity measurement also the aging course can be tracked. The measuring range of the conductivity extends from < 100 up to approx. 800,000 pS/m.

Since the conductivity is highly dependent on the temperature[1], the sensor performs an internal conversion to a reference temperature of 40 °C. An additional parameter results from this conversion: the temperature gradient of the characteristic size, which can also be used for the characterization of the oil - as described above.

1.5 Measuring the relative permittivity

The relative permittivity $\varepsilon_{Öl}$ of the fluid is an indicator for its polarity. Base oils and additive packages with different chemistry and from different manufacturers may differ in their polarity. The polarity and the course of the polarity of the fluid above the temperature are thus characteristics, which may be recognized under specific conditions, as e.g. under consideration of batch variations, oil confusions, oil mixing and refreshments.

Oils often change their polarity during the aging process. Should this lead to a significant change in the polarity, also the course of aging might be monitored. The measuring range of the relative permittivity is between 1...7.

Since the relative permittivity is dependent on the temperature, the sensor performs a conversion to a reference temperature of 40 °C. An additional parameter results from this conversion: the temperature gradient of the characteristic size, which can also be used for the characterization of the oil - as described above.

Note:
When used in highly conductive liquids, the measurement of the relative permittivity may be subject to a cross-interference, despite of the integrated compensation.

[1] Higher conductivity of the oil has a negative effect on the accuracy of the measurement.

1.6 Measurement of the filling level[1]

The sensor is provided with a capacitive filling level detection. The level is measured according to the same principle as the dielectric constant. As a reference for the measurement, the dielectric constant, detected by the sensor, is used. This method allows to detect the filling level capacitively, without having to specify the type of the fluid.

Note:
When used in highly conductive liquids, the measurement of the level may be subject to a cross-interference, despite of the integrated compensation.

1.7 Operating hours counter

The sensor has an integrated operating hours counter whose values are still present even after power failure. After interruption, the counter restarts counting at the last stored value before the interruption.

1.8 Data logger

The integrated operating hours counter, which operates as soon as the sensor has been connected to the power supply, makes it possible to assign hours of operation to the measured characteristics. The time stamp, the four measured values temperature, oil humidity, conductivity and relative permittivity and all other derived parameters are stored in the sensor ring memory (see Chapter 5.9). In total, more than 6000 data sets can be stored in the memory.

1.9 Oil condition

Oil aging is generally understood to include all changes of parameters and properties of the oil during its lifetime.
The goal is, to detect significant aging processes of the oil, based on the changes in the parameters, measured by the sensor. The automatic oil condition analysis however goes beyond this. The aim here is to detect not only the aging, but also other status changes. Possible status changes are:

› Oil aging (e.g., oxidation of the oil)
› Contamination with foreign fluids
› Water ingress (e.g.high water content or free water)
› Oil change, also changing to the wrong oil type
› Oil refreshment
› Oil mixing

The aim of an automatic evaluation is to assist the user in interpreting the characteristics and to recognize various states and status changes comparing the current measurement data and saved history data. This recognition of states and state changes on the used rule base is however only reliable if the measured data and their quality basically allow this interpretation (see Chapter 1.1).

A detailed description of all recognizable state changes and their query, storage and parameterization can be found in the appendix.

1.10 Determination of the Remaining Useful Life Time (RUL)

In addition to the classification of different states or state changes, another sensor function, the Remaining Useful Lifetime (RUL), must be estimated on the basis of the available data.

A distinction is made between two different approaches.

Figure 1 shows the exemplary course of an aging characteristic over the operating time.

After an oil change, the oil parameters do not change or do not significantly change over a long period of time. Only after the so-called incubation period (phase 1), when certain additives, the antioxidants are depleted, the accelerated aging of the oil begins, mostly running progressively (phase 2).

Phase II is characterized by an accelerated aging process and thus changing aging characteristics. Based on the signal trends of the various measured parameters, an extrapolation until a predetermined aging limit and thus the Remaining Useful Lifetime (RUL), can be calculated.

A standard parameterization of the aging limits is set at the factory. For specific information regarding the setting of aging limits, please contact the HYDROTECHNIK service team.

[1] Only CL 120, CL 130 and CL 160

Note:
The limit values should be adjusted for specific applications. The determined residual life represents a reference value, which was determined by linear extrapolation. It is important to note that aging processes can also run non-linear.

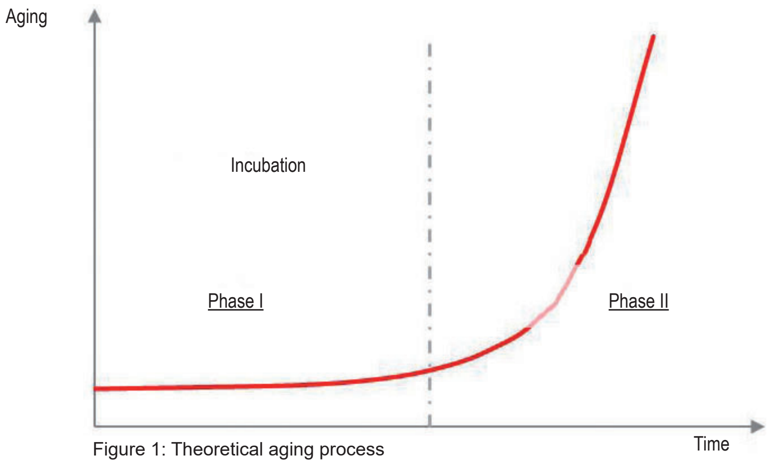


Figure 1: Theoretical aging process

Since in phase I, the measured parameters do not change, the RUL cannot be determined on the basis of the characteristics. At this stage, however, the RUL can be estimated based on the thermal stress at the measuring point. This is permissible as long as the temperature represents the relevant charge for the oil and is key for the aging rate (Arrhenius' law). For this purpose, the sensor continuously records a temperature histogram. In addition, transmission of data is only permitted for similar applications and similar oil types.

1.11 Skope and conditions of the automatic status assesment and RUL calculation

For automatic state judging some constraints must be considered:

- State changes can only be detected if the information is included in the measured parameters. For example, based on the measured parameters usually no statements about the consumption of antioxidants are possible.
- Individual critical changes in the oil can be superimposed in the extreme case, so that the resulting overall change does not reflect this state.
- For the respective states or state changes there are limits of detectability, in which the underlying signal changes or gradients of change will not be recognized.
- The automatic status assessment can be disturbed by cross-influences.
- The calculation of the RUL is only a rough estimate. In open systems with uncontrollable introduction of contaminants and in systems with widely varying operating conditions, the uncertainty of the parameter statement increases. The parameterization also has strong influence on the results.
- Through a purely mathematical estimation of the RUL from measured stress parameters, spontaneous state changes cannot be predicted.

Overall - with a sufficient amount of data and targeted parameterization - you mostly can achieve a satisfying accuracy and prediction of the aging curve.

1.12 Overview on all measured and derived parameters

For characterization of the oil level, the above-described five original characteristics are measured. These parameters and their meaning are again listed in the following table.

#	Parameter	Abbreviation	Unit	Statement
1	Operating hours	Time	h	Counts as soon as the power is turned on
2	Temperature	T	°C	Oil temperature
3	Relative permittivity (rel. DC)	P	-	Polarity of the liquid. Fresh oils differ in P and can thus be distinguished. Furthermore, P changes during the oil aging.
4	Conductivity	C	pS/m	Fresh oils differ in C and can thus be distinguished. Furthermore, C changes during the oil aging.
5	Rel. oil humidity	RH	%	Rel. humidity between 0 and 100 %
6[1]	Filling level	L	%	Filling level between 0 and 100

Table 1: Determined original characteristics

The parameters are dependent on the temperature which is compensated by the sensor. From this compensation two additional temperature gradients do arise, which are used for condition evaluation.

#	Original parameter	Derived characterstic Abbreviation	Unit	Statement
1	P	PTG	1/K	Rel. DC - temperature gradient
2	C	CTG	(pS/m)/K	Conductivity - temperature gradient
3	RH	HTG	%/K	Rel. oil humidity - temperature gradient

Table 2: Derived temperature gradients

From the original parameters P, C and RH and the determined temperature gradients PTG, CTG and HTG, the sensor calculates the temperature compensated parameters P40 and C40 and H20, H40 in the same unit as the respective original parameter.

Note:
The accuracy of detection of PTG, CTG and HTG as well as the quality of the temperature compensation are fluid-dependent.

#	Original parameter	Derived characteristic Abbreviation	Statement
1	P	P40	Rel. DC at reference temperature of 40 °C
2	C	C40	Conductivity at reference temperature of 40 °C
3	RH	RH20[2]	Rel. oil humidity compensated to 20 °C oil temperature

Table 3: Temperature compensated characteristics

[1] Only withCL120, CL130 and CL160
[2] Compensation of the relative humidity to 20 °C is strongly dependent on the fluid, temperature profile and other boundary conditions

The sensor in turn determines temporal gradients from the original parameters, the temperature gradients and the compensated characteristics. The temporal gradients, in particular, give an indication of the kind of change.

#	Original parameter	Derived characteristic Abbreviation	Unit	Statement
1	P40	LGP40	1/h	Long-term gradient of P40
2	P40	MGP40	1/h	P40 gradient over a medium term
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 a medium term
6	C40	SGC40	(pS/m)/h	Short-term gradient of C40
7	T	LGT	K/h	Long-term gradient of the oil temperature
8	T	SGT	K/h	Short-term gradient of the oil temperature
9	H20	SGH20	%/h	Short-term gradient of H_2O

Table 4: Temporal gradients

Rapid changes indicate e.g. topping up of oil, slow gradients might indicate - depending on the size - contamination with a foreign liquid or an oil aging. The sensors determine short-term gradients, where the averaging time takes a few hours and long-term gradients, where the averaging time takes a few hundred up to a few thousand hours.

An overview on all parameters used for the assessment is given in Chapter 10.

Figure 2 is a graphical overview of the interaction between the measured parameters and the algorithms in the sensor.

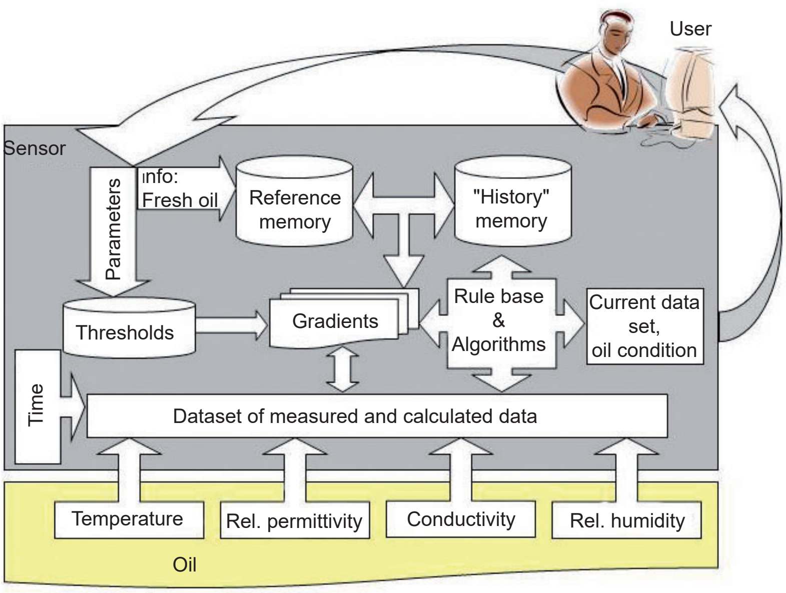


Figure 2: Data processing and interaction between the measured parameters and algo rithms in the sensor

1.13 Calibrating and checking the sensor function

The sensor is designed so that it can be exposed to the specified loads over long periods.

With fluids or applications for which there exists no experience base regarding the long-term stability of the sensor, an inspection and a calibration of the sensor should be carried out in the laboratory, at least every two years.

1.14 Overview on issued parameters for individual commands

The sensors support a series of commands to issue the measured, derived and calculated parameters of the oil. The responses to the individual commands are listed in the following tables. Depending on the version of the sensor firmware, the order or the content of the issues may differ.

#	Parameter name	Unit	Statement
1	Time	h	Operating hours counter of the sensor
2	T	°C	Temperature of the fluid
3	L	%	Height of the oil level referred to the measuring range (only with level sensors)
4	P	-	Relative permittivity of the fluid
5	P40	-	Relative permittivity of the fluid compensated to 40 °C fluid temperature
6	C	pS/m	Viscosity of the fluid
7	C40	pS/m	Viscosity of the fluid compensated to 40 °C fluid temperature
8	RH	%	Relative humidity of the fluid
9	RH20	%	Relative humidity of the fluid compensated to 20 °C (room temperature) fluid temperature (is only issued when the sensor is not configured for AH output)
10	AH	ppm	Absolute water content of the fluid (is only issued when the sensor is calibrated for this oil)
11	TMean	°C	Average temperature of the fluid since the start of the learning process or indication of an oil refilling
12	PCBT	°C	Temperature of the electronics and / or the sensor
13	RULT	h	Temperature-based Remaining Useful Lifetime (RUL) of the oil
14	RULLG	h	Long-term gradient and threshold-based RUL of the oil
15	RUL	h	Summarized 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	%	Summarized and weighted AP
19	fB	-	Temperature load factor since the start of the learning process or indication of an oil refilling
20	OAge	h	Oil age, time since the start of the learning process or indication of an oil refilling
21	ERC	-	Summary auto-recognized oil states

Table 5: Response to the command "RVal"

#	Parameter name	Unit	Statement
1	Time	h	Operating hours counter of the sensor
2	PTG	1/k	Temperature gradient of the relative permittivity
3	CTG	ln(pS/ m)/K	Temperature gradient of the natural logarithm of the conductivity
4	HTG	%/K	Temperature gradient of the 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 the oil temperature
8	MGP40	1/h	P40 gradient over a medium term
9	MGC40	(pS/m)/h	C40 gradient over a medium term
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 the oil temperature
13	SGH20	%/h	Short-term gradient of H_20

Table 6: Response to the command "RGrad"

#	Parameter name	Unit	Statement
1	AO1	-	Setting for the analog output 1
2	AO2	-	Setting for the analog output 2
3	ETrig	-	Error triggered storing in history (1 = on, 0 = off)
4	TrAu	min	Periodic transmission of the data set as it is output at the RVal command in intervals of specified minutes (Range 1..60 minutes, at setting 0, the automatic transmission is turned off)
5	ORef	-	State of the automatic learning process (0: completed, 1..30: still in progress,> 30: not yet started)
6	COEN	-	CANopen communication (0: off, 1: on)
7	MemInt	min	Time interval in which the data are stored in the history (default: 20 minutes)
8	COSpd	kBit/s	Speed of the CAN bus
9	COID	-	NodeID of the sensor
10	COHBeat	ms	CANopen Heart Beat of the sensor
11	TPDO1ID	-	TPDO 1COB-ID for CANopen
12	TPDO2ID	-	TPDO 2 COB-ID for CANopen
13	TPDO1Type	-	TPDO 1 Typ for CANopen
14	TPDO2Type	-	TPDO 2 Typ for CANopen
15	TPDO1Timer	ms	TPDO 1 Timer for CANopen
16	TPDO2Timer	ms	TPDO 2 Timer for CANopen
17	RULowr	h	Timer for overriding the RUL calculation (in case of failure of a sensor in the system, the exchange sensor can get the RUL-value of the previous sensor, from which the RUL is counted down)

Table 7: Response to the command "RCon"

#	Parameter name	Unit	Statement
1	LimP40%	5	Limit for oil aging for P40 in % of fresh oil value (standard: 5%)
2	LimC40%	%	Limit for oil aging for C40 in % of fresh oil value upwards (standard: 300 %), allowed deviation downwards is automatically calculated based on this specification
3	LimT	°C	Permissible maximum temperature for the oil (if exceeded, a corresponding Bit in ERC is set, default value: 85 °C)
4	LimTMean	°C	Permissible average maximum temperature for the oil (if exceeded, a corresponding Bit in ERC is set, default value: 65 °C)
5	RULh	h	Reference value for the oil lifetime in hours (to be defined by the machine manufacturer)
17	RULfB	-	Reference value for the temperature load of the oil (to be defined by the machine manufacturer)

Table 8: Response to the command "RLim"

#	Parameter name	Unit	Statement
1	RefStat	-	State of the automatic learning procedure (0: completed, 1..30: still in progress,> 30: not yet started)
2	RefC40	pS/m	Learned reference value of conductivity at 40 °C of the fresh oil
3	RefP40	-	Learned reference value of the relative permittivity at 40 °C of the fresh oil
4	RefCTG	(pS/m)/K	Learned reference value of the temperature gradient of the conductivity
17	RefPTG	1/K	Learned reference value of the temperature gradient of the relative permittivity

Tabelle 9: Response to the command

2 TECHNICAL SPECIFICATIONS

2.1 General data

Sensor data	Size	Unit
Max. operating pressure	50	bar
Operating conditions Temperature [1] Rel. humidity [1]	 -20...+85 0...100	 °C % r. H. (non-condensing)
Compatible liquids	mineral oils (H, HL, HLP, HLPD, HVLP) synthetic esters (HETG, HEPG, HEES, HEPR), polyalkyleneglycols (PAG) zinc and ash-free oils (ZAF) polyalphaolefins (PAO)	
Wetted Materials	aluminum, HNBR, polyurethane resin, epoxy resin, chemical nickel / gold (ENIG) soldering tin (Sn96,5Ag3Cu0,5NiGe), aluminum oxide, glass (DuPont QQ550), gold, silver-palladium	
Protection class [2]	IP67	
Power supply [3]	9...33	V
Current consumption	max. 0,2	A
Output Current output (2x) [4] Accuracy current output [5] Interfaces	 4...20 ±2 RS232/CAN	 mA % -
Connecting dimensions Threaded connection Tightening torque connection thread Electrical connection Tightening torque M12 connector	 G¾ 45±4,5 M12x1, 8-pole 0,1	 inch Nm - Nm
Measuring range Rel. dielectric number Rel. humidity Conductivity Temperature Filling level	 1...7 0...100 100...800000 -20...+85 115/288/515	 - %r.H. pS/m °C mm
Measuring resolution Rel. dielectric number Rel. humidity Conductivity Temperature Filling level	 $1*10^{-4}$ 0,1 1 0,1 0,1	 - %r.H. pS/m K %
Measuring accuracy [6] Rel. dielectric number [7] Rel. humidity (10...90 %) [8] Rel. humidity (<10 %, >90 %) [8] Conductivity (100...2000pS/m) Conductivity (2000...800000pS/m) Temperature	 ±0,015 ±3 ±5 ±200 Typ <±10 ±2	 - %r.H. %r.H. pS/m % K
Filling level	Typ <±5	%
Response time humidity measurement (0 to 100 %)	<10	min
Weight	170/210/250	g

Outside the specified measuring range, there are possibly no plausible measuring values to be expected
[2] With screwed-on connector
[3] Automatic switch off at U <8 V and U >36 V, with load-dump impulses over 50V an external protection must be provided
[4] Outputs IOut1 and IOut2 are freely configurable (see interfaces and communication commands)
[5] In relation to the analogue current signal (4 ... 20 mA)
[6] Works calibration
[7] Calibrated to n-Pentan at 25 °C
[8] Calibrated to air at room temperature

2.2 Dimensions

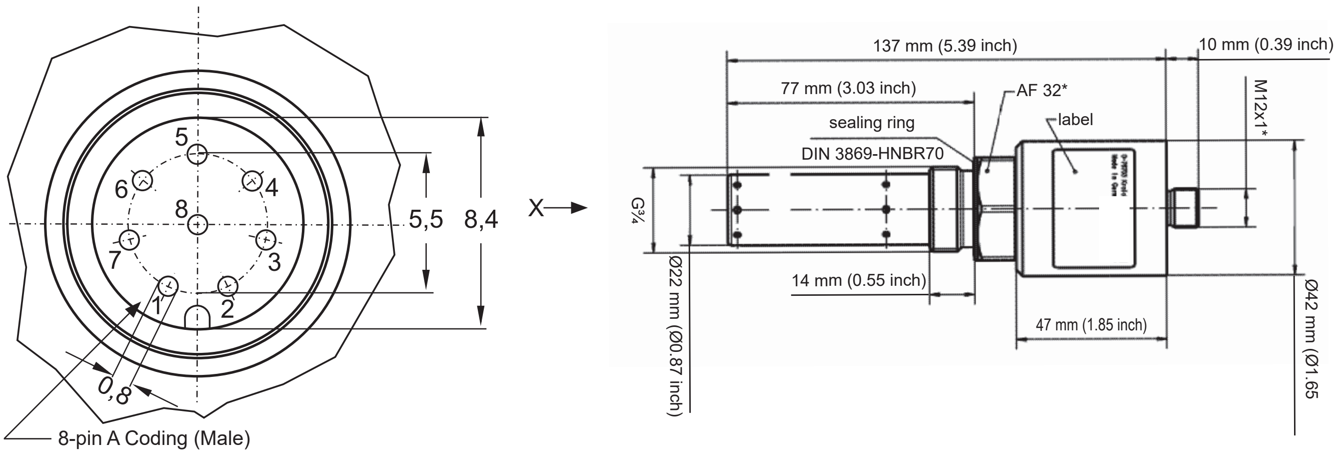


Figure 3: Connection dimensions HySense CM 100

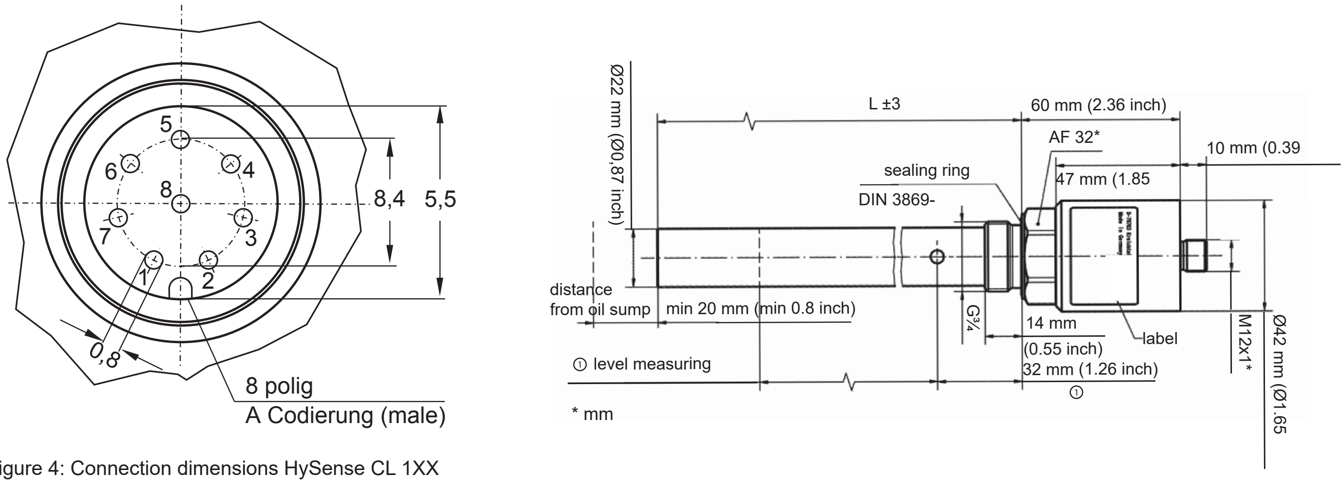


Figure 4: Connection dimensions HySense CL 1XX

CL 120: L = 200 mm, level measuring range = 115 mm

CL 130: L = 375 mm, level measuring range = 288 mm

CL 160: L = 615 mm, level measuring range = 515 mm

3 MOUNTING

The sensor is designed as a screw-in sensor with a ¾" thread. The level sensor must be screwed vertically from above into the tank of the application, the CM 100 sensor can be installed laterally in the tank or via a cable adapter in a flowed through pipe.

For condition monitoring it is necessary that the lower 5 cm of Level 200/375/615 sensor are rinsed with oil. The measuring head of the CM 100hould always be located in the oil. In general, when placing the sensor, the maximum allowable pressures and temperatures are to be considered (see Chapter 2).

Screw the sensor into a prepared position in the tank. The sealing to the oil side is provided by a profile sealing ring. In order to ensure a proper sealing, the sealing surface for inserting the sensor should be specially prepared and the maximum roughness should be R_{max} = 16. The tightening torque of the sensor is 45 Nm ± 4.5 Nm.

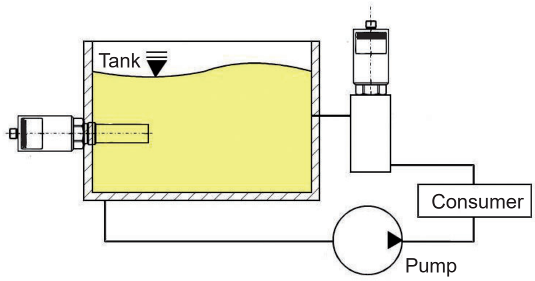


Figure 5: Installation options

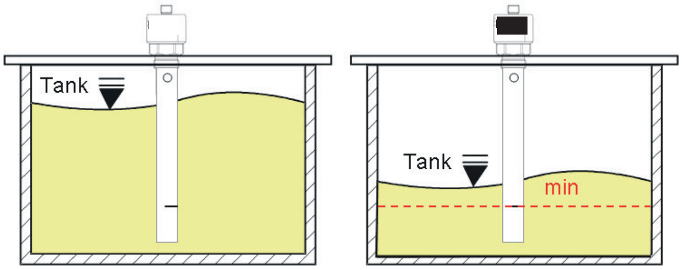
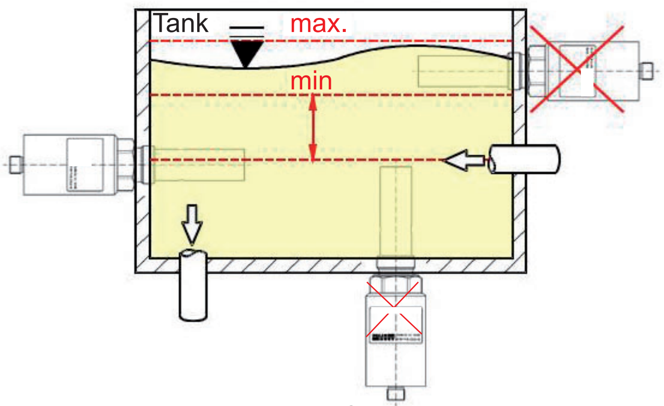


Figure 6: Installation options

To ensure proper operation, please respect the following guidelines and the mounting position and location of the sensor (see Fig. 5, Fig. 6, Fig. 7):

› To analyze a characteristic oil volume for the oil condition, the sensor should not directly be placed in the oil sump of the tank.
› Ideally, with tank mounting, the sensor should be placed in the vicinity of the return or flushing line.
› Ensure that the sensor is completely covered with oil in all operating conditions of the system. Especially note the pendulum volume of the tank and a possible inclined position. Foaming in the tank should be avoided.
› When installed in the return line or flushing line, it must be ensured that the flushing line is not running empty in any operating situation.
› To avoid thermal influences as far as possible, the sensor should not be installed in the immediate vicinity of hot parts and components (e.g. motor).
› In order to allow a calculation of the characteristic values to a reference temperature, varying oil temperatures are required. The greater the temperature changes are, the faster the temperature gradient can be determined.



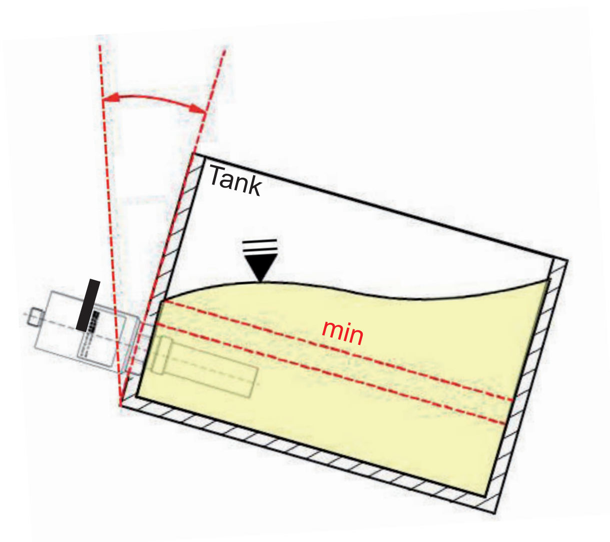


Figure 7: Installation recommendations CM 100

3.1 Allowable mechanical loads

The allowable mechanical loads for the sensors are listed in Table 10. When exceeding the vibration strength of the level sensors, an additional mechanical stabilization must be provided at the lower end of the sensor.

Load	Size	Unit
Max. vibration in longitudinal direction CM 100, CL 120, CL 130 and CL 160 Testing based on DIN EN 60068-2-6	f: 5 - 9 A:+-15 f: 9 - 200 a: 10	HZ mm HZ g
Max. vibration in transverse direction CM 100 Testing based on DIN EN 60068-2-6	f: 5 – 9 A: +- 15 f: 9 - 200 a: 10	HZ mm HZ g
Max. vibration in transverse direction CL 120, CL 130, CL 160	Not specified	-

Table 10: Allowable mechanical loads

4 ELECTRONICAL CONNECTION

4. Genreal information and safety note

The device must be installed by a qualified electrician. Follow the national and international regulations for the installation of electrical equipment.

Voltage supply according to EN 50178, SELV, PELV, VDE 0100-410 / A1.

For installation, disconnect the device from the power and connect the device as follows:

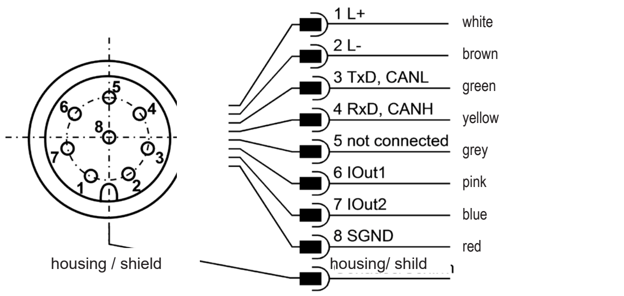


Figure 8: Pin assignment sensor plug

The permissible operating voltage is between 9V and 33V DC. The sensor cable is to be shielded.

In order to achieve the protection class IP67, only suitable plugs and cables may be used.
The tightening torque for the plug is 0.1 Nm.

4.2 Analog current outputs (4...20 mA) - measurement without load resistance

The current measurement should be carried out with a suitable ammeter according to the next figure.

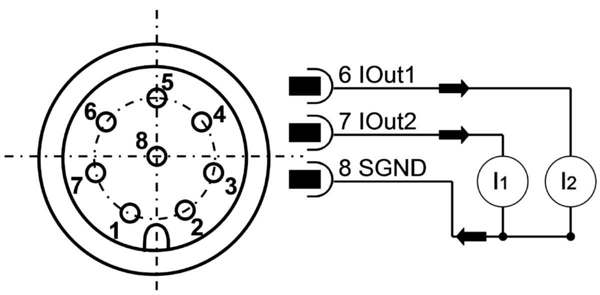


Figure 9: Measurement of the analog outputs 4..20 mA without load resistance

The assignment of the measured current value to the parameter can be found in Chapter 4.3.2.

4.3 Analog current outputs(4...20 mA) - measurement with load restistance

In order to measure the currents of the analog current outputs, a load resistance must be connected to each output as shown in Figure 10. The load resistance should be, depending on the supply voltage, between 25 Ohm and 200 Ohm. With the use of a voltmeter, the voltage at each resistor can now be measured.

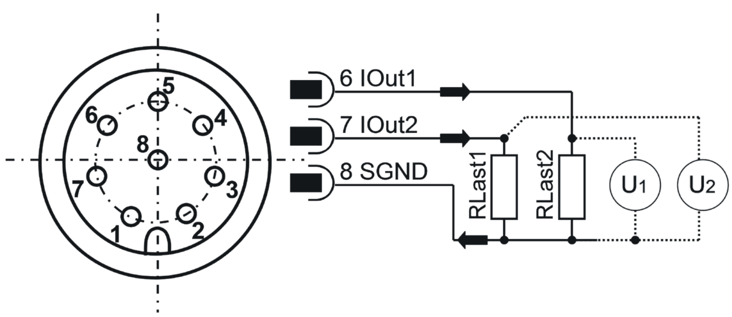


Figure 10: Connection of the load resistances for measuring the analog 4..20 mA outputs

The default configuration provides the oil temperature on channel 1 and the relative humidity on channel 2.
A change in the channel assignment is possible and is described in Chapter 5

4.3.1 Load resistance

The load resistance cannot be chosen arbitrarily. It must be adjusted according to the supply voltage of the sensor. The maximum load resistance can be calculated with the formula (3).

$$R_{max} / \Omega = U_{Versorgung} / V \cdot 25\ (\Omega / V) - 200\ \Omega \qquad 25\ \Omega \leq R_{max} \leq 200\ \Omega \qquad (3)$$

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

Table 11: Determination of the load resistance as a function of the supply voltage

4.3.2 Calibration

Output size X	Output range	Equation	Formula
T in °C	-20 °C...120 °C	$X / °C = \frac{U / V}{R / \Omega} \cdot 8750\ (°C / A) - 55°C$	(4)
RH in %	0 %...100 %	$X / \% = \frac{U / V}{R / \Omega} \cdot 6250\ (\% / A) - 25\%$	(5)
H20; H40 in %	0 %...100 %	$X / \% = \frac{U / V}{R / \Omega} \cdot 6666{,}67\ (\% / A) - 33{,}33\%$ 4mA: Learning	(6)
AH in ppm	0ppm...AHScl	$X / ppm = \frac{U / V}{R / \Omega} \cdot \frac{AHScl /}{16 \cdot 10^{-3}\ A} - \frac{AHScl /}{ppm\ \ 4}$	(7)
P; P40	1...5	$X = \frac{U / V}{R / \Omega} \cdot 266{,}67 \left(\frac{1}{A}\right) - 0{,}3333$ < 5mA: Learning or sensor partly in air	(8)
C; C40 in pS/m	100pS/m... 1000100 pS/m	$X / {}^{pS}/_{m} = \frac{U / V}{R / \Omega} \cdot 6{,}667 \cdot 10^{7} \left(\frac{pS}{A}\right) - 333233 \frac{pS}{m}$ <5mA: Learning	(9)
AP in %	0 %...100 %	$X = \frac{U / V}{R / \Omega} \cdot 6250 \left(\frac{\%}{A}\right) - 25\%$	(10)
L in %	0 %...100 %	$X = \frac{U / V}{R / \Omega} \cdot 6250 \left(\frac{\%}{A}\right) - 25\%$	(11)[1]
log(C); log(C40) in pS/m	1pS/m...1000000 pS/m	$X / {}^{pS}/_{m} = 10^{\left(\frac{U /}{R / \Omega} \cdot 375 \left(\frac{pS}{A}\right) - 1{,}5 \log \left(\frac{pS}{m}\right)\right)}$	(12)[2]

Table 12: Calculation of the output parameters of the analog current

[1] Only with level sensors

By default, the temperature is displayed at the current outputs in a range between -20 °C and 120 °C and the relative humidity between 0 and 100 %. The upper limit for the absolute humidity (ASL) is necessary for the scaling of the analog current outputs. This limit can be freely adjusted (see Table 13). The threshold value however is oil-specific and must be determined in the laboratory together with the other parameters that are necessary for the measurement of the absolute humidity. The scaling of the current output is 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	Learning mode active	1	2,867	5
C; C40 ibn pS/m	Learning mode active	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

Table 13: Scaling of the analog current outputs

5 COMMUNICATION

The communication with the sensor is carried out either via a serial RS232 interface, CANopen or two analogue 4 ... 20 mA outputs.

With operation of the sensor in the CANopen mode, it may permanently be switched to the RS232 interface in the index 0x2020, sub-index 3 (see Chapter 6.2), the change will take effect after the restart of the sensor.
With operation of the sensor in the CANopen mode, it may also temporarily be switched to the RS232 interface. For this purpose, the sensor is connected to an appropriately configured RS232 interface (see Chapter 5.2) During startup, the hash key (#) needs to be kept pressed until the sensor reports with its ID (for example, $HYDROTECHNIK;CV100;S-N;000015;0.55.15;CRC:b). In case the sensor does not respond within 10 seconds after applying the power supply, the process must be repeated.

5.1 Serial interface (RS232)

The sensor is provided with a serial interface, via which it can be read and configured. For this purpose, a PC and an appropriate terminal program or a readout software is required. Both are described in more detail in the following chapters.

First, you need to select an existing, free COM port at your computer to which you connect your sensor. An appropriate communication cable for the serial connection between sensor and computer / controller is available under order no. 8824-T7-00.00. In case the computer should not be provided with a standard COM port, it is possible to use serial interface cards or USB-to-serial converters, 8808-50-01.03 (y connector) and 8812-00-00.36 (power adapter).

If the sensor is started in CAN mode, it must be reset to the RS232 mode. After connecting the sensor to the current supply, the sensor will detect online, if it is connected to a serial interface (interface configuration see below) and if a defined character ("#") is sent, which must be present during the starting phase. If the character is not sent, the sensor will jump in the CANopen mode. If it understands the transmitted character, it will go into the communication mode via RS232. Here, by command „WCOEN0“, the RS-232 mode can be permanently activated. With restart of the sensor, it automatically will start in RS232 mode and the above process can be omitted.

5.1.1 Interface parameters

› Baud rate: 9600
› Data bits: 8
› Parity: none
› Stop bits: 1
› Flow control: none

5.2 Command list

Below, all interface commands for communication with the sensor are listed.
These can be transferred to the sensor by using a terminal program such as e.g. Microsoft Windows Hyper Terminal.

5.2.1 Read commants

#	Instruction format	Meaning	Return format
1	RVal[CR]	Reading all measurements with subsequent checksum (CRC), see Chapter 10, Chapter 1.12	$ Time:x.xxx[h];T:xx.x[°C]; ....;CRC:x[CR][LF]
2	RID[CR]	Reading the identification and subsequent checksum (CRC)	$HYDROTECHNIK;HYSENSECM100; SN:xxxxx;...;CRC:x[CR][LF]
3	RCon[CR]	Reading the configuration parameters and CAN configuration with subsequent checksum (CRC)	$AO1:x;AO2:x;…; CRC:x[CR][LF]
4	RGrad[CR]	Reading the parameter gradients with subsequent checksum (CRC), see Chapter 10, Chapter 1.12	$Time:x.xxx[h]; PTG:x.xxx[1/K]; CTG:x.xxxx[pS/m/K];…; CRC:x[CR][LF]
5	RMemO[CR]	Reading the memory organization, parameter and unit of data is output	Time [h]; T [°C]; P [-];P40 [-];PTG [1/K];C [pS/m];… [CR][LF]
6	RMemS[CR]	Reading the number of storable records	MemS: xxxx[CR][LF]
7	RMemU[CR]	Reading the number of stored records	MemU: xxxx[CR][LF]
8	RMem[CR]	Reading the entire memory, incl. organization, records are separated by [CR] [LF], interruption by pressing either of the keys	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]	Reading the last n records in the memory with subsequent checksum (CRC) per record, separation of data with semicolon, separation of records with [CR] [LF], starting with the oldest record, interruption by pressing either of the keys	$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]	Reading i records in the memory, starting with the (current record) - (n records), followed by the checksum (CRC) per record, separation of data with semicolon, separation of records with [CR] [LF], starting with the oldest record , interruption by pressing either of the keys	$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]	Reading the records of the last n hours in the memory with subsequent checksum (CRC) per record, separation of data with semicolon, separation of records with [CR] [LF], starting with the oldest record, interruption by pressing either of the keys	$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]	Reading stored reference values Ref Stn (status of the learning process: 255 not triggered, 30..1 learning process is running, 0 learning process completed), RefV40, RefP40, REFM, RefPTG	$RefStat:x[-];RefC40:x[pS/m];... ;CRC:x[CR][LF]

Table 14: Serial communication - read commands

5.3 Write commands

#	Instruction format	Meaning	Return format
1	SONew[CR]	Stores the current state as fresh oil. All parameters are deleted (gradient, reference values, learned values), oil age is set to 0 h, learning process is triggered (duration: approx. 250 hours), data remain in memory	ok[CR][LF]
2	WAH-Sclxxxx[CR]	Sets the limit of the absolute humidity. This value is critical for scaling with output via the 4..20 mA interface.	AHScl:xxxxx[CR][LF]
3	SAO1x[CR]	Assignment of the first current output with a corresponding measured value. Standard relative humidity (see Chapter 5.5)	SAO1:x[CR][LF]
4	SAO2x[CR]	Assignment of the second current output with a corresponding measured value. Standard: Temperature (see Chapter 5.6)	SAO2:x[CR][LF]
5	CTime[CR]	Deletes the operating hours counter	ok[CR][LF]
6	CMem[CR]	Deletes all data in the course of storage	ok[CR][LF]
7	WMemIntn[CR]	Sets memory interval to n minutes Range n: 1..1440 minutes	MemInt:n [min] [CR][LF]
8	SMemD[CR]	Stores the currently available data in the memory as a new record	ok[CR][LF]
9	WCOENx[CR]	Activates or deactivates the CANopen mode. x = 0: CAN deactivated, x = 1: CAN activated Implementation with next restart	COEN:x[CR][LF]
10	WCOSpdx[CR]	Sets the baud rate of the CAN interface x = Baud rate in kbit / s Supports the following baud rates (each in kbit / s): 10, 20, 50, 100, 125, 250, 500 Implementation with next restart	COSpd:x[CR][LF]
11	WCOIDx[CR]	Sets the node ID for CANopen mode. Range x: 0..127 COB-ID of the TPDO is automatically set to default values TPDO1 COB ID: 0x180 + Node-ID TPDO2 COB ID: 0x280 + Node-ID TPDO3 COB ID: 0x380 + Node-ID TPDO4 COB-ID: 0x480 + Node-ID Implementation with next restart	COID:xxx[CR][LF]
12	WCOHBeat-n[CR]	Sets Heart Beat Time for CANopen mode. Range x: 0..10000ms, resolution: 50ms When n = 0, Heart Beat is turned off Corresponds to SDO entry index: 0x1017 Implementation with next restart	COHBeat:n[ms] [CR][LF]
13	WTPDOyn[CR]	Sets 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-ID[1] cannot be changed and is always set to 0x480+ Node-ID Implementation with next restart	TPDOy:n[CR][LF]
14	WTPDOyTypes [CR]	Sets TPDOy-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 type TPDO2 Implementation with next restart	TPDOyType:n [CR][LF]

#	Instruction format	Meaning	Return format
15	WTPDOyTimern [CR]	Sets TPDOy-Timer for CANopen-mode. Range *y*: 1..2 Range *n*: 0..10000ms, resolution: 50ms When *n* = 0, heartbeat is turned off Corresponds to SDO entry index: 0x1017 TPDO3 and TPDO4[1]-Timer cannot be changed and always corresponds to TPDO2 Timer Implementation with next restart	TPDOyTimer:n[ms] [CR][LF]
16	WLimP40%n [CR]	Sets limit for allowable change P40 compared to learned reference value in % When approaching and exceeding the current P40 deviation from this value, warnings and alerts are set Range n: 1,0..100,0% Default value n: 5%	LimP40%:n[%] [CR][LF]
17	WLimC40%n [CR]	Sets limit for allowable change C40 compared to learned reference value in % When approaching and exceeding the current C40 deviation from this value, warnings and alerts are set Range n: 1,0..1000,0% Default value n: 300 %	LimC40%:n[%] [CR][LF]
18	WLimTn [CR]	Sets limit on maximum allowable temperature When exceeding the limit value, alarm is set Range n: 20,0..120,0 ° C Default value n: 80 ° C	LimT: n.n[°C][CR][LF]
19	WLimTmeann [CR]	Sets limit for allowable maximum average temperature When exceeding the limit value, alarm is set Range n: 20,0..120,0 °C Default value n: 60 °C	LimT:n.nn[°C][CR][LF]
20	SETrign [CR]	Switches off event triggered storage of measurements (n = 0) or (n = 1) Range n: 0..1 Default value n: 0	MemETrig:n[CR][LF]
21	WRULhn [CR]	Enter the reference lifetime of the current oil for temperature-based RUL calculation (see Chapter 1.10)	RULh:n[CR][LF]
22	WRULfBn [CR]	Enter the reference load factor of the current oil for temperature-based RUL calculation (see Chapter 1.10)	RULfB:n[CR][LF]
23	STrAun[CR]	Switches off automatic transmission of measured values (n = 0) or (n = 1..60), every n minutes, transfer corresponds to the response to command RVal Range n: 0..60 Default value n: 0	TrAu:n[min][CR][LF]
24	WLMaxn[1]	Sets maximum allowable level in % When exceeding this limit, an alarm is set Range n: 0 ...100 % Default value n: 90 %	LMax: n[%] [CR][LF]
25	WLMinn[1]	Sets minimum allowable level in % When falling below this limit, an alarm is set Range n: 0...100 % Default value n: 20 %	LMin:n[%] [CR][LF]

Table 15: Serial communication - write commands

Note:
[CR] = [Carriage Return (0xD)]   [LF] = [Linefeed (0xA)]

[1] only with level sensors

5.4 CRC calculation

Each character sent in the string (incl. Line Feed and Carriage Return) must be added up, based on a range of 8 bits (0→255). If the result is zero, there is no error.

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

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

Table 16: Example of a checksum calculation (CRC)

5.5 Terminal program (example: Microsoft Windows Hyper Terminal)

If the sensor is connected to a PC and is supplied with power, communication with the sensor is possible by using an arbitrary program. On the internet, various terminal programs are offered as freeware. The easiest way is to use the "Hyper Terminal" included in the Microsoft Windows scope of delivery. By default, this program can be found under Start / Programs / Accessories / Communication (not from Windows 2010 upwards). After starting the program, three windows will appear one after another in which first a name for the connection, a COM port and the correct communication parameters must be specified. The three windows are shown in Figure 11 up to Figure 13.

Figure 11:
Microsoft Windows Hyper Terminal
Giving a name to a new connection

Figure 12:
Microsoft Windows Hyper Terminal
Choice of the interface for communication

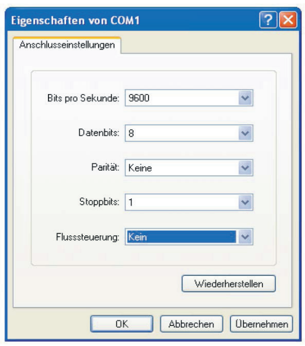


Figure 13:
Microsoft Windows Hyper Terminal
Choice of the interface parameters

In the subsequent input window, the corresponding commands for reading or configuration can be entered. The command list is shown in Chapter 5.2.

Note, that by default all characters, which are entered into the terminal program via the keyboard will not be displayed on the screen. This can be changed in the Hyper Terminal via the option "Activate Local Echo".

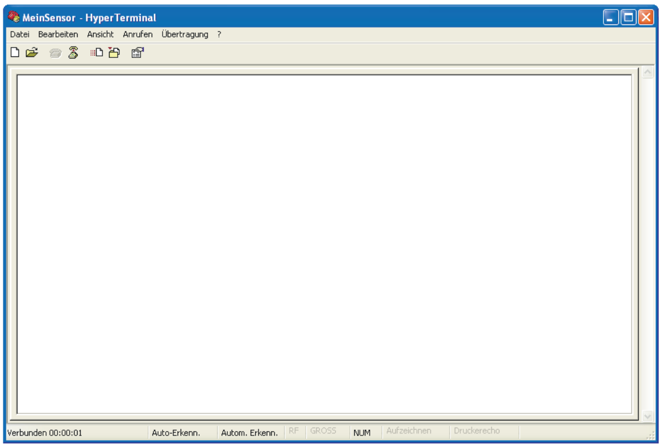


Figure 14: Windows Hyper Terminal - Input window

5.6 Setting the analog current outputs

The two analog current outputs are factory-set. On channel 1 (Pin 6, see Figure 8) the temperature and on channel 2 (Pin 7, see Figure 8) the relative humidity is issued. However, the sensor makes it possible to change the default output parameters. The command for this is: "SAO1x[CR]" and "SOA2x[CR]" with the corresponding numerical code x. Table 17 shows the possible parameters for the configuration of 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	Filling level[2]
11	log(conductivity) (log(C)) (from version 1.21.12 onwards)
12	log(conductivity at 40 °C) (log(C40)) (from version 1.21.12 onwards)
30	Alarm 4mA = no alarm 20mA = oil level too low (sensor in air) or with level sensor oil level < set minimum) or free water (>95 %) or very high water content (>75 %) or set maximum oil temperature exceeded
40	Sequential output of T, rel. H, P, C, P40, C40, AP and L[2]
100	Output fixed at 4 mA
101	Output fixed at 12 mA
102	Output fixed at 20 mA

Table 17: Numerical code for the output parameters of the analog current outputs

[1] Only available with level sensors

5.7 Sequential output of the values

A sequential output of the main parameters is possible via the analog interfaces. The sensor is configured according to the specifications in Table 17. The appropriately configured sensor displays the main parameters as shown in following Figure.

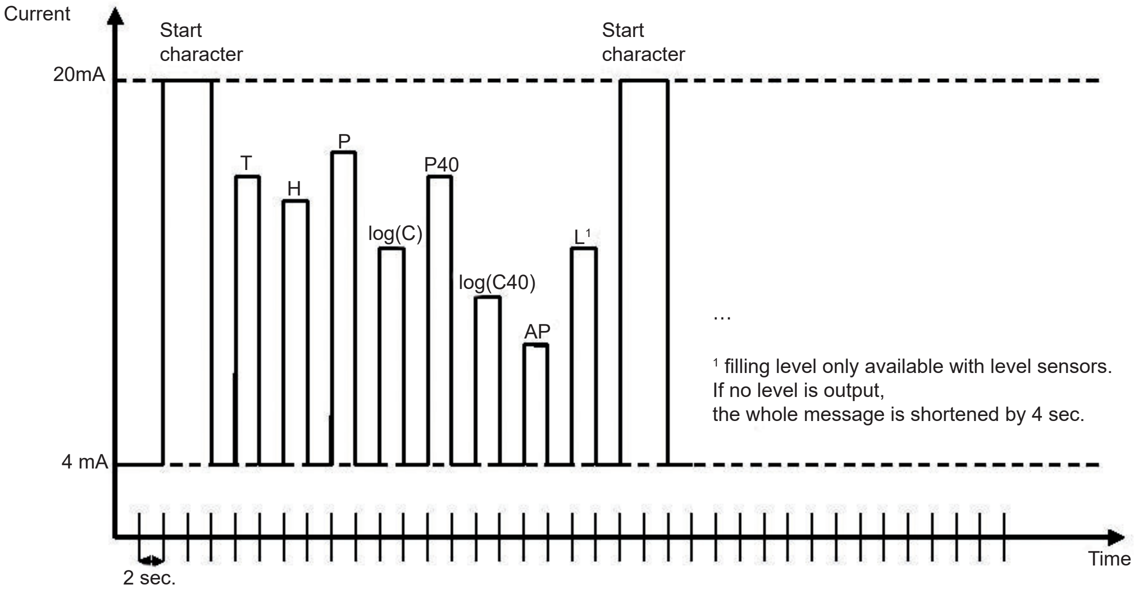


Figure 15: Sequential output of the values via analog interface

5.8 Output trigger

The measured values can in principle be output via the RS232 interface in two different ways: time-triggered or command-triggered.

The list of commands to query parameters is given in Chapter 5.2 and in the Annex. There are both commands to query the current parameters, as well as to query the characteristics from the recent past (time may vary depending on the selected setting).

5.9 Storrage trigger

In order to keep the device- and programming-related effort for the user low, the automatic evaluation of the sensor characteristics is carried out in the sensor itself. The collected data are stored event-, time- or command-triggered in the data and error memory. "Event" is understood as a change of state codes of the summarized states in Table 33. The event-dependent storage can be set using the command "SETrig" (see Chapter 5.2).

5.10 Configuration for automatic status assessment

For automatic evaluation of the condition, the sensor is pre-configured with default values. If individual configuration values are changed, a procedure is recommended as shown in Table 18 (example for standard configuration).

Step		Parameter
1	Setting of the memory interval to 20 minutes	WSaveInt20.0[ENTER]
2	Writing the aging limits	WLimP40 5.0[ENTER] WLimC40 300[ENTER]
3	Writing the temperature limits	WLimT80.0[ENTER] WLimTMean50.0[ENTER]
4	If known, setting of the reference lifetime of the oil	WRULhxxxx[ENTER]
5	If known, setting the reference load factor of the oil	WRULfBxxxx[ENTER]
6	Clear memory if required	CMem[ENTER]
7	Indicating the current oil as fresh oil	SONew[ENTER]

Table 18: Procedure for default configuration of the sensor

After an oil change, these steps have to be repeated with adapted parameters, in so far as the type of oil has changed. With the same type of oil as before the oil change, it is sufficient to perform step 7 (marking the current oil as fresh oil). The sensor resets internally learned values, gradients, oil age, etc. and initializes a new learning cycle which can take up to 250 hours. During this time, the condition evaluations, dependent on the learned values and gradients, are not detectable. Overtemperature and water ingress still are detected.

The 64bit Hex code is represented by 16 hex numbers.
The value and meaning of the individual bits is shown in Table 33.

The time-controlled output can be activated or deactivated via a command (see Section 5.2).

6 CAN

6.1 CAN communication

The CAN interface corresponds to the "CAN 2.0B Active Specification". The data packets correspond to the format shown in Figure 16. The picture is intended for illustration purposes only, the implementation corresponds to the CAN 2.0B specification.

The sensor supports a limited number of transmission speeds on the CAN bus (see Table 19).

By CiA recommended and by the sensor supported data rates			
Data rate	Supported	CiA Draft 301	Bus length (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 bkit/s	yes	yes	5000 m

Table 19: Supported bus speeds with CANopen communication and associated cable lengths

The electrical parameters of the CAN interface are listed in Table 20.

Parameter	Size	Unit
Typ. response time to SDO requests	<10	ms
Max. response time to SDO requests	150	ms
Supply voltage CAN transceiver	3,3	V
Integrated scheduling	no	-

Table 20: Electrical parameters CAN interface

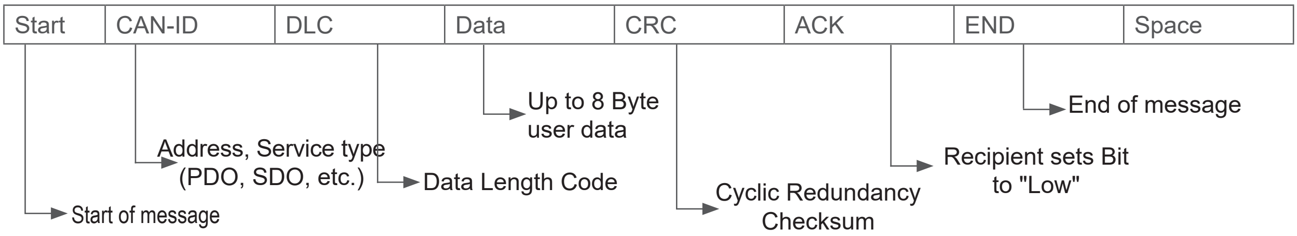


Figure 16: CAN message format

6.2 CANopen

CANopen defines "what" and not "how" something is described. With the implemented method, a spread control network is realized, which can connect very simple participants to very complex controls without causing communication problems between the participants.

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

In the following chapter, there is detailed information, first on the Object Dictionary, then on the Communication Profile Area (CPA), and then on the CANopen communication process itself.

6.2.1 „CANopen Object Dictionary“ in general

The CANopen Object Dictionary (OD) is an object dictionary in which each object can be addressed with a 16-bit index. Each object can consist of several data elements that can be addressed by an 8-bit sub-index.

The basic layout of a CANopen object directory is shown in following Table.

CANopen Object Dictionary		
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. equipment type, fault register, supported PDOs, ..)
2000	- 5FFF	Communication Profile Area (manufacturer-specific)
6000	- 9FFF	Device profile area (e.g. "DSP-401 Device Profile for I / O Modules")
A000	- FFFF	Reserved

Table 21: General CANopen Object Dictionary Structure

6.2.2 CANopen Communication Objects

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

- Network Management (NMT) provides services and for bus initialization, error handling and node controller
- Process Data Objects (PDOs) are used to transfer process data in real time
- Service Data Objects (SDOs) enable read and write access to the object directory of a node
- Special Function Object Protocol allows application-specific network synchronization, time stamp transmission and emergency messages

Below, the initialization of the network with a CANopen master and a sensor is described as an example.

After application of the current, the sensor sends a Boot Up Message within 5 seconds and once the pre-operational state has been reached. In this state the sensor only sends the heartbeat messages, if configured accordingly (Point A in Figure 17).

Subsequently, the sensor can be configured via SDOs, in most cases this is not necessary, since the once set communication parameters are automatically stored by the sensor (see Point B in Figure 17).

In order to restore the sensor in the operational state, either an appropriate message can be send to all the CANopen participants or specifically to the sensor. In operational state, the sensor sends the supported PDOs according to its configuration either at periodic intervals or triggered to Synch messages (see Point C in Figure 17).

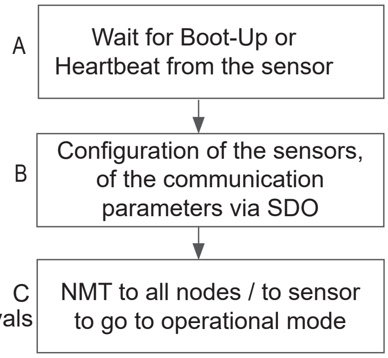


Figure 17:
CANopen Bus initialization process

Depending on the state of the sensor, different services of the CANopen protocol are available (see Table 22).

Availability of services, depending on the sensor condition				
Com. Object	Initializing	Pre-Operational	Operational	Stopped
PDO			X	
SDO		X	X	
Synch		X	X	
BootUp	X			
NMT		X	X	X

Table 22: Available CANopen services in different sensor statesn

6.2.3 Service Data Object (SDO)

Service Data Objects allow read and write access to the object directory of the sensor. The SDOs are acknowledged and the transmission always takes place only between two participants, a so-called client / server model (see Figure 18).

The sensor can only function as a server, thus only answers to SDO messages and does not send requests to other participants by itself. The SDO messages from the sensor to a client need the NodeID + 0x580 as ID. For inquiries from the client to the sensor (Server), the NodeID + 0x600 is expected as ID in the SDO message.

The standard protocol for SDO transfer requires 4 bytes to encode the transmit direction, the data type, the index and the sub-index. Thus, 4 bytes of the 8 bytes of a CAN data field remain for the data content. For objects whose data content is larger than

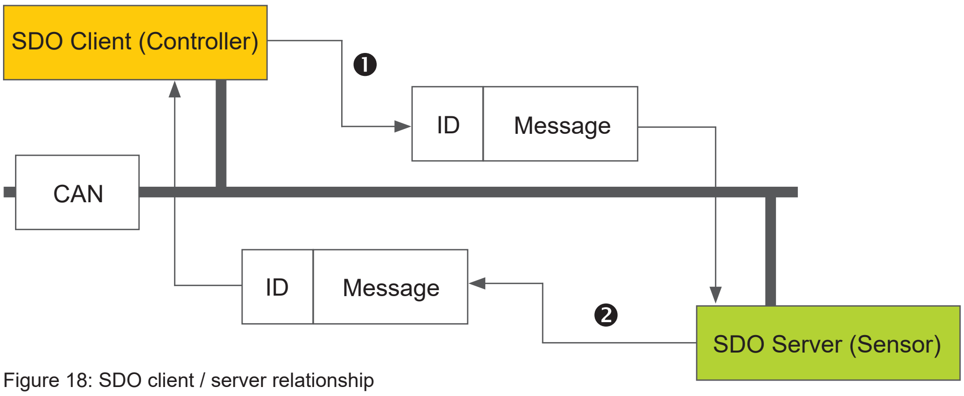


Figure 18: SDO client / server relationship

SDOs are intended to configure the sensor via access to the object directory, to request rarely used data or configuration values or to download large amounts of data. The SDO features at a glance:

- All the data in the object directory can be accessed
- Confirmed transfer
- Client / server relationship when communicating

The control and user data of a non-segmented SDO standard message spread across the CAN message as shown in Table 23. The user data of an SDO message are up to 4 bytes in size. Using the control data of an SDO message (Cmd, Index, Subin-dex), the access direction to the object directory and possibly the transmitted data type are determined. For exact specifications of the SDO protocol, the "CiA Draft Standard 301" should be consulted.

CAN	CAN-ID	DLC	User data CAN message							
			0	1	2	3	4	5	6	7
CANopen SDO	COB-ID 11 Bit	DLC	Cmd	Index		Subindex	User data CANopen SDO Message			

Table 23: Structure of an SDO message

An example of a SDO query of the serial number of the sensor from the object directory at index 0x1018, sub-index 4, with data length 32 bits is shown below. The client (controller) sends a read request to the sensor with the ID "NodeID" (see Table 24).

CAN	CAN-ID	DLC	User data CAN Message							
			0	1	2	3	4	5	6	7
CANopen	COB-ID 11 Bit	DLC	Cmd	Index		Subidx	User data SDO			
				1	0	0	3	2	1	0
Message from client to sensor	0x600 + NodeID	0x08	0x40	0x18	0x10	0x04	dont care	dont care	dont care	dont care

Table 24: SDO Download request to the server by the client

The sensor responds with the appropriate SDO message (see Table 25) in which the data type, index, sub-index and the serial number of the sensor are encoded, here as an example serial number 200123 (0x30DBB).

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

Table 25: SDO download response by the server to the client

An example for the upload of data (heartbeat time) via SDO in the object directory of the sensor at index 0x1017 with data length 16 bits is shown below. The client (controller) sends a write request to the sensor with the ID "NodeID" (see Table 26) in order to set the heartbeat time to 1000 ms (0x03E8).

CAN	CAN-ID	DLC	Nutzdaten CAN Message							
			0	1	2	3	4	5	6	7
CANopen	COB-ID 11 Bit	DLC	Cmd	Index		Subidx	Nutzdaten SDO			
				1	0	0	3	2	1	0
Nachricht vom Client an Sensor	0x600 + NodeID	0x08	0x2B	0x17	0x10	0x00	0xE8	0x03	0	0

Table 26: SDO Uploadanfrage durch den Client an den Server

The sensor responds with an appropriate SDO message (see Table 27) in which is confirmed that the access was successful and the index and sub-index are encoded, to which access had been made.

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

Table 27: SDO Upload response to the client by the server

6.2.4 Process Data Object (PDO)

PDOs are one or more records, that are reflected from the object dictionary in the up to 8 bytes of a CAN message, to transfer data quickly and with the least possible expenditure of time from a "Producer" to one or more "Consumers" (see Figure 19). Each PDO has a unique COB-ID (Communication Object Identifier), is sent by a single node, but may be received from a plurality of nodes and does not need to be acknowledged / confirmed.

PDOs are ideally suited for the transfer of sensor data to the controller or from the controller to actuators. The PDO attributes of the sensor at a glance:

- The sensor supports three TPDOs, no RPDOs (level sensors support four TPDOs)
- The mapping of the data in PDOs is fixed and cannot be changed
- COB-IDs for TPDO1 and TPDO2 are freely selectable, TPDO3 always has the COB ID 0x380+NodeID (TPDO4 with level sensors always has the COB-ID 0x480+NodeID)
- TPDO1 and TPDO2 can be event / timer-triggered or be transferred cyclically, to SYNCH-triggered and can be set individually for each of the two TPDOs, TPDO3 (and TPDO4 with level sensors) takes over the settings of the TPDO2.

The sensor supports two different PDO transmission methods.

1. In the event or timer-triggered method, the transmission is initiated by a sensor internal timer or event.
2. In the SYNC-triggered method, the transfer takes place in response to a SYNC message (CAN message by a SYNC producer without user data). The answer with PDO is carried out either with each received synch or set to all n-received SYNC messages.

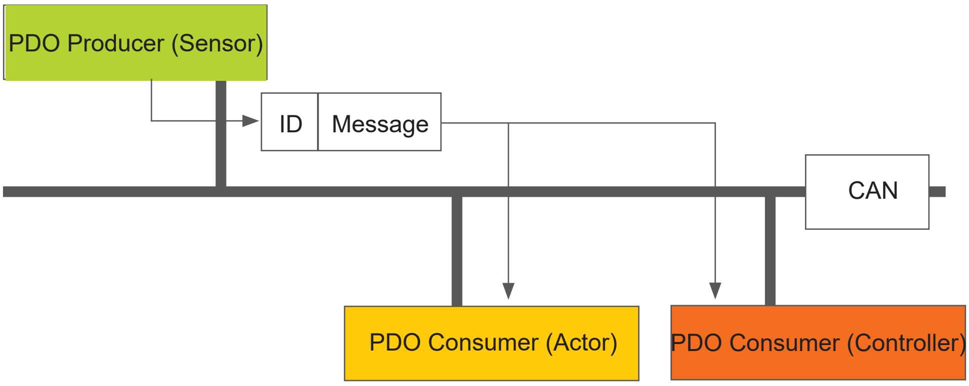


Figure 19: PDO consumer / producer relationship

6.2.5 PDO Mapping

The device supports three to four transmit PDOs (TPDO) to allow the most efficient operation of the CAN bus. The sensor does not support dynamic mapping of PDOs, the mapping parameters in the OD are therefore only readable but not writable.

Figure 21 shows the principle of the mapping of objects from the OD in a TPDO, it corresponds to the CiA DS-301. Which objects are mapped in TPDO 1 to 4, can be found in the OD at Index 0x1A00 to 0x1A03. The structure of the PDO mapping entries is shown in Figure 20. Furthermore, each TPDO has a description of the communication parameters, i.e. transmission type, COB-ID and possibly Event Timer. The communication parameters for TPDO 1 to 4 are documented in the OD at index 0x1800 to 0x1803.

Byte: MSB | LSB

Index (16 Bit)	Subindex (8 Bit)	Object length in Bit (8 Bit)

Figure 20: Basic structure of a PDO mapping entry

Complete OD, a.o. with map-enabled objects			
Index	Sub	Type	Object
...	...	...	...
2001	00	S16	Oil temperature
...	...	...	...
2007	02	U16	Compensated conduct
...	...	...	...
2006	02	U16	Compensated perm.
...	...	...	...
2008	01	U16	Rel. humidity
...	...	...	...

TPDO2 mapping parameters in OD, at index 0 x 1 A01		
Sub	Type	Value
00	U 8	04
01	U32	0x20010010
02	U32	0x20080110
03	U32	0x20060210
04	U32	0x200703210

TPDO2 communication parameters in OD, at index 0x1801		
Sub	Type	Object
00	U 8	Highest subindex
01	U 32	COB-ID
02	U 8	Transmission type
03	-	n. a.
04	-	n. a.

TPD02	Temp		Rel.Hum.		Comp. P		Comp. C	
Byte in CAN-Msg.	0	1	2	3	4	5	6	7

Figure 21: Principle of the mapping of multiple OD objects in a TPDO

The sensor supports certain types of the TPDO (see Table 28), which can be entered for the respective communication parameters of the TPDOs.

By sensor supported TPDO types					
Type	supported	cyclically	not cyclically	synchronous	asynchronous
0	yes		X	X	
1-240	yes	X		X	
241-253	no				
254	yes				X
255	yes				X

Table 28: Description of TPDO types

6.2.6 „CANopen Object Dictionary“ in detail

The complete object dictionary of the sensor is shown in Table 29 and Table 30. In Table 29, the communication-related part of the object directory is displayed. The here possible settings correspond, with a few exceptions, to the CANopen standard as described in DS 301. There are some restrictions regarding the communication due to the used hardware platform. The setting procedure for "Heartbeat Time" (Index 1017h), "TPDO1 event timer" (Index 1800h, Sub-index 5), "TPDO2 event timer" (Index 1801h, Sub-index 5), "TPDO3 event timer" (Index 1802h, Sub-index 5) are limited to 50 ms instead of the intended 1 ms. This means that these objects can be set, for example, to 0 ms, 50 ms, 250 ms, but not to 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 DS301
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	0000001C0	HYDROTECHNIK GMBH
	2	Product Code	U32	ro	Device dependant	CM100: 0x434D0064 CL120: 0x434C0078 CL130: 0x434C0082 CL160: 0x434C00A0
	3	Revision Number	U32	ro	Device dependant	CM100: 1010 CL120: 1200 CL130: 1375 CL160: 1615
	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

Idx (hex)	Sub	Name	Type	Attr.	Default	Notes
	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 %
	2	2nd app obj. to be mapped	U32	co	20060110h	Permittivity, multiplied by 1000
	3		U32	co	20070110h	Conductivity, divided by 100 in pS/m

Table 29: "Communication Profile Area", communication related object directory

All oil and sensor related objects are placed in the object directory from Index 2000h onwards and shown in Table 30. This part of the object directory is sensor specific and reflects the by the sensor measured and derived parameters for the oil. Furthermore, some configuration options are supported, for example, for setting the values for maximum temperature or to make the necessary adjustments for the calculation of RUL (see Chapter 1.10, 1.11, 7.3).

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		see chapter “1.9 oil condition”
	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 ae	U16	ro		Time since last 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, see chapter “1.10 Bestim-mung der Remaining Useful Lifetime (RUL)”
	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, see chapter “1.10 Bestimmung der Remaining Useful Lifetime (RUL)”
	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

Idx (hex)	Sub	Name	Type	Attr.	Default	Notes
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 Tempera-ture	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		Aiging Progress	U16	ro		Aging Progress in % multiplied by 10
200B		Level related Parameters	record		Only for level sensors	
	0	Number of entries	U8	ro	3h	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

Idx (hex)	Sub	Name	Type	Attr.	Default	Notes
	3	Threshold for im. oil level	U8	rw	20	Level where an alarm bit is set, range: 0..100
2020		Commandos	record			
	0	Number of entries	U8	ro	3h	largest sub index
	1	New Oil	U8	wo		new oil commandos 0x01 = new oil, same as RS232 command “SONew”
	2	Rule Base settings	U8	wo		rule base commandos 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	3h	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

Table 30: “Manufacturer-specific Profile Area“, sensor related part of the CANopen communication profile

7 COMMISSIONING

In the following, the commissioning of the sensor is described in each case with the RS232 and CAN interface.

Check, if the device is properly installed and securely electrically connected. For proper functionality of the sensor, the conditions listed in Chapter 2.1 and Chapter 3 must be observed.

7.1 Commissioning with RS232 interface

After connecting the sensor to the power supply, the sensor automatically reports via RS 232 with its sensor identification number (see Chapter 5.1).

The sensor is now ready for operation and can be read with the help of the analog outputs or the digital interface. An overview of the supported commands is given in Chapter 5.2. Please follow the instructions in Chapter 1 for quick setup.

7.2 Commissioning with CAN interface

The sensor is standardly supplied with activated RS232 and deactivated CAN interface. For permanent activation of the CAN interface, the sensor must be configured via RS232 interface.

On delivery, the CANopen interface of the sensor is configured according to Table 31.

Standard configuration CANopen interface		
Parameter	Set value	RS232 command
Node-ID	0x64 (dez: 100)	WCOID
CAN Baud rate	250 kBit/s	WCOSpd
Heart Beat - Timer	1000 ms	WHBeat
TPDO1 ID	Node ID + 0x180 = 0x1E4 (dez: 484)	WTPDO1
TPDO2 ID	Node ID + 0x280 = 0x2E4 (dez: 740)	WTPDO2
TPDO3 ID	Node ID + 0x380 = 0x3E4 (dez: 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 (only with level sensors)	= TPDO2 Timer	-
CAN activated	0	WCOEN

Table 31: CANopen standard configuration

After configuration of the CAN interface in accordance with the existing CANopen network, the CAN interface of the sensor can be activated and the sensor can be connected to the CANopen network (see Chapter 7).

7.3 Range of functions depending on the configuration

Depending on the desired functionality, the sensor can be configured with additional information, to offer the respective functions. Table 32 provides an overview on the necessary configuration of the sensor to the respective functions. An information on the configuration of the sensor is given in Chapter 5.9.

Required configurations for receipt of functions	
Features / Scenario	Necessary information on the system / configuration needs
› Basic parameters: temperature, humidity, P, C, P40, C40 › Average temperature, load factor since commissioning of the sensor › Short-term gradients › Alarms on water content, „Low oil level“	› No further information on system necessary
› Alarms for exceedance of temperature	› Limits for maximum and average temperature must be adapted to the application
› Contamination detection with other oils / fluids › Long-term gradient	› Learning process must always be initiated with fresh oil
› Aging progress of parameters (P40 and V40) › Alarms for aging progress of limits	› Learning process must always be initiated with fresh oil › Limit values for P40 and C40 must be configured (if default configuration is not enough)
› Prediction for "Remaining Useful Lifetime" of the oil	› Learning process must always be initiated with fresh oil › Limit values for P40 and C40 must be configured (more information available than specified by standard configuration) › Load factor of the system (see Chapter 10.2.) and associated service life of the oil must be known

Table 32: Range of functions depending on the configuration

8 TROUBLESHOOTING

Error: No sensor communication with Hyper Terminal	
Reason	Measure
› Cable is not properly connected	First, please check the correct electrical connection of the sensor or the data and power cable. Please be aware of the prescribed connection assignment.
› Operating voltage is outside the prescribed range	Please operate the sensor in the range between 9 V und 33 V DC.
› Interface configuration is faulty	Check and possibly correct the settings of the interface parameters (9600, 8,1, N, N). Test the communication using a terminal program, if necessary by using an interface tester.
› Wrong communication port selected	Check and correct the choice of the communication port (e.g. COM1).
› Incorrect spelling of sensor commands	Check the spelling of the sensor commands. Note in particular the capitalization and lowercase. With invalid commands, the sensor returns the entered string with a prefixed question mark.
› Cable wrong or defective	If possible, use HYDROTECHNIK data cables.
› RS232 interface is not activated	Activate the RS232-interface either temporarily or permanently.

Error: Measurement values are not plausible or vary	
Reason	Measure
› Sensor measures the air due to a heavily oscillating tank volume	Check if the sensor is correctly installed in accordance with the installation instructions.
› Sensor measures air in the oil or polar deposits in the oil sump	Check if the sensor is correctly installed in accordance with the installation instructions.
› The oil is strongly foamed	Check if the sensor is correctly installed in accordance with the installation instructions. Foaming can be expected especially in transmissions and with unfavorable installation positions.
› Measured values are out of specification	Observe the technical data and operate the sensor within the specified ranges.

Error: No analog output	
Reason	Measure
› Cable is not properly connected	First, please check the correct electrical connection of the sensor or the data and power cable. Please be aware of the prescribed connection assignment.
› Operating voltage is outside the prescribed range	Please operate the sensor in the range between 9 V und 33 V DC.
› Interface configuration is faulty	Check and possibly correct the settings for the analog outputs.
› Wrong connection of the analog outputs	Observe the indications for measuring the analog outputs.

Error: No sensor communication via CAN	
Reason	Measure
› Cable is not properly connected	First, please check the correct electrical connection of the sensor or the data and power cable. Please be aware of the prescribed connection assignment.
› Operating voltage is outside the prescribed range	Please operate the sensor in the range between 9 V und 33 V DC.
› Interface configuration is faulty	Check and possibly correct the settings of the interface parameters. The setting to be selected depends on the configuration of the sensor.
› CAN interface is not activated	Activate the CAN-interface with the help of the RS232-interface or with a terminal program, as described in Chapter 5

Error: Incorrect measurement of the absolute humidity	
Reason	Measure
› Calibration parameter is set incorrectly	The measuring range is oil-specific and must be programmed. Contact the HYDROTECHNIK service team.
› Measuring range is set incorrectly	The measuring range is oil-specific and must be programmed. Contact the HYDROTECHNIK service team.

9 APPLICATION EXAMPLE

The oil condition is a factor, formed out of many parameters. Limits for specific oil parameters are dependent on the particular application, such as the components used and the materials. The type and speed of the oil parameter change is in turn dependent on the application, the specific system load as well as on the pressure or lubricating medium used.

It is thus not possible to define universally valid limits of individual parameters. Below, however, some characteristics for status changes of pressure and lubricants are exemplarily listed. The mentioned values are to be understood as guide values. For a system-specific adaptation of the guide values, laboratory tests are needed.

State / status change	Criteria
1. Oil refreshment / oil change	A refreshment of small amounts of oil is characterized by a change in sensor characteristics within a short period of time. Depending on the temperature, fluid viscosity, flow conditions and mixing in the system, the refilling of oil can be recognized within a few hours. The same applies for an oil change. With an oil change, in so far as the sensor is operated during the oil change, - at oil drain - an interim drop in the measured values on the respective air value can be recognized. Whether an oil refreshing can be detected, largely depends on the refilled oil quantity, the difference of the oil characteristics and the resolution of the sensor. Relative permittivity (DZ): If an oil is filled up with a - compared to the currently existing medium in the system - higher or lower relative permittivity, the value rises or falls by homogeneous mixing. This state change occurs when a different type of oil is filled up or when the oil in the system already shows a change due to aging effects. If an oil with exactly the same relative permittivity as the oil in the system is filled up, this cannot be determined on the basis of this parameter. Nevertheless, the oil refreshment can be recognized by other parameters, which are described in the following.
2. Use of proper oil	The use of prescribed lubricants can be checked with the help of the conductivity and relative permittivity. For the fresh oils, the respective characteristics must be present. Then, the theoretically present and the currently measured values can be compared.
3. Oil aging	The oxidative aging of pressure and lubrication media usually results in polar aging products. Typically, there arise aldehydes and ketones and in the next sequence acid and high-molecular aging products. In analysis laboratories, the neutralization number NZ is often used as characteristic value for the determination of free acids in the oil. Since oils already have different neutralization numbers in the fresh oil condition, usually the trend history of the NZ is observed. A change in the NZ to 2 mg KOH/g is seen for example in hydraulic oils as an indicator for an oil change. Relative permittivity (DZ): The increase of polar oil components can be traced with the sensor with the help of the relative DZ. As with the observation of the NZ, the trend curve rather than the absolute parameter is crucial. Due to an oxidation, typically an increase in the relative DZ is noted. In general, the change will be slow. If there is a change in the relative permittivity exceeding 10 to 20 % compared to the fresh oil value, the oil should be examined more closely. A closer examination is also then advised if the rate of change of the signal increases significantly and a progressive signal waveform is observed. Conductivity: In the course of aging, the conductivity as well as the relative DZ are subject to changes. In many cases, the number of charge carriers in the oil and the conductivity increase. In the sensor, the fresh oil values of conductivity and relative DZ are stored. Oil aging can thus be detected by comparing fresh oil values and current characteristics. The sensor records this evaluation independently and derives the corresponding aging progress (AP) out of this.

10 ERRORBITS

Block	#	Bit	Type	Description	Recommended light status
1	0	0	Alarm	Low oil level summary	RED
1	1	1	Alarm	Sensor in air	RED
1	2	2	Alarm	Reserved	RED
1	3	3	Alarm	Sensor partially in air	RED
1	4	4	Alarm	Free water (RH > 95 %)	RED
1	5	5	Alarm	Extreme water content (RH > 75 %)	RED
1	6	6	Alarm	Current temperature exceeds limit	RED
1	7	7	Alarm	Average of temperature history exceeds limits	-
1	8	8	Alarm	Oil aging*, parameter exceed set limits	RED
1	9	9	Alarm	Reserved	-
1	10	10	Alarm	Reserved	-
1	11	11	Alarm	Reserved	-
1	12	12	Alarm	Oil change is recommended* ** (RUL<= 0h)	RED
1	13	13	Alarm	Reserved	-
1	14	14	Alarm	Forecast: free water at room temperature**	-
1	15	15	Alarm	Forecast: extreme water content at room temperature**	-
2	16	0	Info/warning	Reserved	-
2	17	1	Info/warning	Reserved	-
2	18	2	Info/warning	Reserved	-
2	19	3	Info/warning	Filling level above set limit (only with level sensors)	-
2	20	4	Info/warning	High water content (RH > 50 %)	YELLOW
2	21	5	Info/warning	Reserved	-
2	22	6	Info/warning	Reserved	-
2	23	7	Info/warning	Reserved	-
2	24	8	Info/warning	Reserved	-
2	25	9	Info/warning	Temperature: Measuring range exceeded	-
2	26	10	Info/warning	Humidity: Measuring range exceeded	-
2	27	11	Info/warning	Conductivity: Measuring range exceeded	-
2	28	12	Info/warning	rel. DC: Measuring range exceeded	-
2	29	13	Info/warning	Oil does not correspond to a pre-determined reference oil (the characteristics of the oil vary too much from the values of the learned fresh oil)	-
2	30	14	Info/warning	Other oil type detected than with previous filling / set reference oil* **	-
2	31	15	Info/warning	Reserved	-
2	32	0	Info/warning	Learning phase has not yet been completed, is set as fresh oil after designating of the current oil	-
3	33	1	Info/warning	Slow water ingress**	-
3	34	2	Info/warning	Modified reference value (reference values / limits were externally reset, remains active for about 15 seconds)	-
3	35	3	Info/warning	Reserved	-
3	36	4	Info/warning	Forecast: high relative humidity at room temperature**	-
3	37	5	Info/warning	Soon oil change advised* (RUL under 15 % of reference lifetime)	YELLOW

Block	#	Bit	Type	Description	Recommended light status
3	39	7	Info/warning	PowerUp (Sensor has been rebooted, remains active for about 15s)	-
3	40	8	Info/warning	Reserved	-
3	41	9	Info/warning	Reserved	-
3	42	10	Info/warning	Reserved	-
3	43	11	Info/warning	Reserved	-
3	44	12	Info/warning	Oil type recognition** 44: HLP 45: HEPR 44+45: HEES/HETG	-
3	45	13	Info/warning		-
3	46	14	Info/warning	Gradients not yet reliable	-
3	47	15	Info/warning	Event-depending memory deactivated	-
4	48	0	Error	Reserved	-
4	49	1	Error	Sensor defective (summary of the self-diagnosis, sensor partially failed or specified measuring range strongly exceeded)	-
4	50	2	Error	Forecast aging implausible* **	-
4	51	3	Error	Electronics temperature out of permissible range	-
4	52	4	Error	Humidity: Measured value out of permissible range	-
4	53	5	Error	Temperature: Measured value out of permissible range	-
4	54	6	Error	Conductivity: Measured value out of permissible range	-
4	55	7	Error	rel. DC: Measured value out of permissible range	-
4	56	8	Error	Reserved	-
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	-

Table 33: Detectable state changes and the associated bit encoding

* After an oil change, these parameters are only available after a completed learning phase, depending on the system after 10 to 250 operating hours and several load conditions, since the required gradients can only be determined with sufficient accuracy after some learning time.
** This state assessment is currently in the testing phase.

10.2 Load factor of a system

For the calculation of the load factor of a system, a typical temperature histogram or a temperature histogram at the measuring point of the sensor must be available. With the formula (13), the load factor can be calculated from a temperature histogram. H_n is the number of counts in the currently considered temperature class of the histogram, N is the total number of counts in the histogram, T_{class} is the average temperature of the currently considered class and T_{class} must be set to 95 °C.

$$\beta = \sum_{n=0}^{n=N} \left[\frac{H_n}{N} \cdot 1{,}5^{\frac{T_{klasse} - T_{max}}{10}} \right] \qquad (13)$$

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

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