ICMS

Inline Condition Monitoring Sensor for physical fluid properties



Features

- Multi-parameter monitoring:
 - Viscosity
 - Mass Density
 - Permittivity
 - Temperature
- High sensitivity and low drift
- 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 physical fluid properties such as viscosity, mass density, and electrical permittivity.

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. 7.)			⊖30 × 93.4		mm
Mass			150		g
Mounting			G3/8"		
Operating Conditions					
Tolerated Particle Size				250	μm
Oil Pressure				50	bar
Ambient Temperature	T_{amb}	-40		105	°C
Fluid Temperature	T_{fluid}	-40		125	°C
Supply					
Voltage		9	24	35	V
Power Consumption	without analog outputs		1		W
Interfaces					
Connector	EN 61076-2-101		M12-8		
			A–coding		
Analog Outputs	2 × 4-20 mA				
Digital	Modbus RTU				
Conformity					
CE	EN 61000-6-1/2/3/4				
Ingress Protection (M12 mated, 24h)	DIN EN 60529		IP68		
Compliant Fluids					
Mineral and Synthetic Oils					
further approvals on request					



2 Measurement Specifications

Specifications at an ambient temperature of 24°C in reference liquid: Cannon Instruments N140 viscosity standard at 40°C, unless otherwise noted.

Description		min	typ	max	Unit
Measurement Range					
Resonator Frequency			20 - 25		kHz
Viscosity (kinematic)	ν	1		400	cSt (=mm 2 /s)
Density	ρ	0.5		1.5	g/cm^3
Permittivity (relative)	$\varepsilon_{ m r}$	1		10	
Temperature		-40		125	°C
Data Rate			1		1/s
Analog Output 4-20mA					
Accuracy				± 1	% FS
Supply headroom	$V_{Supply} - V_{Load}$	4.8			V
Trueness (according to ISO 5725-1) ^{1, 2}					
Viscosity	$\nu \leq 200\text{cSt}$		± 1	±2	$\%\pm0.1cSt$
	$\nu>200\text{cSt}$			± 5	%
Density	$\nu \leq 200\text{cSt}$		±0.2	± 1	%
	$\nu>200\text{cSt}$			±2	%
Permittivity (relative)			± 1	±2.5	%
Temperature			±0.1	± 1	°C
Repeatability (relative standard deviation) ³					
Viscosity ⁴	$\nu=50cSt$		0.3		%
Density ⁴	$\nu=50cSt$		0.05		%
Permittivity (relative)			0.1		%
Temperature			0.02		°C

⁴See Fig. 1 and 2.



¹Valid for Newtonian liquids.

²Custom calibration on request.

³Standard deviation for 100 consecutive measurements under constant conditions, data filter disabled.



Figure 1: Normalized relative standard deviation (RSD) of viscosity as a function of viscosity.



Figure 2: Normalized relative standard deviation (RSD) of density as a function of viscosity.

3 Electrical Connections

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

Pin	Signal	Notes
1	OUT 1	4-20mA output
2	CFG reset	Connect to Ground
3	Terminator	Connect to pin 4 for termination
4	RS485 A	Modbus RTU
5	RS485 B	Modbus RTU
6	OUT 2	4-20mA output
7	+24V	Supply
8	0V	Ground



Pin arrangement (sensor side)

The internal 120 Ω resistor for RS485 bus termination is activated by connecting pin 3 to the RS485 A line (pin 4). To deactivate termination either connect pin 3 to RS485 B line (pin 5) or leave it unconnected. Any connection should be as close as possible to the sensor.



4 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 Modbus register with a default value set to 60 s. 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.

5 Modbus 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:

- 3: read holding registers
- 6: write single holding register
- 16: write multiple holding registers

5.1 Default Configuration

The default configuration is 19200 baud and device address 1. When communicating with the device a timeout value of at least 2s should be used. Please note that 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.

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

- Make sure the sensor is powered properly.
- Connect pin 2 to the supply voltage (nominal +24 VDC, pin 7) for at least 10 seconds.
- Unpower the sensor.
- Connect pin 2 to ground and power the sensor again.
- After restart, the configuration (in particular baud rate and device address) will be reset to factory defaults.



5.2 Modbus Register Map

Ac	ldress	Description	Unit	size	datatype	r/w
DEC	HEX			words		
0	0x0000	General Purpose		1	uint16	rw
1	0×0001	HW Revision ID		1	uint16	r
2	0x0002	Serial Number		2	uint32	r
4	0×0004	Firmware Date		2	ulnt32	r
6	0×0006	reserved		1		
7	0×0007	reserved		1		
8	0×0008	Error Count		2	ulnt32	r
Meas	urement	Results				
16	0x0010	Measurement $\#$		2	ulnt32	r
18	0x0012	Viscosity	0.01 cSt	1	ulnt16	r
19	0×0013	Density	0.1 g/l	1	ulnt16	r
20	0×0014	Permittivity	0.01	1	ulnt16	r
21	0×0015	reserved		1		
22	0×0016	Temperature	0.01 °C	1	sInt16	r
23	0x0017	Status Code		1	ulnt16	r
Confi	g Data B	lock				
32	0×0020	LOCK Register		1	ulnt16	rw
33	0×0021	Command		1	ulnt16	r(w)
34	0x0022	Baud Rate		2	ulnt32	r(w)
36	0×0024	Address		1	ulnt16	r(w)
37	0×0025	reserved		1		
38	0×0026	Filter Length		1	ulnt16	r(w)
39	0×0027	reserved		1		
40	0×0028	OUT1_select		1	ulnt16	r(w)
41	0×0029	OUT1_min		1	u/slnt16	r(w)
42	0x002A	OUT1_max		1	u/slnt16	r(w)
43	0x002B	reserved		1		
44	0x002C	OUT2_select		1	uint16	r(w)
45	0x002D	OUT2_min		1	u/slnt16	r(w)
46	0x002E	OUT2_max		1	u/slnt16	r(w)
47	0x002F	reserved		1		

Table 1: Modbus register map.

5.3 Description of Registers

General Purpose

This is an unused register that can be used freely. Content of this register may be altered at reset.

HW Revision ID

Hardware version of the sensor.

Serial Number

Serial number of the sensor.



Firmware Date

Timestamp of the sensor firmware in UNIX time format.

Error Count

Counter for measurement errors including out-of-range events. At powerup, this value is set to zero.

Measurement Results

Each measurement is assigned a unique number which is reset to 0 at powerup and can be read from the Modbus registers. Measurement results are scaled according to section 5.2 and encoded in signed/unsigned 16-bit integers. Invalid results are indicated by a value of 0xFFFF.

Status Code

This register 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 exploration 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
8-15	reserved	

Table 2: Meaning of Status Code bits.

LOCK Register

To enable write mode for the Config Data Block including the Command register write 44252 ($0 \times ACDC$) to the LOCK register. After the configuration is done write 0 to the LOCK register 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.

Baud Rate

Baud rate of the Modbus interface. Possible values are 9600, 19200, and 115200 baud. Default value: 19200 baud. Changes are activated after a restart.

Address

Device address of the sensor. Default value: 1. Changes are activated after a restart.

Filter Length

Length of the moving average data filter in the range of 1 to 256. Default value: 60.



OUTx_select

Selection of parameter that is mapped to analog output x, where x is 1 or 2.

Value	Selection
0	Output disabled
18	Viscosity
19	Density
20	Permittivity
22	Temperature

Table 3: Selection of analog output parameter.

OUTx_min

Value that is mapped to 4 mA output current. This value must be scaled and encoded in the same way as the selected measurement parameter (see section 5.2). 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 and encoded in the same way as the selected measurement parameter (see section 5.2). 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 output 1 is configured for temperature (-40 \dots 125 °C) and analog output 2 is configured for viscosity (0 \dots 400 cSt). An invalid measurement result is represented by an output current of 1 mA.

6 Mounting and Handling

The ICMS provides a permanent protective cap to prevent the resonator from mechanical impacts. The liquid can enter this cap through an opening at the tip and leave through recesses on 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 the use of a bonded seal washer is recommended.

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 rigid objects (e.g. needles or wires).



7 Dimensions



All dimensions in mm, scale 1:1.

Revision History

03/2022 Register table added 02/2022 Initial release 09/2021 Preliminary revision

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Specifications subject to change without notice.

