ICMS

Inline Condition Monitoring Sensor for physical fluid properties

ICMS3-0MI

Features

- Multi-parameter monitoring:
  - Viscosity
  - Mass Density
  - Temperature
- High sensitivity and low drift
- Excellent long–term stability
- Compact and robust design
- Easy to install
- Modbus RTU interface
- Dual programmable 4 - 20mA outputs
- High pressure option available

Applications

- Oil condition monitoring
- Fuel quality control
- Analysis of process media
- Monitoring of mixing processes

Description

The ICMS is a compact sensor for monitoring the mechanical fluid properties viscosity and mass density based on a low frequency resonant sensor element.

The outstanding performance of the ICMS is achieved by combining a patented resonator evaluation technology with a robust and reliable quartz crystal tuning fork resonator. The sensor offers a high sensitivity and long-term stability and thus is particularly suitable for oil condition monitoring in predictive maintenance programs.
Due to the high measurement rate excellent data quality can be obtained even in unsteady environmental conditions (pressure, temperature, flow).
The ICMS offers digital and configurable analog interfaces for easy and cost–effective integration into existing environments.

1 General Specifications

Description		min	typ	max	Unit
Mechanical					
Size (drawings see sec. 10.)			⬡30 x 90		mm
Mass			150		g
Mounting			G3/8"		
Torque		31		39	Nm
Operating Conditions					
Tolerated Particle Size				250	µm
Oil Pressure				50	bar
Operating Temperature[1]	T_{op}	-40		100	°C
Fluid Temperature[2]	T_{fluid}	-40		125	°C
Flow Velocity				20	m/s
Supply					
Voltage		9	24	32	V
Power Consumption					
Analog Outputs unconnected			0.5	1	W
Analog Output Driver[3]	$(V_{\text{supply}} - V_{\text{out}}) \times I_{\text{out}}$			1.3	W
Interfaces					
Connector	EN 61076-2-101		M12-8 A–coding		
Analog Outputs	2 x 4-20 mA				
Digital	Modbus RTU				
Conformity					
CE	EN 61000-6-1/2/3/4				
Ingress Protection (M12 mated, 24h)	DIN EN 60529		IP67		
Compliant Fluids					
Mineral and Synthetic Oils					
further approvals on request					

[1] Permissible temperature range of the sensor electronics (housing surface).

[2] Permissible temperature range of the liquid. Be aware that the liquid temperature influences the housing temperature and thus the operating temperature of the electronics.

[3] Temperature derating see Fig 4.

2 Measurement Specifications

Unless otherwise noted specifications valid at an ambient temperature of 24°C in reference liquid: Hydraulic oil HLP 32 at 40°C, laminar flow regime.

Description		min	typ	max	Unit
Measurement Range[i]					
Resonator Frequency			23		kHz
Viscosity (kinematic)	ν	1		650[ii]	cSt (=mm^2/s)
Viscosity (dynamic)	$\eta = \nu \cdot \rho$				mPas
Density	ρ	0.5		1.5	g/cm^3
Temperature		-40		125	°C
Data Rate			1		1/s
Analog Output 4-20mA					
Accuracy				±1	% FS
Supply Headroom	$V_{supply} - V_{out}$	5			V
Trueness (according to ISO 5725-1) [1, 2, 3]					
Viscosity	$\nu = 1$ to 300 cSt		±1	±2	% ± 0.1 cSt
	$\nu = 300$ to 650 cSt			±5	%
Density	$\nu = 1$ to 300 cSt		±0.2	±1	%
	$\nu = 300$ to 650 cSt			±2	%
Temperature			±0.1	±1	°C
Repeatability (relative standard deviation) [4]					
Viscosity [5]	$\nu = 50$ cSt		0.3		%
Density [5]	$\nu = 50$ cSt		0.05		%
Temperature			0.02		°C

Notes:

i: For applications beyond specified limits please contact MicroResonant.

ii: For firmware versions prior to 2024-06-28 this value is 400 cSt. The default range setting for the analog output is kept at 400 cSt for compatibility reasons (see Section 8).

[1] Maximum permissible deviation between the measured values and reference measurements according to ASTM D7042 in a hydraulic oil HLP 32.

[2] In fluids with pronounced non–Newtonian behavior additional deviations have to be expected.

[3] Custom calibration on request.

[4] Standard deviation for 100 consecutive measurements under constant conditions, data filter disabled.

[5] See Fig. 1, 2, and 3, for information on the influence of individual parameters.

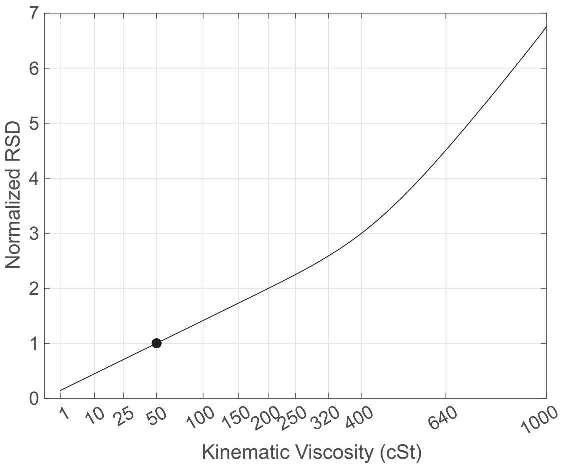


Figure 1: Normalized relative standard deviation (RSD) of viscosity as a function of viscosity. The marker refers to the values in table above.

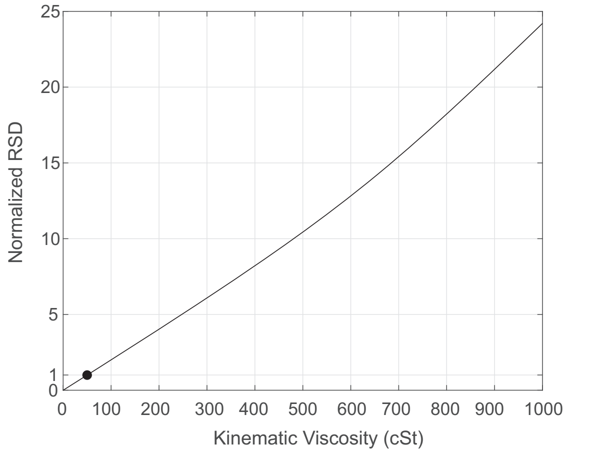


Figure 2: Normalized relative standard deviation (RSD) of density as a function of viscosity. The marker refers to the values in table above.

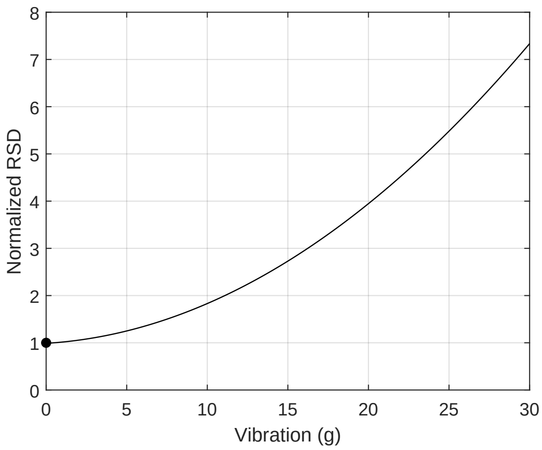


Figure 3: Normalized relative standard deviation (RSD) of viscosity and density as a function of vibration acceleration (g_{RMS} in all directions). The marker refers to the values in table above.

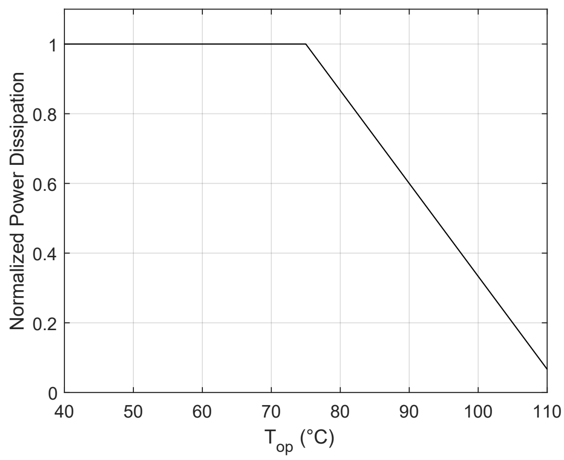


Figure 4: Derating of the power dissipation of the analog output driver.

3 Data Filter

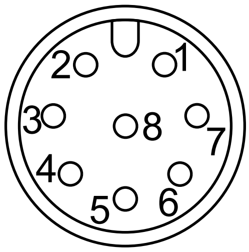
The raw data rate of the sensor is approximately one measurement per second. In order to provide reliable low-noise results in applications with lower data rate requirements, the ICMS provides a moving average filter for all measured parameters. The length of the filter is configurable from 1 to 256 seconds through a configuration register with a default value shown in Tab. 3. Erroneous measurements (such as e.g. out–of–range) are stored in the filter as well but discarded in the averaging process. Therefore, the output of the filter will provide valid results as long as there is valid data in the filter.

Please note that the status code information (see Tab. 2) corresponds to the raw (input) data of the filter. Therefore, in case the sensor is operated very close to measurement range limits, measurement noise may trigger the out–of–range bit while the average (filter output) is still within the specified range.

4 Electrical Connections

Power supply and signals share a male M12-8 connector with A–coding according to EN 61076-2-101. Install using shielded cables only.

Pin	Signal	Notes
1	OUT 2	4-20mA output
2	CFG reset	Connect to Ground
3	BUS H	Digital interface High
4	Terminator	Connect to pin 3 for termination
5	BUS L	Digital interface Low
6	OUT 1	4-20mA output
7	+24V	Supply
8	0V	Ground, connected to chassis



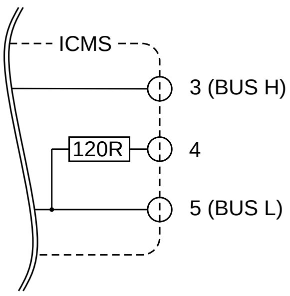
Pin arrangement (sensor side)

CFG reset pin

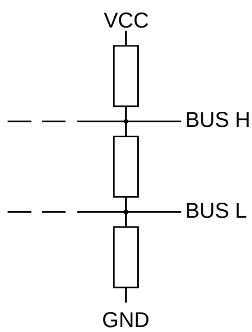
The CFG reset pin can be used to reset the sensor to factory default settings. Default settings and reset procedure is outlined in Sec. 8 below. During normal operation this pin should be connected to ground.

RS–485 / Modbus RTU

The digital interface requires three wires: BUS H, BUS L, and Ground. In applications where the bus ground cannot be connected to the sensor ground, an external galvanic isolator must be provided.
An internal bus termination can be enabled by connecting pin 4 to BUS H (pin 3). To deactivate termination either connect pin 4 to BUS L (pin 5) or leave it unconnected. Any connection should be implemented as close as possible to the sensor.



RS–485 termination circuit.

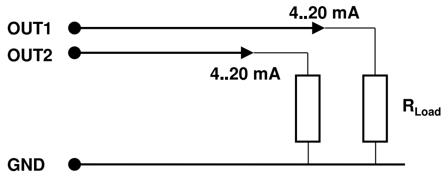


RS–485 interface biasing.

As RS–485 is a half duplex bus there are conditions where there is no active transmitter on the bus. In order to avoid undefined bus states in this case, fail safe biasing is recommended to ensure BUS H $>$ BUS L. Typically this is implemented at the location of the bus master. **The values of the resistors as well as the bus supply voltage VCC have to be chosen according to actual bus load / termination and the used RS485–transceiver.**

5 Analog Outputs

The sensor provides two independent analog current loop transmitter outputs (4-20 mA). For both outputs, the measured variable as well as the measuring range can be configured by the user. Please note that each analog output driver contributes to the total power dissipation of the sensor by $(V_{\text{supply}} - V_{\text{out}}) \times I_{\text{out}}$. In order to avoid overheating the tolerated dissipation has a temperature dependent limitation as shown in Fig. 4. It is recommended to reduced the power dissipation by adding external load resistance, especially when the supply voltage is significantly higher than the output voltage of the current transmitter. Both analog outputs may be left unconnected if not used.



Analog outputs wiring.

Each analog output x can be configured using the following registers where x is 1 or 2:

OUTx_select
Selection of parameter that is mapped to analog output.

Value	Selection	Unit
0	Output disabled	
19	Density	$0.1\,\text{g/cm}^3$
22	Temperature	$0.01\,^\circ\text{C}$
26	kinematic Viscosity	0.1 cSt
30	dynamic Viscosity [2]	0.1 mPas

Table 1: Selection of analog output parameter.

OUTx_min
Value that is mapped to 4 mA output current. This value must be scaled according to the selected measurement parameter (see Tab. 1). If the measurement result is lower than this limit, the output remains at 4 mA as long as the result is valid (saturation).

OUTx_max
Value that is mapped to 20 mA output current. This value must be scaled according to the selected measurement parameter (see Tab. 1). If the measurement result is higher than this limit, the output remains at 20 mA as long as the result is valid (saturation).

By default analog outputs are configured as shown in Tab. 3 below. Invalid measurement results are represented by an output current of 1 mA.
From a valid analog output current Ix the associated output value $OUTx$ can be calculated using this formula:

$$OUTx = \frac{Ix - 4\,\text{mA}}{16\,\text{mA}} \cdot (OUTx_{\text{max}} - OUTx_{\text{min}}) + OUTx_{\text{min}}$$

[2]This register is available since firmware version 2024-02-21.

6 Modbus RTU Interface

Modbus RTU over RS–485 can be used to retrieve measurement results and status information and for configuration of filter settings, analog outputs, and the Modbus interface itself. All data is organized in 16–bit registers using signed or unsigned integer values. Where necessary two registers are combined (MSB first) to represent a 32–bit integer.
The supported Modbus function codes are:

Code	Function
3	read holding registers
6	write single holding register
16	write multiple holding registers

The Baud rate, parity / stop bits, and Modbus address can be configured using the according registers. For the default settings see Table 3. Changes to this registers are activated after restart. Supported Baud rates are 9600, 19200, and 115200 Bd. The supported parity / stop bit combinations are:

Value	Selection
0	no parity / 1 stop bit
1	no parity / 2 stop bits
2	even parity / 1 stop bit
3	even parity / 2 stop bits
4	odd parity / 1 stop bit
5	odd parity / 2 stop bits

Table 2: Selection of Modbus parity and stop bits.

When communicating with the device a timeout value of at least 2 s should be used.

6.1 Modbus Register Map

Address		Description	Unit	size	datatype	r/w
DEC	HEX			words		
0	0x0000	General Purpose		1	uInt16	rw
1	0x0001	HW Revision ID		1	uInt16	r
2	0x0002	Serial Number		2	uInt32	r
4	0x0004	Firmware Date (UNIX time)		2	uInt32	r
8	0x0008	Error Count (reset at power cycle)		2	uInt32	r
Measurement Results						
16	0x0010	Measurement #		2	uInt32	r
18	0x0012	kinematic Viscosity	0.01 cSt	1	uInt16	r
19	0x0013	Density	0.1 g/l	1	uInt16	r
20	0x0014	dynamic Viscosity [2]	0.01 mPas	1	uInt16	r
22	0x0016	Temperature	0.01 °C	1	sInt16	r
23	0x0017	Status Code		1	uInt16	r
24	0x0018	kinematic Viscosity (long)	0.001 cSt	2	uInt32	r
26	0x001A	kinematic Viscosity (high range)	0.1 cSt	1	uInt16	r
28	0x001C	dynamic Viscosity (long) [2]	0.001 mPas	2	uInt32	r
30	0x001E	dynamic Viscosity (high range) [2]	0.1 mPas	1	uInt16	r
Config Data Block						
32	0x0020	LOCK Register		1	uInt16	rw
33	0x0021	Command		1	uInt16	r(w)
34	0x0022	Baud Rate	1 Bd	2	uInt32	r(w)
36	0x0024	Address		1	uInt16	r(w)
37	0x0025	Parity / Stop Bits [1]		1	uInt16	r(w)
38	0x0026	Filter Length		1	uInt16	r(w)
40	0x0028	OUT1_select		1	uInt16	r(w)
41	0x0029	OUT1_min		1	u/sInt16	r(w)
42	0x002A	OUT1_max		1	u/sInt16	r(w)
44	0x002C	OUT2_select		1	uInt16	r(w)
45	0x002D	OUT2_min		1	u/sInt16	r(w)
46	0x002E	OUT2_max		1	u/sInt16	r(w)

Table 3: Modbus register map.

Do **not** attempt any read or write access to Modbus registers that are not explicitly listed above as this might lead to erroneous behavior.

[1] This register is available since firmware version 2023-01-11.
[2] This register is available since firmware version 2024-02-21.

6.2 Description of Registers

Measurement Results

Each measurement is assigned a consecutive number which is reset to 0 at powerup and can be read from the Modbus registers. Measurement results are scaled according to section **??** and encoded in signed/unsigned 16–bit integers. Invalid results are indicated by the maximum value of the according datatype which is 0xFFFF for uInt16 and 0x7FFF for sInt16.

LOCK Register

Registers of the Config Data Block are prevented from accidental write access by the LOCK register. To enable write mode for the Config Data Block (including the Command register) write 44252 (0xACDC) to the LOCK register. After the configuration is finished set the LOCK register 0 to prevent accidental damage to the configuration.

Command Register

To permanently save changes write 1 (0x0001) to the Command register. Please note that this operation may take about 1 s. When writing 255 (0x00FF) to the Command register the device is restarted.

General Hints

For changing configuration settings please refer to the procedure outlined above (LOCK and Command register). All changes to the configuration (except for the Modbus interface) are applied immediately but are only saved permanently when 1 (0x0001) is written to the command register.

7 Status Code

This field is used to report measurement and error/warning conditions. Each bit that is set to 1 indicates a specific condition:

Bit	Description	Possible Reasons
0	No resonance detected	Resonance search is still in progress, Liquid out of measurement range, Sensor damaged or contaminated
1	Out of range	At least one parameter is out of range
2	Frequency controller error	Viscosity or density out of range
3	Noise error	Electromagnetic interference, Very high flow velocity
4	Invalid configuration	Invalid or missing configuration
5	Resonator error	Resonator damaged
6	Temperature sensor error	Temperature sensor damaged
7	Hardware error	Damaged sensor electronics
8	Firmware error	An unspecified firmware error was triggered
9	reserved	ignore
10	Supply voltage too low or too high	Improper or unstable power supply
11	Internal temperature limit	The sensor is operated beyond the thermal specification
12-15	reserved	ignore

Table 4: Interpretation of status code bits.

Note: If one or more of the above status code bits is set, the measurement results may be invalid or compromised.

8 Default Configuration

The following table summarizes the factory default configuration:

Parameter	Value
Analog output 1	Temperature -40 .. +125 °C
Analog output 2	Viscosity (kinematic) 0 .. 400 cSt
Data filter	60 s
Modbus Address	1
Baud rate	19200 Baud
Data bits	8
Parity	no
Stop bits	1

Table 5: Factory default settings.

Reset to default configuration

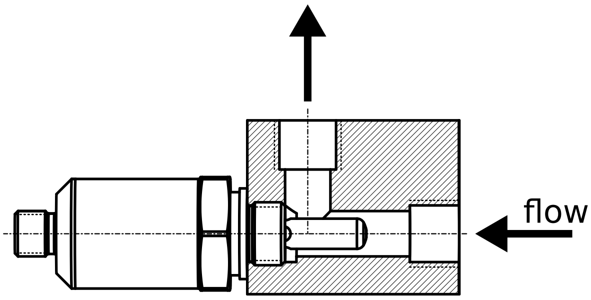
In case of misconfiguration the sensor can be reset to above factory defaults by applying the following procedure:

Step	Action
1	Make sure the CFG reset pin is connected to ground.
2	Power up the sensor properly and wait at least 5 seconds.
3	Connect the CFG pin to the supply voltage (nominal +24 VDC)
4	Wait at least for 10 seconds.
5	Connect the CFG reset pin to ground again.
6	Power cycle the sensor.
7	The sensor will start with factory default configuration.

Table 6: Reset factory default procedure.

9 Mounting and Handling

The sensor element of the ICMS is a quartz crystal tuning fork resonator. To protect this resonator from mechanical impacts, the sensor features a permanent protective cap. The liquid can enter this cap through an opening at the tip and leave through openings at the side.
It is recommended to mount the sensor in a T–fitting (inlet opposite to the sensor and outlet to the side) or a similar setup. For sealing we recommend a bonded seal washer; Torque required for these washers typically is the range of 31 – 39 Nm.



Recommended mounting orientation.

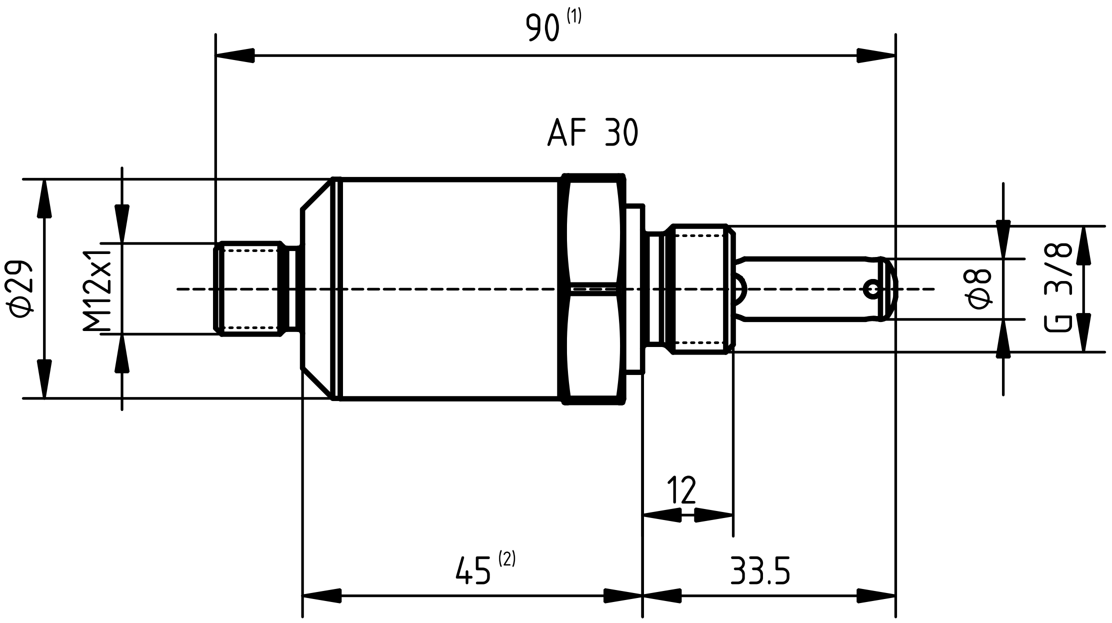
The sensor element of the ICMS is virtually insensitive to mounting orientation, flow direction or pressure. Nevertheless, for optimal performance we recommend considering a few details:

- Air bubbles change the mechanical properties of a liquid and thus influence the measurement. Make sure no air pockets can get trapped at the sensor and potential bubbles are carried away from the sensor by flow or buoyancy. Avoid feeding oil with entrained air to the sensor and be aware that dissolved gases in the oil may form bubbles when pressure is reduced.
- When placing the sensor in a reservoir or a sump the flow rate may be very low. This may lead to extremely slow reaction of the sensor, to residuals influencing the measurement, or even clogging the sensor.
- Although the sensor element itself is virtually insensitive to pressure, the viscosity of oil is a function of pressure. The effect of pressure fluctuation on the measurements are generally more pronounced at higher pressure.
- Consider the heat transfer from the liquid to the sensor case when operating at high liquid temperature.
- Laminar flow is required in the vicinity of the sensor. Turbulence is a source of high acoustic energy and can therefore increase the noise of the measurement results or temporarily interrupt the measurement.

If cleaning of the sensor is necessary use suitable solvents (e.g. white spirit or alcohol).

Do **not**
- use compressed air as this may damage the resonator permanently due to high flow velocity.
- penetrate the protective cap with any kind of object (e.g. needles or wires).

10 Dimensions



All dimensions in mm, drawing is probably not to scale.

11 Copyright Notice

This product may use copyrighted third-party software components under the following licenses:

Revision History

08/2024	Measurement range extended
	AOUT swap corrected
05/2024	Specification extended
04/2024	Register table extended
12/2023	Bus specification extended
02/2022	Initial release

Micro Resonant Technologies GmbH
A–4040 Linz, Austria
office@micro-resonant.at

Specifications subject to change without notice.

[1] For hardware revisions 0 and 1 this dimension is 93.4 mm.
[2] For hardware revisions 0 and 1 this dimension is 48.9 mm.