HYDROTECHNIK

EN

HySense® CV 100
Oil condition sensor

Manual

Version 1.0 EN

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® CV 100 oil condition sensor, hereinafter referred to as CV 100 serves to measure and document changes in the properties of the hydraulic and lubricating media. The corresponding measured valuesare continuously recorded, saved and can be read at any time via a serial interface or CAN bus. Thus, the aging of the oil and other oil changes can be detected.

Furthermore, it can be checked whether the correct viscosity grade is used. As a result, incipient damage can be detected at an early stage or completely avoided. This offers the possibility, to prevent serious machine faults and consequential damages by suitable measures as well as to prolong maintenance and oil change intervals. By monitoring of the lubricant, also oil changes and oil refreshments can be detected and thus properly performed plant maintenance and the use of the prescribed lubricant quality can be documented.

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

› temperature
› viscosity
› relative permittivity of the fluids

Since the viscosity and the relative permittivity show a strong temperature dependence, the sensor offers the possibility to convert these parameters to a fixed reference temperature. For the 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

To measure the oil temperature, a PT1000 platinum resistance sensor is used.
The measuring range extends from -20 °C to +85 °C.

1.3 Viscosity measurement

Viscosity is defined as a fluid property which is based on internal friction and counteracts speed differences of adjacent fluid particles. It describes how viscous the medium is and is therefore referred to as toughness.

Viscosity is an important parameter for characterizing the lubricity of oils or of flow resistances and power losses in fluid power systems. Depending on the type of plant and its lubrication points, the viscosity should be kept in fixed boundaries, over the entire operating temperature range.

In general, the viscosity can be changed by the following events:

Thermal oxidation

Hydraulic oil is aging by oxidation, this means, the oil reacts with oxygen. This aging mechanism may subsequently cause polymerization of the oil in the form of an increase in the oil molecules. In extreme cases, even sludge and resinous coatings form at components. In this case, the aging mostly leads to an increase in viscosity compared to the fresh oil values.

Shearing

By shearing in frictional contacts, the chain length of molecules can be reduced.
In this case, the shearing mostly leads to a decrease in viscosity compared to the fresh oil values.

Mixing of oils

Different fresh oil types may on the one hand differ in their viscosity values at a specified reference temperature (40 °C) and on the other hand, the temperature viscosity profiles may differ. For example, there are so-called multi-grade oils which have an as flat as possible V-T curve.

Since the viscosity is highly dependent on the temperature, the sensor performs an internal conversion to a reference temperature of 40 °C (V40). An additional parameter results from this conversion: the dimensionless direction constant m (DIN 51563). The determination of the viscosity at a reference temperature and the direction constant m may therefore be an indication of a correct or incorrect oil or indicate oil mixtures.

A low value of the direction constant m denotes a relatively small change in the viscosity above the temperature and vice versa.

The measurement of the viscosity is done electronically with the help of an acoustic surface wave transducer and, therefore, without mechanical wear parts.

It is important to consider that the acoustic surface wave sensor supplies different results due to its measuring principle, compared to results determined by Ubbelohde viscometers.

Furthermore, it must be ensured that - for correct measurement - the sensor must be free of dirt and debris.

1.4 Measuring the relative permittivity

The relative permittivityεεÖl of the fluid is an indicator of its polarity. Base oils and additive packages with different chemistry and from different manufacturers may differ in their polarity. The polarity of the fluid thus is a feature through which oil confusion, oil mixtures and refreshments can be detected. Furthermore, oils change their polarity during the aging process. It is thus also possible to monitor the course of aging.

The measurement of the relative permittivity εÖl is based on a capacitive, oil wetted transducer.
The measuring range and resolution can be taken from the general technical specifications.

Since the relative dielectric constant is dependent on the temperature, the sensor performs a conversion to an internal reference temperature of 40 °C (P40). An additional parameter results from this conversion: the temperature gradient of the characteristic size (PTG), which can also be used for the characterization of the oil - as described above.

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

1.5 Filling level sensor

With suitable positioning of the sensor in the tank / system, a fall below a specified oil-filling level can be detected. Therefore, the sensor must be placed in the height of the filling level limit. As a measure for the shortfall of the oil level, the relative permittivity is used. Once the limit level has been undercut, the relative permittivity drops to values between 1 and 1.8 and thus differs significantly from the values measured during the wetting with oil.

1.6 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.

1.7 Data logger

The sensor has an operating hours counter, which operates as soon as the sensor has been connected to the power supply. Thus, it is possible to assign hours of operation to the measured characteristics. The time stamp, the measured values, inter alia, temperature, viscosity and relative permittivity and all other derived parameters are stored in the sensor ring memory. In total, more than 7500 data sets can be stored in the memory. The storing interval can be changed by command.

1.8 Automatische Zustandsauswertung

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
› Oil change
› Changing to the wrong oil type
› 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.
However, this recognition of states and status changes within the framework of the used rule base is only reliably possible if the measured values and their quality allow this interpretation at all (see Section 2.1).
A detailed description of all recognizable state changes and their query, storage and parameterization can be found in the appendix.

1.9 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 Lfetime (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 when certain additives, the antioxidants are depleted, the accelerated aging of the oil begins, mostly running progressively. 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.

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.

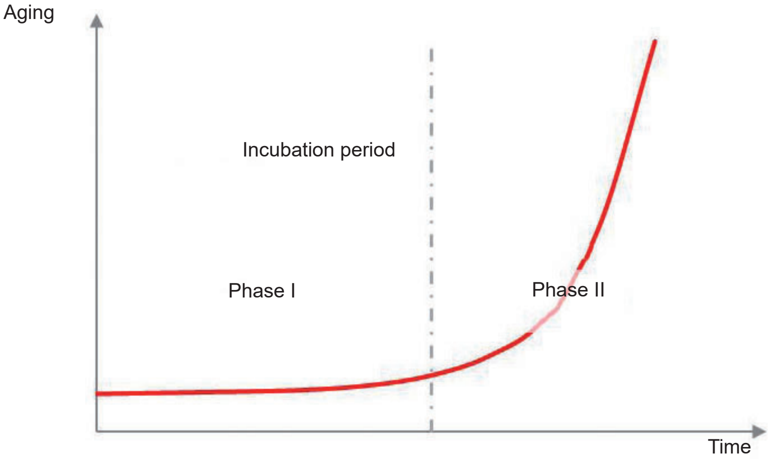


Figure 1: Theoretical aging process

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.

1.10 Scope and conditions of the automatic status assessment and RUL calculation

For automatic state judging some constraints must be considered:

1. 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.
2. Individual critical changes in the oil can be superimposed in the extreme case, so that the resulting overall change does not reflect this state.
3. 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.
4. The automatic status assessment can be disturbed by cross-influences.
5. The calculation of the URL 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.
6. Through a purely mathematical estimation of the RUL from measured stress parameters, spontaneous state changes cannot be predicted.

1.11 Overview on all measured and derived parameters

For characterization of the oil level, the above-described four 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	Rel. dielectric constant (DC)	P	-	Polarity of the liquid. Fresh oils differ in P and can thus be distinguished. Furthermore, P may change during the oil aging.
4	Viscosity	V	mm^2/s	Fresh oils differ in V and can thus be distinguished. In addition, V may change during the oil aging.

Table 1: Determined original characteristics

The parameters P and V 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 parameters	Derived characteristic	Statement
1	P	PTG	Relative DC - temperature gradient
2	V	m	Viscosity - direction constant

Table 2: Derived temperature gradients

From the original parameters P and V as well as the determined temperature PTG and m, the sensor calculates the temperature compensated parameters P40 and V40.

The accuracy of detection of PTG and m as well as the quality of the temperature compensation are fluid-dependent.

#	Original parameters	Derived characteristic	Statement
1	P	P40	Relative DC at reference temperature of 40°C
2	V	V40	Viscosity at reference temperature of 40°C

Table 3: Temperature compensated characteristics

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. 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.

#	Derived characteristic abbrev.	Original parameters	Unit	Statement
1	LGP40	P40	1/h	Long-term gradient of P 40
3	SGP40	P40	1/h	Short-term gradient of P 40
4	LGV40	V40	$(mm^2/s)/h$	Long-term gradient of V40
6	SGV40	V40	$(mm^2/s)/h$	Short-term gradient of V40
7	LGT	T	K/h	Long-term gradient of the temperature
8	SGT	T	K/h	Short-term gradient of the temperature

Table 3: Temporal gradients

An overview on all parameters used for the assessment is given in Chapter 14.

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

1.12 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.

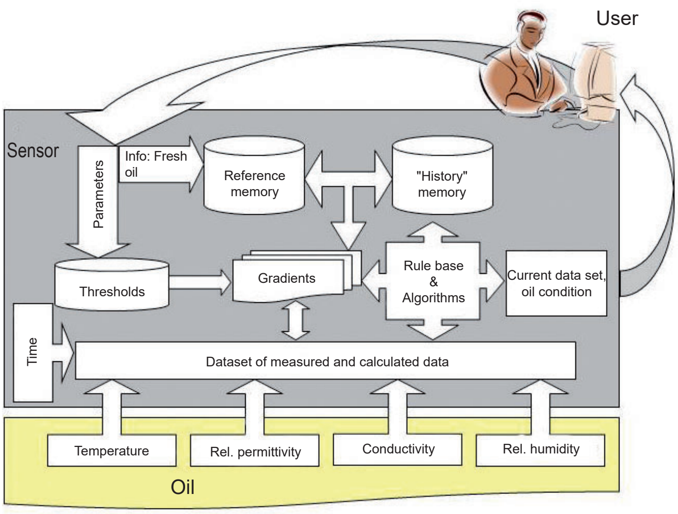


Figure 2: Data processing and interaction between the measured parameters and algorithms in the sensor

1.13 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
4	P	-	Relative permittivity (rel. dielectric constant) of the fluid
5	P40	-	Relative permittivity of the fluid compensated to 40 °C fluid temperature
6	V	mm²/s	Viscosity of the fluid
7	V40	mm²/s	Viscosity of the fluid compensated to 40 ° C fluid temperature
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 (APP) based on P40 and set limits
17	APV40	%	APP based on V40 and set limits
18	fB	-	Temperature load factor since the start of the learning process or indication of an oil refilling
19	OAge	-	Oil age, time since the start of the learning process or indication of an oil refilling
20	ERC	-	Summary auto-recognized oil states

Table 4: 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	m	-	Direction constant of the kinematic viscosity
5	LGP40	1/h	Long-term gradient of P40
6	LGV40	(mm²/s)/h	Long-term gradient of V40
7	LGT	K/h	Long-term gradient of the oil temperature
10	SGP40	1/h	Short-term gradient of P40
11	SGV40	(mm²/s)/h	Short-term gradient of V40
12	SGT	K/h	Short-term gradient of the temperature

Table 5: 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 0 setting 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	-	RPDO 1 COB ID for CANopen
12	TPDO2ID	-	RPDO 2 COB ID for CANopen
13	TPDO1Type	-	RPDO 1 Type for CANopen
14	TPDO2Type	-	RPDO 2 Type for CANopen
15	TPDO1Timer	ms	RPDO 1 Timer for CANopen
16	TPDO2Timer	ms	RPDO 1 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 6: Response to the command „RCon“

#	Parameter name	Unit	Statement
1	LimP40%	%	Limit for oil aging for P40 in % of fresh oil value (standard: 5%)
2	LimV40%	%	Limit for oil aging for V40 in % of fresh oil value (standard: 20%)
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: 60°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)

Tabelle 7: 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	RefV40	mm²/s	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	Refm	-	Learned reference value of the direction constant of the kinematic viscosity
17	RefPTG	1/K	Learned reference value of the temperature gradient of the relative permittivity

Table 8: Response to the command „RORef“

2 TECHNICAL SPECIFICATIONS

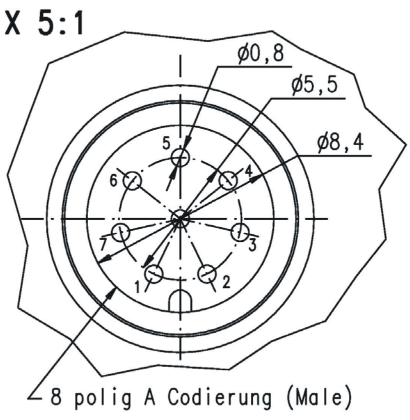
2.1 General data

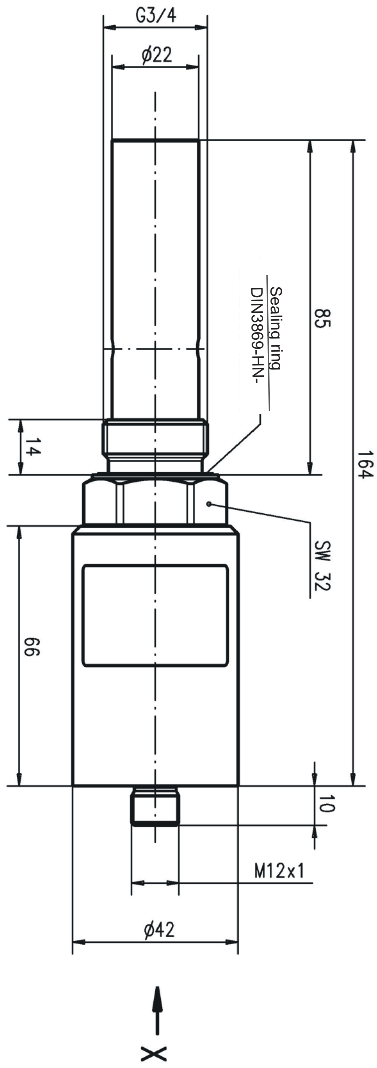
Sensor data	Size	Unit
Max. operating pressure	50	bar
Operating conditions Temperature [1] Rel. humidity [1]	 -20 ... +85 0 ...100	 °C % r.H. (not condensing)
Compatible liquids	mineral oils (H, HL, HLP, HLPD, HVLP) synthetic esters (HETG, HEPG, HEES, HEPR) polyalkyleneglycols (PAG) zinc and ash-free oils (ZAF) polyalphaolefins (PAO)	
Wetted Materials	aluminum, HNBR, polyurethane resin, epoxy resin, chemical nickel / gold (ENIG) solder (Sn96,5Ag3Cu0,5NiGe), alumina, glass (DuPont QQ550) silicon carbide, silicon oxide	
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 SAW shear viscosity Rel. dielectric number Temperature	 8…400 1…7 -20…+85	 mm^2/s - °C
Measuring resolution SAW shear viscosity Rel. dielectric number Temperature	 0,1 $1*10^{-3}$ 0,1	 mm^2/s - K
Measurement accuracy [6] SAW shear viscosity (8 ... 100mm²/s) [7] SAW shear viscosity (100 ... 400mm²/s) [7] Rel. permittivity [8] Temperature	 Typ. < ±5 Typ. < ±5 ±0,02 ±0,5	 mm^2/s % - K
Weight	155	g

Tabelle 9: Technical data

[1] 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] Depending on the oil type used
[8] Calibrated to n-Pentan at 25 °C

2.2 Dimensions





3 MOUNTING

The sensor is designed as a screw-in sensor with a ¾“ thread. Ideally, the sensor is installed in hydraulic circuits in the tank or in the return line. With gear units with forced flushing, the sensor can also be arranged in the purge line. In general, when placing the sensor, the maximum allowable pressures and temperatures are to be considered (see Chapter 3).

Screw the sensor into a prepared position in the tank or in the return line. For installation in the return line also the return line adapter can be used. 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 Rmax = 16. The tightening torque of the sensor is 45 Nm ± 4.5 Nm.

For service purposes, the sensor can also be dipped by hand into the medium to be measured, whereby the sensor surface must be completely wetted.

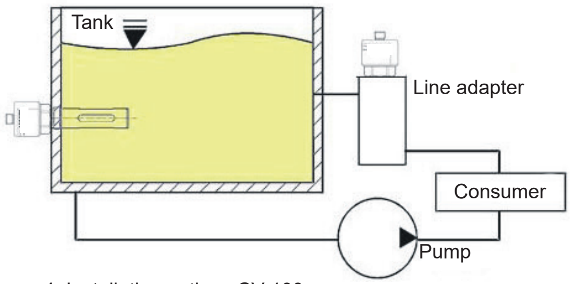


Figure 4: Installation options CV 100

To ensure proper operation, please respect the following guidelines and the mounting position and location of the sensor (see Fig. 4, Fig. 5):

› To analyze a characteristic oil level 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.

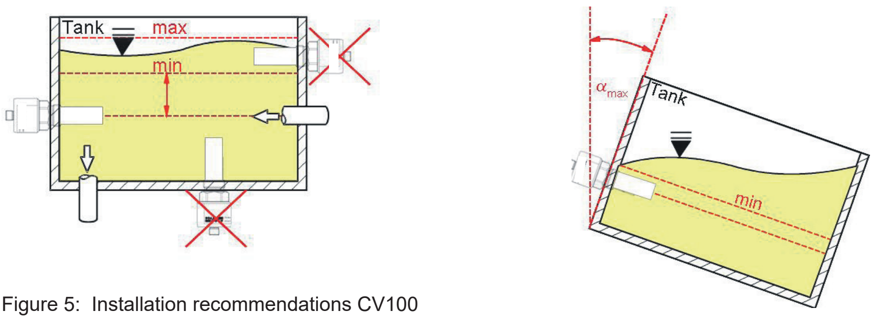


Figure 5: Installation recommendations CV100

3.1 Allowable mechanical loads

The allowable mechanical loads for the sensors are listed in Table 10.

Load	Size	Unit
Max. vibration in longitudinal direction 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 Testing based on DIN EN 60068-2-6	f: 5-9 A: +-15 f: 9-200 a: 10	Hz mm HZ g

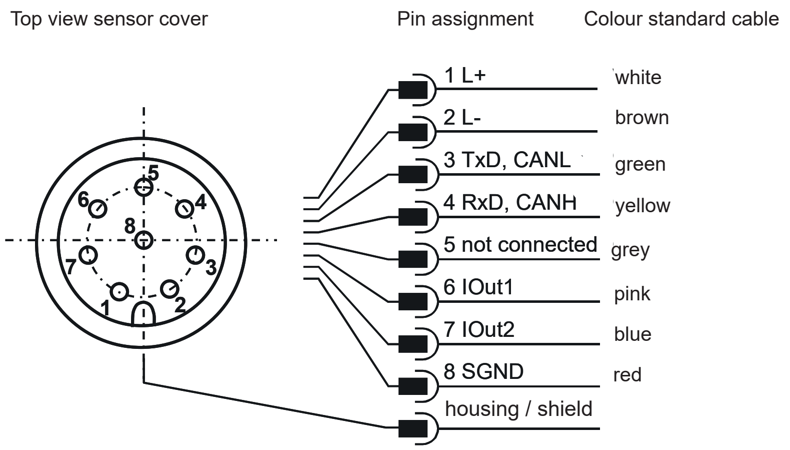
4 ELECTRICAL CONNECTION

4.1 General 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:



The permissible operating voltage is between 9V and 33V DC. The sensor cable is to be shielded.
Please make sure that no potential differences occur between the sensor housing (or installation point / machine) and the ground (negative pole) of the supply power, this can under certain circumstances lead to a defect at the sensor. To compensate possibly occurring potential differences, the negative pole of the power supply must be connected with the sensor housing or the machine by an adequately dimensioned cable (> 2.5 mm²).

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.

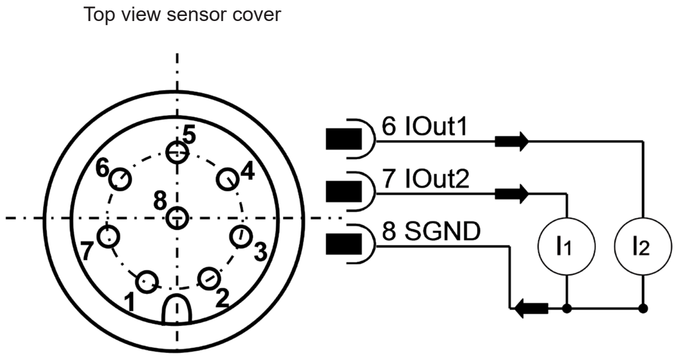


Figure 7: Measurement of the analog outputs 4...20 mA without load resistance

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 resistance

In order to measure the currents of the analog current outputs, a load resistance must be connected to each output as shown in Figure 8. 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.

Top view sensor cover

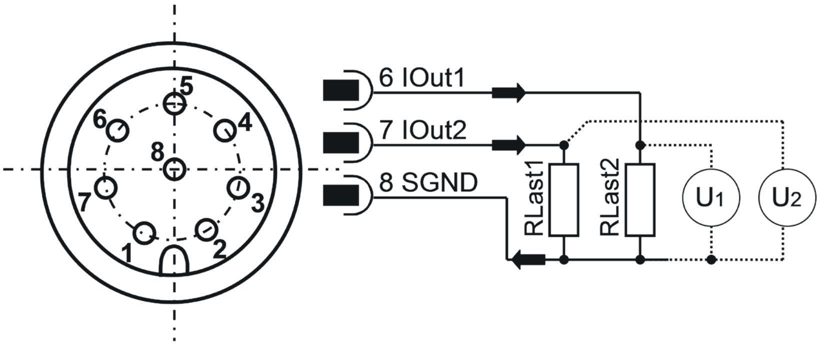


Figure 8: Connection of the load resistances for measuring the analog 4..20 mA outputs

In order to determine the corresponding parameters from the present voltages, the tensions must be converted according the formulas from Table 11.

The default configuration provides the oil temperature on channel 1 and the viscosity on channel 2. A change in the channel assignment is possible and is described in Section 5.4.

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 (6 -1). Alternatively, the Table 11 is available.

$$R_{max} / \Omega = U_{Supply} / V \cdot 25\ (\Omega / V) - 200\ \Omega \qquad 25\ \Omega \leq R_{max} \leq 200\ \Omega \qquad (1)$$

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	$X / °C = \frac{U / V}{R / \Omega} \cdot 8750\ (°C / A) - 55°C$	(6-2)
P; P40	1...5	$X = \frac{U / V}{R / \Omega} \cdot 266{,}67 \left(\frac{1}{A}\right) - 0{,}3333$ < 4mA: Learn	(6-3)
V; V40 in mm²/s	8...400 mm²/s	$X / \frac{mm^2}{s} = \frac{U / V}{R / \Omega} \cdot 26133{,}33 \left(\frac{mm^2/s}{A}\right) - 122{,}666$ <5mA: Learn	(6-4)
AP in %	0%...100%	$X = \frac{U / V}{R / \Omega} \cdot 6250 \left(\frac{\%}{A}\right) - 25\%$	(6-5)

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

By default, the temperature is displayed at the current outputs in a range between -20 °C and 120 °C and the viscosity between 8 and 400 mm2/s. These limits are fixed and cannot be changed.

Iout in mA	4	5	12	20
T in °C	-20	-11.25	50	120
P; P40	Learning mode active	1	2.867	5
V; V40 in mm²/s	Learning mode active	8	190.9	400
AP in %	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.

By default, the sensors are supplied with an activated RS232 interface. In this mode, it is very easy to carry out the configuration of the analog interface as well as the configuration of the CANopen communication parameters. If necessary, you may then switch to the CANopen interface via RS232 command (see Chapter 6.2 write commands, command WCOEN), the change will become effective after the restart of the sensor.

With operation of the sensor at a PC, the software allows convenient access to the sensor data and the configuration of the sensor without help of terminal programs.

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 7.2), 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 6.1) During startup, the hash key (#) needs to be kept pressed until the sensor reports with its ID (for example, $HYDROTECHNIK;CV100;SN;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 HyperTerminal.

5.2.1 Read commands

#	Instruction format	Meaning	Return format
1	RVal[CR]	Reading all measurements with subsequent checksum (CRC)	$ Time:x.xxx[h];T:xx.x[°C]; ....;CRC:x[CR][LF]
2	RID[CR]	Reading the identification and subsequent checksum (CRC)	$HYDROTECHNIK;CV100; 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 14, Chapter 2.12	$Time:x.xxx[h]; PTG:x. xxx[1/K]; m: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];V [mm²/s];… [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[-];Ref- V40:x[pS/m];... ;CRC:x[CR] [LF]
13	RLim[CR]	Reading set limits for alarm and calculation of the aging progress value and RUL Defaults: LimitP40%: 5.0 % LimitV40%: 20 % MaxT: 85 °C MaxTMean: 60 °C RULh: 0h (not set) RULfB: 0 (not set)	$LimitP40%:x.x[%]; LimitV40%:x[%]; MaxT:x[°C]; MaxTMean:x.x[°C];...; CRC:x[CR][LF]

Table 14: Serial communication - read commands

5.2.2 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]
3	SAO1x[CR]	Assignment of the first current output with a corresponding measured value. Standard relative humidity (see Chapter 6.6)	SAO1:x[CR][LF]
4	SAO2x[CR]	Assignment of the second current output with a corresponding measured value. Standard: Temperature (see Chapter 6.6)	SAO2:x[CR][LF]
5	CTime[CR]	Deletes the operating hours counter	ok[CR][LF]
6	CMem[CR]	Deletes all data in the history memory	ok[CR][LF]
7	WMemInt*n*[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 for 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 Implementation with next restart	COID:xxx[CR][LF]
12	WCOHBeat*n*[CR]	Sets heartbeat time for CANopen mode. Range x:0..10000ms, resolution: 50ms When n = 0, heartbeat is turned off Corresponds to SDO entry index: 0x1017 Implementation with next restart	COHBeat:n[ms] [CR][LF]
13	WTPDO*yn*[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 always set to 0x380+ Node-ID Implementation with next restart	TPDO*y*:n[CR][LF]
14	WTPDO*y*Type*n* [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]
15	WTPDOyTimer*n* [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 Timer cannot be changed and always corresponds to TPDO2 Timer Implementation with next restart	TPDOyTimer:n[ms] [CR][LF]

Table 15: Serial communication - write commands

#	Instruction format	Meaning	Return format
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	WLimV40%*n* [CR]	Sets limit for allowable change V40 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..1000.0% Default value n: 300%	LimV40%:*n*[%] [CR][LF]
18	WLimT*n* [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	WLimTmean*n* [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	SETrig*n* [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	WRULh*n* [CR]	Enter the reference lifetime of the current oil for temperature-based RUL calculation (see Chapter 2.9)	RULh:*n*[CR][LF]
22	WRULfB*n* [CR]	Enter the reference load factor of the current oil for temperature-based RUL calculation (see Chapter 2.9)	RULfB:*n*[CR][LF]
23	STrAu*n*[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]

Table 16: Serial communication - write commands

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

5.2.3 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.

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 17: Example of a checksum calculation (CRC)

5.3 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. If you have started the program, three windows 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 9 to Figure 11.

Fig. 9:
Microsoft Windows Hyper Terminal
Giving a name to a new connection.

Fig. 10:
Microsoft Windows Hyper Terminal
Choice of the interface for communication. Here COM port. 1.

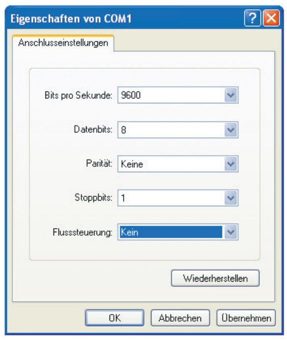


Fig. 11:
Microsoft Windows Hyper Terminal
Choice of the interface parameters.

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“.

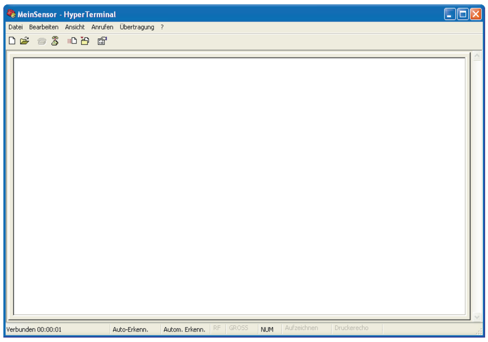


Figure 12:
Microsoft Windows Hyper Terminal
Input window

5.4 Setting the analog current outputs

The two analog current outputs are factory-set. On channel 1 (pin 6, see Fig. 6) the temperature and on channel 2 (pin 7, see Fig. 6) the viscosity 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 18 shows the possible parameters for the configuration of the analog outputs.

Numerical code x	Parameter
0	Temperature (T)
1	Aging progress (AP)
2	Relative permittivity (P)
3	Relative permittivity at 40 °C (40 P)
4	SAW shear viscosity (V)
5	SAW shear viscosity at 40 °C (V40)
30	Alarm 4mA = no alarm 20mA = oil level too low (sensor in air) or set maximum oil temperature exceeded
40	Sequential output of T, P, V, P 40, V40 and AP (see Fig. 7.5)
100	Output fixed at 4 mA
101	Output fixed at 12 mA
102	Output fixed at 20mA

Table 18: Numerical code for the output parameters of the analog current outputs

5.4.1 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 18. The appropriately configured sensor displays the main parameters as shown in Figure 13.

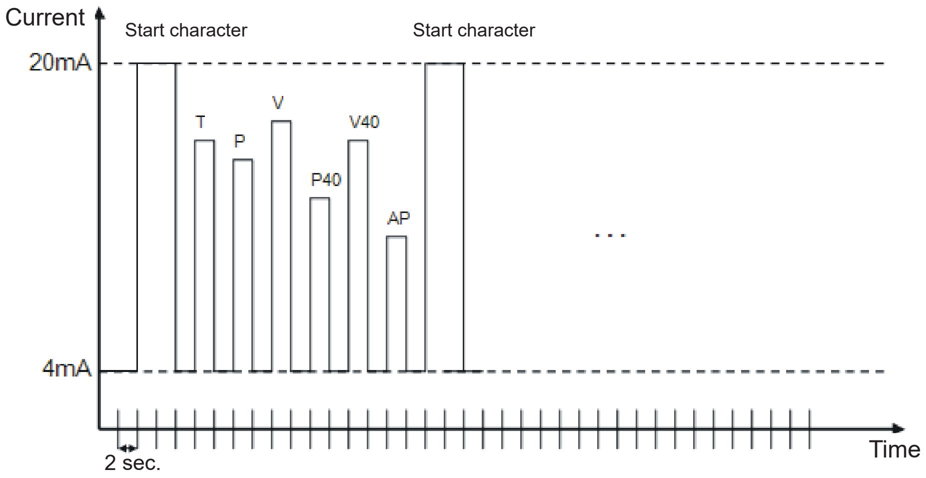


Figure 13: Sequential output of the values via analog interface

5.5 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 6.2 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).

5.6 Storage trigger

In order to keep the device- and programming-related effort for the user low, the automatic evaluation of the sensor characteristics 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 8. The event-dependent storage can be set using the command „SETrig“ (see Chapter 5.2).

5.7 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 19 (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] WLimV40%20[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 19: 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 10.

The time-controlled output can be activated or deactivated via a command (see Section 5.5).

6 CAN

6.1 CAN communication

he CAN interface corresponds to the „CAN 2.0B Active Specification“. The data packets correspond to the format shown in Figure 7.1. 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 20).

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 kbit/s	yes	yes	5000 m

Table 20: Supported bus speeds with CANopen communication and associated cable lengths

The electrical parameters of the CAN interface are listed in Table 7.2.

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 21: Electrical parameters CAN interface

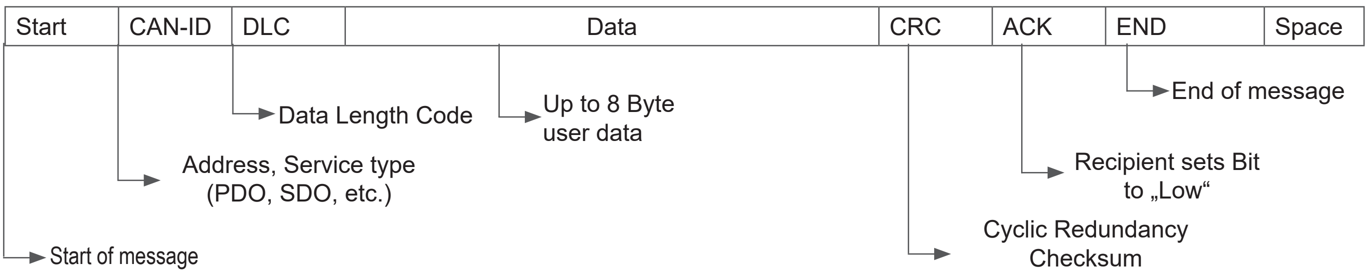


Figure 14: CAN message format

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 Table 22

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 22: 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 15).

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 15).

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 15).

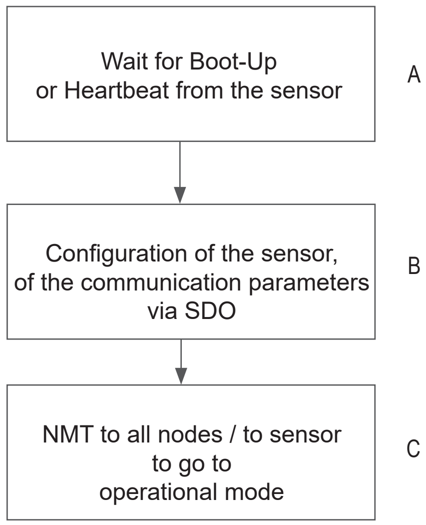


Figure 15:
CANopen Bus initialization process

Depending on the state of the sensor, different services of the CANopen protocol are available (see Table 7.4).

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 23: Available CANopen services in different sensor states

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 7.3).

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
4 bytes, there are two other protocols for the so-called fragmented or segmented SDO transfer.

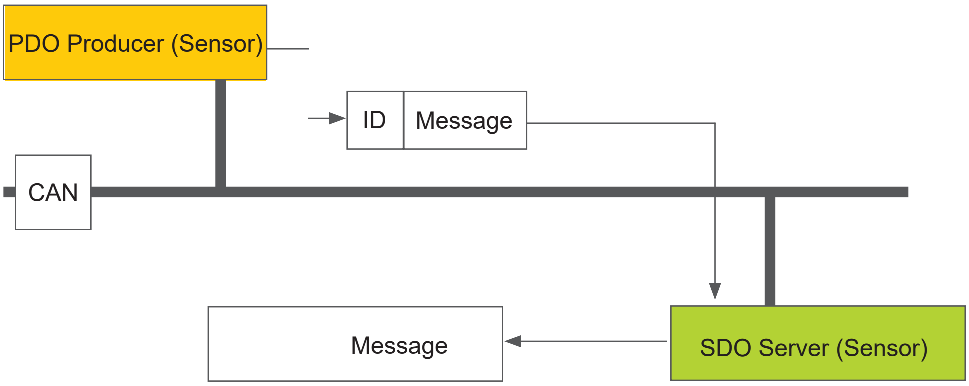


Figure 16: SDO client / server relationship

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 7.5. The user data of an SDO message are up to 4 bytes in size. Using the control data of an SDO message (Cmd, Index, Subindex), 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 24: 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 7.6).

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	02x10	0x01	dont care	dont care	dont care	dont care

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

The sensor responds with the appropriate SDO message (see Table 7.7) in which the data type, index, sub-index and the serial number of the sensor are encoded, here as an example serial number 200123 (0x30E15).

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	0x43	0x18	0x10	0x01	0x15	0x0E	0x03	0x00

Table 26: 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 7.8) in order to set the heartbeat time to 1000 ms (0x03E8).

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	0x2B	0x17	0x10	0x00	0xE8	0x03	0	0

Table 27: SDO upload request by the client to the server

The sensor responds with an appropriate SDO message (see Table 7.9) 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 28: SDO Upload response by the server to the client

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 Figure17). 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
TPDO1 and TPDO2 can be transferred event / timer-triggered or 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.

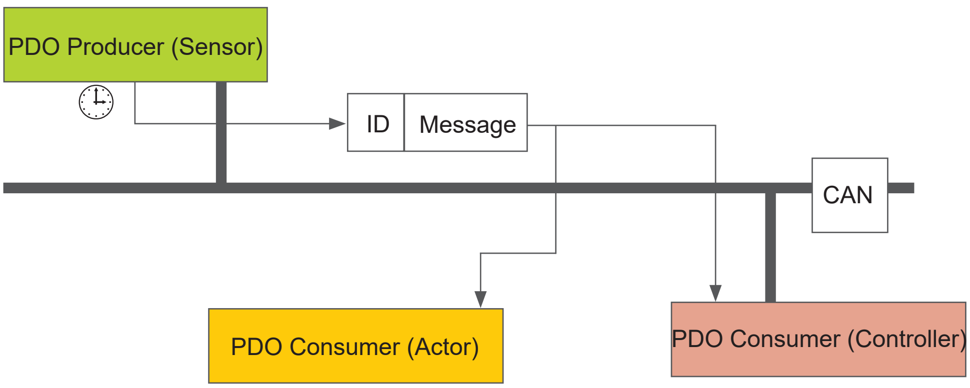


Figure 17: PDO consumer / producer relationship

6.2.5 PDO Mapping

The sensor 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 10 shows the principle of the mapping of objects from the OD in a TPDO, it corresponds to the CiA DS-301, Chapter 19. 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 7.5. 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)	Objektlänge in Bit (8 Bit)

Figure18: Basic structure of a PDO mapping entry

Complete OD, a.o. with map-enabled objects			
Index	Sub	Type	Object
...	...	...	...
2001	01	S16	Oil temperature
...	...	...	...
2007	01	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	U 32	0x20010110
02	U 32	0x20080110
03	U 32	0x20060210
04	U 32	0x20070110

TPD02 communication parameters in the OD, at index 0 x 1801		
Sub	Type	Object
00	U8	Highest sub-index
01	U32	COB-ID
02	U8	Transmission type
03	-	n.a.
04	-	n.a.
05	U16	Event timer

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

Abbildung 19: Principle of the mapping of multiple OD objects in a TPDO

The sensor supports certain types of the TPDO (see Table 29), which can be entered for the respective communication parameters of the TPDOs (see Figure 19).

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 29: Description of TPDO types

6.2.6 „CANopen Object Dictionary“ in detail

The complete object dictionary of the sensor is shown in Table 7.11 and Table 7.12. In Table 7.11, 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 DS404
1001	0	Error register	U8	ro	00h	mandatory, see DS301
100A	0	Manufacturer Software Version	string	ro	depends current firmwa-re	e.g.: “1.01”
1017	0	Producer heartbeat time	U16	rw	1388h	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	200	-
	3	Revision Number	U32	ro	1000	-
	4	Serial Number	U32	ro		Device dependant lower 3 bytes contain the serial number, the top byte is reserved for future use
1800		Transmit PDO1 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 of 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	rw	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 of 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

Communication Profile Area						
Idx (hex)	Sub	Name	Type	Attr.	Default	Notes
1A00		TPDO1 Mapping Parameter	record			
	0	Number or 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	20070110h	Viscosity
	3	3rd app obj. to be mapped	U32	co	20070210h	Viscosity @ 40°C
	4	4th app obj. to be mapped	U32	co	20060210h	Permittivity @ 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

Table 30: „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 20. 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 1.8, 1.9, 1.10, 7.3).

Manufacturer-specific Profile Area						
Idx (hex)	Sub	Name	Type	Attr.	Default	Notes
2000		Condition Monitoring Bit Field	array			
	0	Number of entries	U8	ro	04h	largest sub index
	1	Sensor status bits	U16	ro		see Chapter “2.8 Automatic condition evaluation”
	2	Oil status bits	U16	ro		
	3	Oil information bits	U16	ro		
	4	Oil alarm bits	U16	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, see chapter “2.9 Determination of the 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 “2.9 Determination of the Remaining Useful Lifetime (RUL)”

Manufacturer-specific Profile Area						
Idx (hex)	Sub	Name	Type	Attr.	Default	Notes
	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 taught 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 taught 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		Viscosity related parameters of the oil	record			
	0	Number of entries	U8	ro	06h	largest sub index
	1	Viscosity	U16	ro		Viscosity, multiplied by 10, 8…400mm²/s
	2	Viscosity, temperature compensated to 40°C	U16	ro		Viscosity @ 40°C, multiplied by 10, 8…400mm²/s
	3	Viscosity, deviation from fresh oil value in %	S16	ro		Deviation of V @ 40°C from taught value in %, multiplied by 100
	4	Threshold for Viscosity, deviati-on from fresh oil value in %	S16	rw		LimitV40%, threshold for deviation of V @ 40°C from taught value in %, multiplied by 100
	5	Aging Progress of Viscosity in %	U16	ro		V @ 40°C Aging Progress in %, multiplied by 10
	6	Viscosity, fresh oil value	U16	rw		Viscosity of the oil, compensated to 40°C, multiplied by 10, 8…400mm²/s
2008		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	60	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

Manufacturer-specific Profile Area						
Idx (hex)	Sub	Name	Type	Attr.	Default	Notes
200C		Aging Progress	U16	ro		Aging Progress in % multiplied by 10
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 com-mand “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		Node ID 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 depen-dent
	2	Used history memory (write pointer)	U16	ro		Used history memory (write pointer)
	3	Reading pointer, dataset	U16	rw		auto-incrementing 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 31: 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.

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 (command „WCOEN“, see Chapter 5.2)

Standard configuration CANopen interface		
Parameter	Set value	RS232 command
Node-ID	0x78 (dez: 120)	WCOID
CAN Baud rate	250 kBit/s	WCOSpd
Heart Beat - Timer	1000 ms	WHBeat
TPDO1 ID	Node ID + 0x180 = 0x1F8 (dez: 504)	WTPDO1
TPDO2 ID	Node ID + 0x280 = 0x2F8 (dez: 760)	WTPDO2
TPD03 ID	Node ID + 0x380 = 0x3F8 (dez: 1016)	-
TPD01 Type	255	WTPDO1 Type
TPDO2 Type	255	WTPDO2 Type
TPDO3 Type	= TPDO2 Type	-
TPDO1 Timer	5000 ms	WTPDO1Timer
TPDO2 Timer	5000 ms	WTPDO2Timer
TPDO3 Timer	= TPDO2 Timer	-
CAN activated	0 (deactivated)	WCOEN

Table 32: CANopen standard configuration

How to communicate with the sensor via RS232 interface despite of the activated CAN communication is described in Chapter 4.

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.

Required configurations for receipt of functions	
Features / Scenario	Necessary information on the system / configuration needs
› Basic parameters: temperature, viscosity, V40, P, P 40 › Average temperature, load factor since commissioning of the sensor › Short-term gradients › Alarms "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 V40 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 V40 must be configured › (more information available than specified by standard configuration) › Load factor of the system (see Chapter 14.2.) and associated service life of the oil must be known

Table 33: Range of functions depending on the configuration

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8 TROUBLESHOOTING

Error	Reason	Measure
› No sensor communication with Hyper Terminal	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, using a terminal program, as described in Chapter 6
› Measurement values are not plausible or vary	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 at analog output	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	Cable is not properly connected	▢ First, please check the correct electrical connec 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, with LubConfig or with a terminal program, as described in Chapter 6
› Incorrect measurement of the relative humidity	Calibration parameter is set incorrectly	▢ The measuring range is oil-specific and must be programmed.
	Measuring range is set incorrectly	▢ The measuring range is oil-specific and must be programmed.

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 systemspecific 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, depends largely 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 can not 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.

10 APPENDIX
10.1 Coding of error bits

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	Oil level falling (reacts with delay)	RED
1	3	3	Alarm	Sensor partially in 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	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	Aged gradients	RED
1	12	12	Alarm	Oil change is recommended*	RED
1	13	13	Alarm	Slow contamination with other liquid*	-
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	Oil refreshment* **	-
2	22	6	Info/warning	Oil change* **	-
2	23	7	Info/warning	Oil aging warning*, Parameter 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 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	Reserved	-
2	31	15	Info/warning	Reserved	-
3	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	Reserved	-
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	Oil change performed*	-
3	36	4	Info/warning	Reserved	-
3	37	5	Info/warning	Soon oil change advised*	YELLOW
3	38	6	Info/warning	The counter for oil aging was stopped externally, will be deleted again at next sensor reboot or by command	-

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	Oil change to another oil	-
3	41	9	Info/warning	Oil change to another oil	-
3	42	10	Info/warning	Oil refreshment to another oil	-
3	43	11	Info/warning	Oil refreshment to another oil	-
3	44	12	Info/warning	Bit 44/45: Oil type recognition** 44: HLP 45: HEPR 44+45: HEES/HETG	-
3	45	13	Info/warning		-
3	46	14	Info/warning	Gradient learning progress active	-
3	47	15	Info/warning	Event-dependent memory is activated	-
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 range	-
4	52	4	Error	Reserved	-
4	53	5	Error	Temperature: Sensor defective	-
4	54	6	Error	Reserved	-
4	55	7	Error	rel. DZ: Sensor defective	-
4	56	8	Error	Viscosity: Sensor defective	-
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 36: 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 (15-1), the load factor can be calculated from a temperature histogram. Hn 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 Tclass must be set to 95 °C.

$$\beta = \sum_{n=0}^{n=N} \left[\frac{H_n}{N} \cdot 1{,}5^{\frac{T_{klasse} - T_{\max}}{10}} \right] \qquad (6)$$

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.

11 ACCESSORIES

11.1 Viscosity sensor

Part	Order number	Comment
CV 100	3402-CV10-G926C0-000	

11.2 Accessories and spare parts

Order number	Description	Comment
8812-00-00.36	Power supply M12x1; 8 pol Socket, with Countries plug adapter	power supply
8824-T1-02.50	Measuring cable M12x1; 8 pin Socket / open end	CAN connection cable
8824-T6-02.50	Measuring cable M12x1; 8 pol Plug / 8 pol. Socket	CAN connection cable MS 4010/ MS 5060+
8808-50-01.03	Y-distribution M12 8-pol Socket, plug, Socket	Required to use power supply and CAN / RS232 at the same time
8824-T7-01.00	Interface cable M12 Plug, 8 pol. on D-SUB socket, 9 pol	Required to use serial interface with power supply
8824-T2-02.50	CAN connection cable M12x1; 8 pol Socket	Commitment with Y-distribution 8808-50-01.03

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L3402-CV10-G926C0-00EN