

fluidFOX

*The Quick and Clever
Oil Condition Monitor*



Features

- Multi-parameter monitoring:
 - viscosity, viscosity index
 - density, thermal expansion
 - humidity, dew point
 - permittivity, conductivity
- Active temperature control
- High sensitivity, low drift
- Low contamination sensitivity
- Compact and robust design
- Easy to install
- High pressure option available

Applications

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

The fluidFOX is a precise instrument for monitoring physical fluid parameters such as viscosity (dynamic and kinematic), density, permittivity, electric conductivity and humidity.

The integrated active temperature control enables the determination of the strongly temperature dependent viscosity at any desired reference temperature and, furthermore, the acquisition of several parameters derived from temperature (or pressure) dependence of primary parameters.

The outstanding performance of the fluidFOX is achieved by combining a patented technology for resonator evaluation and well established quartz crystal resonators.

Due to the high sensitivity and long-term stability, the fluidFOX is particularly suitable for oil condition monitoring in predictive maintenance programs.

Designed as on-line monitoring system, that fluidFOX autonomously takes measurements at different temperature or pressure levels.

With a rate of one measurements per second, even fast changes can be reliably determined.

1 General Specifications

Description		min	typ	max	Unit
Mechanical					
Size (drawings see sec. 5.)	162 x 130 x 80				mm
Mass			1.5		kg
Mounting	4 x Ø5.5				mm
Fluid Connections	G1/8"				
Oil Volume	internal tubing + sensor		4.5		cm ³
Operating Conditions					
Particle Size				500	µm
Oil Pressure				50	bar
Ambient (Backplane) Temperature ^{1 2}	<i>optional</i> T_{amb}	0		400	bar
Permitted Flow Velocity	during measuring		TBD	80	°C
				25	l/h
Supply					
Voltage		22	24	26	V
Current				4	A
Power Consumption	standby		<3		W
	during temperature change		<35		W
Switching Outputs					
optically isolated outputs	common ground		4		
output type	transistor		O.D.		
switching characteristic			N.O.		
Voltage			24	27	V
Current				2	A
Communications					
LAN					
Connection			RJ45		
Protocol			UDP,		
			Modbus		
CAN					
Connection	<i>not available on F2 models</i>		Terminal		
RS485					
Connection			Terminal		
Protocol			Modbus		
Service Port					
Connection			Mini-USB		
Protocol			USB 2.0		
Conformity					
CE	EN 61000-6-2 EN 61000-6-3				
Ingress Protection	DIN EN 60529		IP30		

2 Measurement Specifications

Ambient Temperature $T_{amb} = 24^{\circ}\text{C}$, Measurement Rate $f_m = 1$ sample/s, liquid not conductive, unless otherwise noted.

Description		min	typ	max	Unit
Measurement Range					
Resonator frequency			25 - 30		kHz
Viscosity (dynamic) η		1		400	mPa s
Density ρ		0.4		1.2	g/cm ³
Conductivity σ				30	$\mu\text{S/m}$
Permittivity (relative) ϵ_r				20	
Humidity	<i>optional</i>		1 - 99		%RH
Temperature Regulation					
Control Range ²	T_{meas}	0		100	$^{\circ}\text{C}$
	$T_{meas} - T_{amb}$	-30		+70	$^{\circ}\text{C}$
Change rate	$\Delta T_{meas}/\Delta t$		20		$^{\circ}\text{C min}^{-1}$
settling time	$\Delta T = 10^{\circ}\text{C}$ to 0.01°C		1		min
Heat Flow ²	steady state			15	W
	during temperature change			60	W
Trueness	factory calibration required				
Viscosity ^{3 4}	$\eta \leq 200$ mPa s		0.4	1	%reading
	$\eta > 200$ mPa s			5	
Density ^{3 4}	$\eta \leq 200$ mPa s		0.04	0.2	%reading
	$\eta > 200$ mPa s			2	
Humidity			TBD		%RH
Conductivity			d.o.c.		
Permittivity (relative)			d.o.c.		
Temperature				0.01	$^{\circ}\text{C}$
Repeatability					
Viscosity ⁵	$\eta \leq 200$ mPa s		< 0.12		%reading
	$\eta > 200$ mPa s		< 0.2		%reading
Density ⁵	$\eta \leq 200$ mPa s		< 0.03		%reading
	$\eta > 200$ mPa s		< 0.1		%reading
Temperature			< ± 0.003		$^{\circ}\text{C}$
Humidity			< ± 2		%RH
Conductivity			d.o.c.		$\mu\text{S/m}$
Permittivity (relative)			d.o.c.		

d.o.c.: depending on configuration.

Permitted media: liquid hydrocarbons (oils, fuels).

Cleaning agents: white spirit, air.

¹Non condensing.

²When $T_{cell} < T_{amb}$, sufficient cooling is required at the backplane (see Fig. 2).

³Valid for Newtonian liquids only. For further details see section 4.

⁴The accuracy is influenced by the reference liquids. See section 4.

⁵Error propagation depends on the fluid. More detailed information is given in section 4, Fig. 5 and 6.

3 Concept and Operation

The fluidFOX is a compact and versatile instrument designed to monitor physical properties of lubricants and hydraulic fluids. Based on an electromechanical resonating sensor, the fluidmechanical (such as viscosity and density) and electrical (permittivity and conductivity) properties of the liquid are determined. The fluidFOX is particularly distinguished by its outstanding viscosity measurement capability, which has been specially tailored to the requirements of online condition monitoring.

Viscosity is a strongly temperature dependent property and consequently accurate temperature information is essential for comparability and interpretation of acquired data. For this reason the fluidFOX incorporates an active temperature control of the measurement cell, where special measures are taken to achieve a high long-term stability of the temperature measurement. A system overview is shown in Figure 1 below. Furthermore the active temperature control is used to determine fluid properties at multiple temperatures by sequential cycling. Doing this, the temperature coefficients of all primary parameters can be obtained, yielding additional parameters for condition monitoring and allowing for consistency checks of the data. Likewise, pressure cycling can be implemented by means of an optional pressure sensor in order to obtain the pressure coefficients of properties as well.

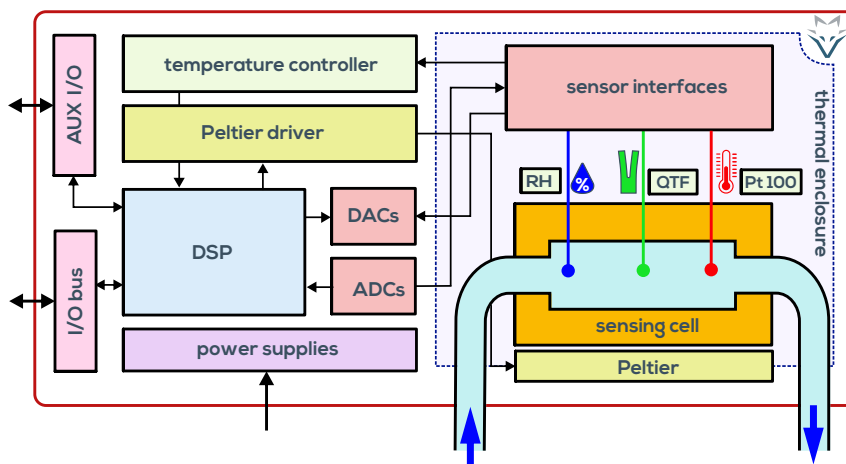


Figure 1: FluidFOX system overview.

Depending on the particular application, different resonators can be used in the fluidFOX measuring cell. In addition to different resonance frequencies and resonator sizes, electrode material and passivation layers can also be adjusted to meet various chemical or rheological requirements.

The mounting position of the fluidFOX has to be chosen such that the heat flow requirements at the backplane of the instrument are met. The internal temperature control is based on a thermoelectric module controlling the heat flow between measurement cell and backplane. In applications where a large temperature range (either for measurement temperature or as ambient temperature) has to be covered, active conditioning of the ambient temperature should be considered.

The configuration of temperatures levels, cycling sequences, and sampling, can be adjusted to meet the requirements of various applications. For reporting the acquired results, the fluidFOX offers a variety of common interfaces such as CAN, Modbus, RS485, and Ethernet.

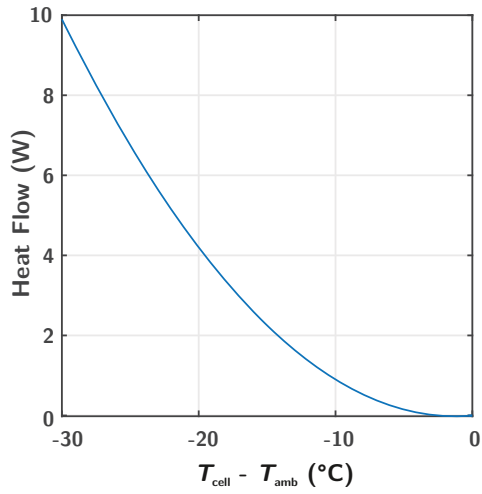


Figure 2: Heat flow at the bottom of the housing in cooling mode (steady state).

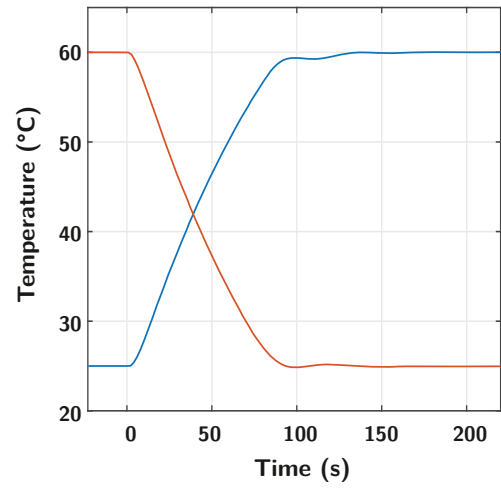


Figure 3: Step response of the temperature control for steps from 25°C to 60°C, and vice versa.

4 Measurement and Calibration Principle

The electrical measurement of the mechanical fluid parameters viscosity and density is performed using a resonant piezoelectric element, which serves for excitation and readout of the vibration simultaneously. The electrical and mechanical fluid properties are reflected in the measured frequency responses. The fluid forces acting on the vibrating sensor element affect the resonant frequency (f) and the bandwidth (B) of the electromechanical resonance. By means of a fluid-mechanical model these resonance parameters are uniquely mapped to accelerated mass and dissipative damping, which correspond to density and viscosity for Newtonian fluids (as shown in Figure 4).

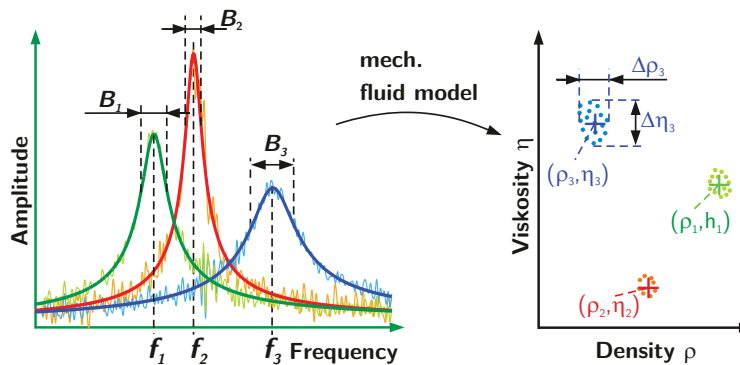


Figure 4: Determination of fluid parameters of Newtonian liquids using spectral analysis.

For non-Newtonian fluids apparent parameters are obtained. The apparent viscosity typically shows frequency (shear rate) dependent components, partial elastic fluids (i.e. viscoelastic) influence the apparent density. Note that precision and repeatability of the given results are unaffected by these effects.

The effects of the electrical fluid properties (permittivity and conductivity) are unambiguously separable from the mechanical components and are available as additional parameters. The fluid mechanical model contains several parameters which are subject to fabrication tolerances and therefore not known ad hoc with sufficient accuracy. For each sensor element these parameters are determined in the course of a calibration process which is performed by MicroResonant using certified viscosity and density standards (NIST traceable). The specified measurement uncertainties include both, calibration and model errors¹.

The Figures 5 and 6 show the effects of measurement noise on the relative standard deviations of density and viscosity results for a sampling rate of 1 value/s. The scattering of the calculated values ($\Delta\rho$ and $\Delta\eta$) due to the measurement noise increases with viscosity², with only small influence of the density. The error propagation follows a well-defined function and reduces by a factor of \sqrt{k} when the averaging time by is increased by the factor k . In case of fluids containing conductive components, the standard errors are slightly increased.

¹Basically, it is not possible to distinguish between calibration and model errors; the uncertainty of the reference fluids thus is partially included.

²This is a fundamental property of the resonant measurement principle

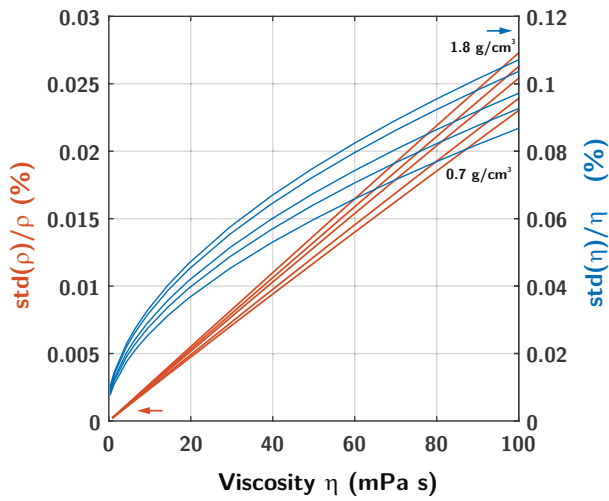


Figure 5: Standard error percentage due to the measurement noise on density ρ and viscosity η as a function of ρ and η . The curves are plotted for the non-conducting fluids with density values of 0.7, 0.9, 1.1, 1.5, 1.8 g/cm³. The sampling rate is 1 sample/s.

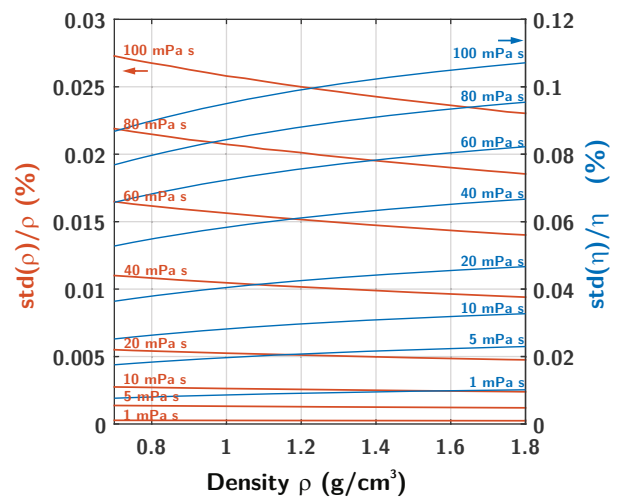
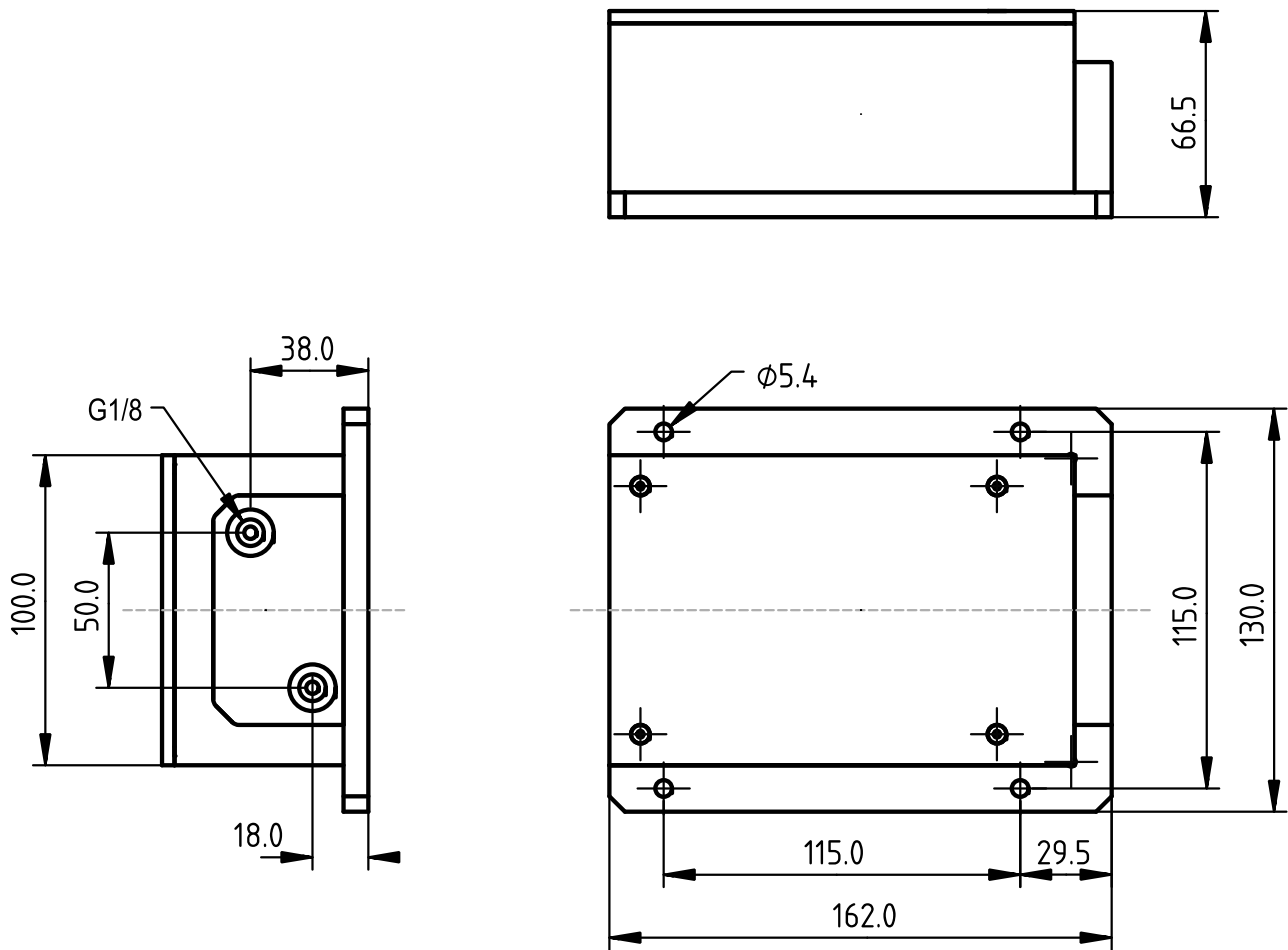


Figure 6: Standard error percentage due to the measurement noise on density and viscosity for non-conducting fluids and a sample rate of 1 sample/s.

5 Dimensions



All dimensions in mm, scale 1:2.
Electrical connections not shown.

Revision History

12/2019 Preliminary Revision
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Micro Resonant Technologies GmbH
A-4040 Linz, Austria
office@micro-resonant.at

Specifications subject to change without notice.