ICMS

Inline Condition Monitoring Sensor
for physical fluid properties

ICMS3-0CI

Features

- Multi-parameter monitoring:
  - Viscosity
  - Mass Density
  - Temperature
- High sensitivity and low drift
- Excellent long–term stability
- Compact and robust design
- Easy to install
- CANopen 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]	$(V_{supply} - V_{out}) \times I_{out}$			1.3	W
Interfaces					
Connector	EN 61076-2-101		M12-8 A–coding		
Analog Outputs	2 x 4-20 mA				
Digital	CANopen				
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 3.

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	$V_{\text{supply}} - V_{\text{out}}$	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, **??**, and 2, for information on the influence of individual parameters.

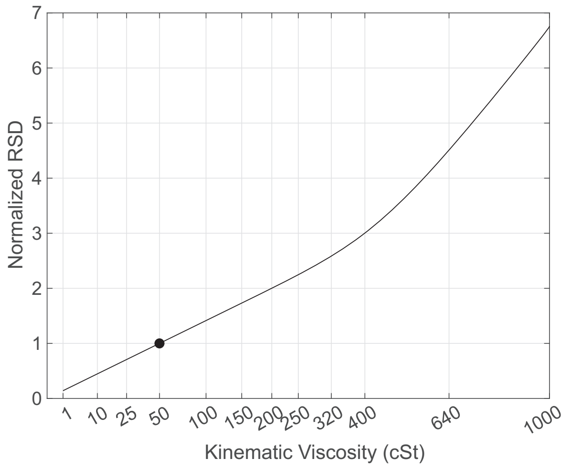


Figure 1: Normalized relative standard deviation (RSD) of viscosity as a function of viscosity. The marker refers to the values in table above.

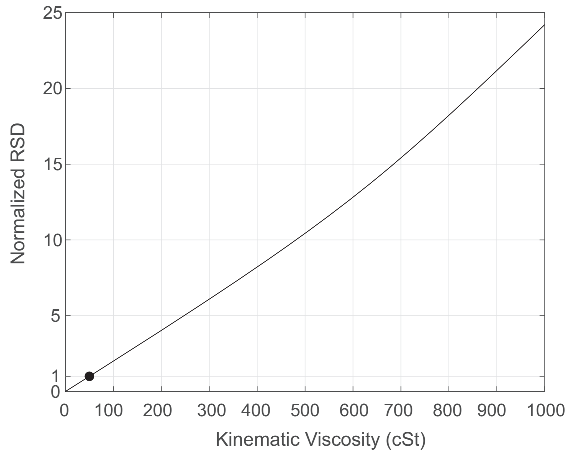


Figure 2: Normalized relative standard deviation (RSD) of density as a function of viscosity. The marker refers to the values in table above.

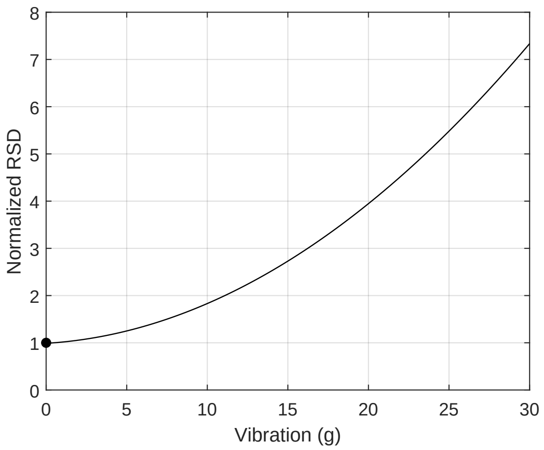


Figure 3: Normalized relative standard deviation (RSD) of viscosity and density as a function of vibration acceleration (g_{RMS} in all directions). The marker refers to the values in table above.

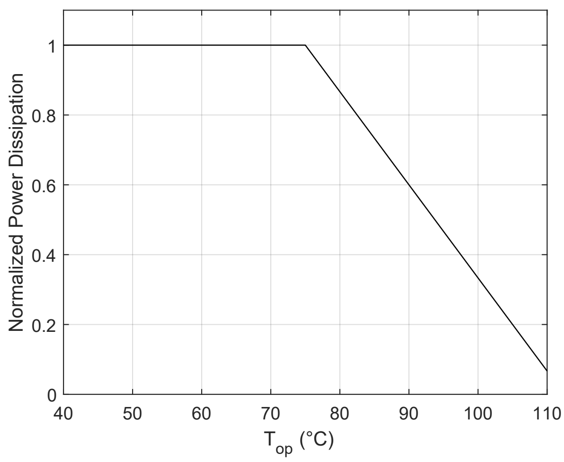


Figure 4: Derating of the power dissipation of the analog output driver.

3 Data Filter

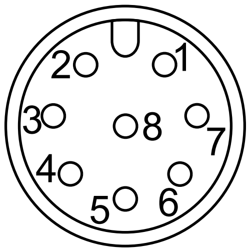
The raw data rate of the sensor is approximately one measurement per second. In order to provide reliable low-noise results in applications with lower data rate requirements, the ICMS provides a moving average filter for all measured parameters. The length of the filter is configurable from 1 to 256 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



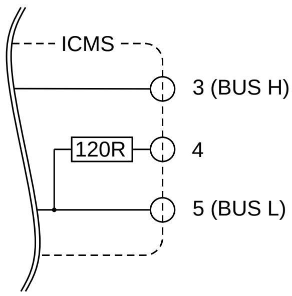
Pin arrangement (sensor side)

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.

CAN

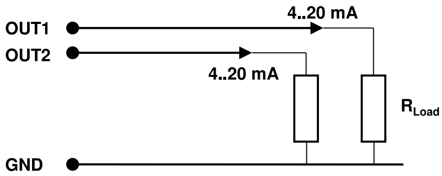
The digital interface requires three wires: BUS H, BUS L, and Ground. In applications where the bus ground cannot be connected to the sensor ground, an external galvanic isolator must be provided.
An internal bus termination can be enabled by connecting pin 4 to BUS H (pin 3). To deactivate termination 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.



CAN termination circuit.

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. 3. 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 °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 CANopen Interface

This device is compatible to the CANopen Standard as specified in CiA 301 and implements a device profile for measuring devices (CiA 404). This document will only give a brief overview over the supported CANopen features. For an in detail description please refer to the according CiA documents and the electronic datasheet.

6.1 Supported Features

The device supports the following CANopen features:

- NMT commands (start, stop, preoperational, reset communication, reset node)
- Heartbeat producer
- SDO read and write
- 1 configurable TPDO for measurement results
- LSS slave for configuration of node ID and bit rate
- all configuration can be saved permanently
- all configuration can be restored to default values

6.2 Startup

When powered up the device starts into preoperational mode using the default bit rate and node ID (see Tab. 3) and begins to send heartbeat messages with an interval of 1000 ms. The device can then be switched to operational mode using the NMT start command. However this behavior can be changed by setting the parameter **0x2025 – "Autostart"**, to 1, in this case the device will start directly into operational mode.

6.3 Configuration

In general all changes to the configuration are only temporarily. To save configuration permanently, the field **0x1010 – "Store Parameters"**, can be used. For manufacturer specific parameters, the device has to be restarted to activate changes (with exception of **0x2026 - "Filter Length"**).

6.4 Measurement Results

The measurement results together with the corresponding consecutive measurement number and status code can be read using **0x7130 – "AI Input PV"**. The measurement values are scaled using the number of decimal digits configured in **0x6132 – "AI decimal digits PV"**. The scaling of result values can be changed, however keep in mind that scaled values exceeding the range of the 16 bit datatype will be clipped. Invalid results are indicated by the maximum value of the according datatype which is 0xFFFF for uInt16 and 0x7FFF for sInt16.

6.5 TPDO

By default the measurement results (measurement number, kinematic viscosity, density and temperature) are sent after every measurement cycle ($\approx$1/s) using a TPDO. The behavior of the TPDO as well as the mapping of result values can be configured using **0x1800 – "TPDO communication"** and **0x1A00 – "TPDO mapping"**. E.g. to send the TPDO every 10 s, set the "Transmission Type" to 255 and the "Event Timer" to 10000.

6.6 Object Dictionary Overview

Index	Sub	Name	Datatype	
Communication Specific Parameters				
0x100A	0	Manufacturer SW version	uInt32	Firmware Date (UNIX time)
0x1010	1	Store Parameters	uInt32	Write "save" (0x65766173) to save config.
0x1011	1	Restore Default	uInt32	Write "load" (0x64616F6C) to restore default configuration.
0x1017	0	Producer Heartbeat Time	uInt16	Heartbeat producer time in ms, 0 to disable.
0x1018		Identity		
	1	Vendor ID	uInt32	0x000005A1 Micro Resonant Technologies
	2	Product Code	uInt32	"030C" (0x43303330)
	3	Revision Number	uInt32	hardware revision
	4	Serial Number	uInt32	
0x1800		TPDO communication		
	1	COB ID	uInt32	NodeID + 0x40000180
	2	Transmission Datatype	uInt8	254
	3	Inhibit Time	uInt16	0
	5	Event Timer	uInt16	0
	6	SYNC start value	uInt8	0
0x1A00		TPDO mapping		
	0	number of mapped objects	uInt8	4
	1	Application Object 1	uInt32	0x71300110 (Measurement Number)
	2	Application Object 2	uInt32	0x71300210 (Kinematic Viscosity)
	3	Application Object 3	uInt32	0x71300310 (Density)
	4	Application Object 4	uInt32	0x71300510 (Temperature)
Manufacturer Specific Parameters				
0x2022	0	Bit Rate	uInt16	CAN bit rate in kBaud (10 ... 1000)
0x2024	0	Node ID	uInt16	CAN node ID (1 ... 127)
0x2025	0	Operational Autostart	uInt16	auto start to operational mode (true / false)
0x2026	0	Filter Length	uInt16	length of data filter (1 ... 256)
0x2028	0	OUT1_select	uInt16	selection of analog output 1 (see Tab. 1)
0x2029	0	OUT1_min	uInt16	minimum process value for analog output 1
0x202A	0	OUT1_max	uInt16	maximum process value for analog output 1
0x202C	0	OUT2_select	uInt16	selection of analog output 2 (see Tab. 1)
0x202D	0	OUT2_min	uInt16	minimum process value for analog output 2
0x202E	0	OUT2_max	uInt16	maximum process value for analog output 2
Device Profile Specific Parameters				
0x6132		AI decimal digits PV		number of digits for result values
	1	Measurement Number	uInt8	0
	2	Kinematic Viscosity	uInt8	1 (0 ... 3)
	3	Density	uInt8	1 (0 ... 1)
	4	Dynamic Viscosity	uInt8	1 (0 ... 3)
	5	Temperature	uInt8	2 (0 ... 2)
	6	Status Code	uInt8	0
0x7130		AI Input PV		result values
	1	Measurement Number	uInt16	
	2	Kinematic Viscosity	uInt16	cSt
	3	Density	uInt16	g/cm^3
	4	Dynamic Viscosity	uInt16	mPas
	5	Temperature	sInt16	°C
	6	Status Code	uInt16	

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 2: 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
Node ID	1
Bit rate	250 kBaud
Operational Autostart	false

Table 3: Factory default settings.

Reset to default configuration

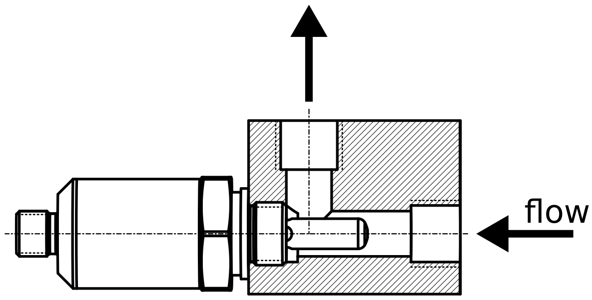
In case of misconfiguration the sensor can be reset to above factory defaults by applying the following procedure:

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 4: 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.

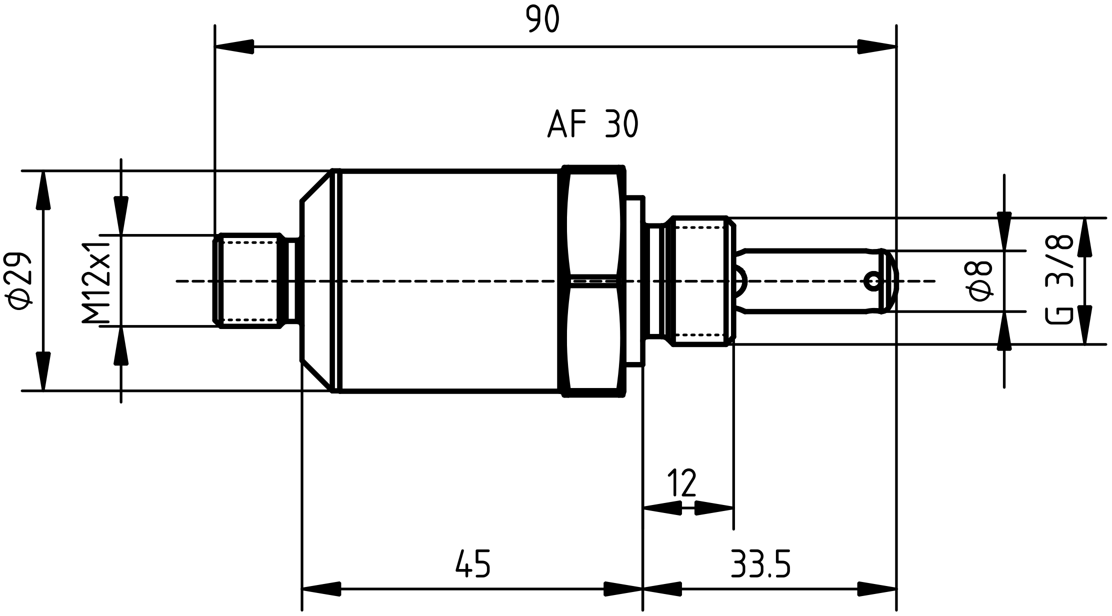
The sensor element of the ICMS is virtually insensitive to mounting orientation, flow direction or pressure. Nevertheless, for optimal performance we recommend considering a few details:

- 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

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Revision History

02/2025	added firmware date to object dictionary
01/2025	Initial release

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Specifications subject to change without notice.