Innovative Sensor Technology

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OOL Module
Thermal mass flow

Benefits & Characteristics

- Continuous mass flow and temperature monitoring in liquids
- Outstanding repeatability and long-term stability
- Ready to use module with digital signal outputs (I²C)
- Suitable also for aggressive liquids with particles
- Stainless steel as single wetted material
- High accuracy between 1 and 20 kg/h

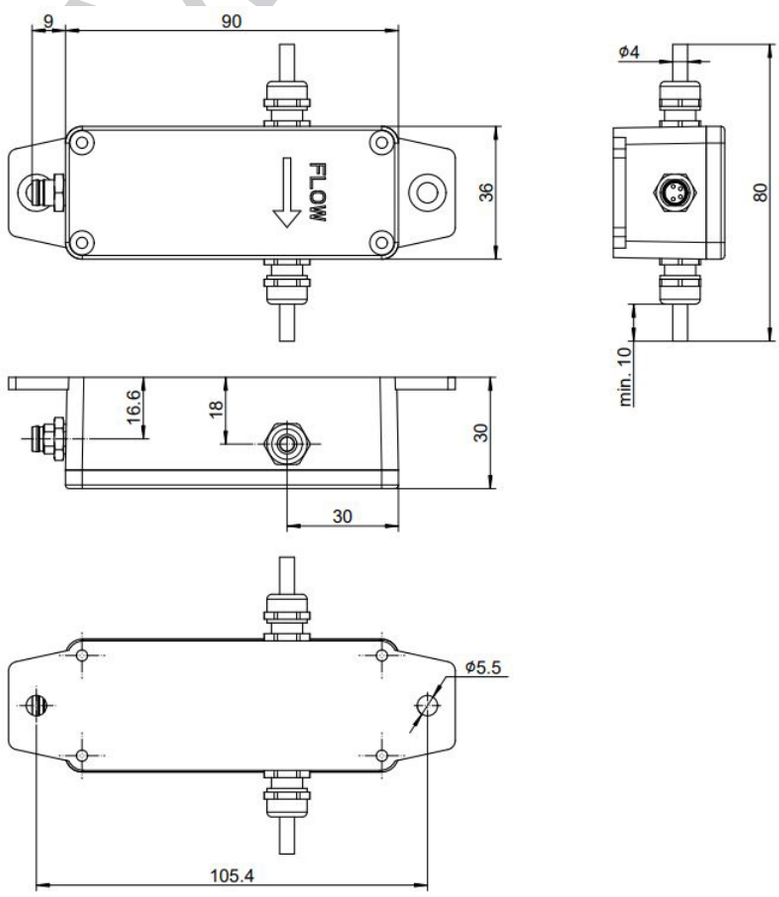
Applications

- Industrial temperature control systems
- Lubrication systems, incl. gear oil processing
- Various dosing systems, incl. food, life science, agriculture, white goods and mining
- Leakage, incl. water drip detection

Output signals

- Temperature on electronic board in °C
- Temperature of liquid in °C
- Power to heater in mW (non-linearized flow signal)
- Mass flow in kg/h (calibrated for H_2O, temperature compensated)

Illustration



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Performance

Parameter	Value	Unit	Comment
Operating parameters			
Flow range	0.1 ... 20	kg/h	Calibrated for deionized water (DI-H_2O)
Temperature range	+5 ... +50	°C	
Max operating pressure	70	bar	Estimated value
Warm-up time	5	min	
Flow parameters			
Accuracy	< 3 *	% f.s.	Value for DI-H_2O
Repeatability	< 0.3	% f.s.	Value for DI-H_2O
Response time t_{63}	0.5 - 1	s	Value for DI-H_2O
Temperature sensitivity	< 0.3	% / K f.s.	Value for DI-H_2O
Temperature parameters			
Accuracy	< 1	°C	Value for DI-H_2O
General parameters			
Pressure loss	0 ... 0.9	mbar	Based on DI-H_2O for 1 ... 20 kg/h at 25°C
Orientation dependence	< 1	% f.s.	
Flow insertion dependence	Yes **		
Storage temperature	0 ... +60	°C	

* To achieve the specified performance, the sensor needs to be warmed up for 3 to 5 minutes to attain thermal equilibrium.

** Factory calibration is done with a straight insertion length of 30 cm, where the angle between the sensor tube and the insertion us smaller than 2°.

Mechanical parameters

Parameter	Value	Unit	Comment
Flow channel			
Media wetted material	Stainless steel 1.4301		
Length	80.0	mm	
Outer diameter	4.0	mm	
Inner diameter	3.7	mm	
Process connection	4.0	mm	Open ended steel tube
Housing			
Material	Aluminium		
Width	30	mm	
Length	90	mm	excl. flanch
Height	36	mm	

General parameters

Protection class	IP65	
Weight	140	g

Electrical parameters

Parameter	Value	Unit	Comment
Supply voltage	10 ... 26	V	DC
Power consumption	≤ 1	W	
Electrical connection	M8 4-pin		Connector compatible with Phoenix SACC-DSI-M8MS-4CON-L90 SH / Binder 09-3421-82-04

Output signal (I²C, 3.3V)

Mass flow	kg/h	Linearized, 16bit
Power to heater	mW	Not linearized, 16bit
Temperature of liquid	°C	Accuracy unspecified, 16bit
Temperature of microcontroller	°C	Accuracy unspecified, 16bit

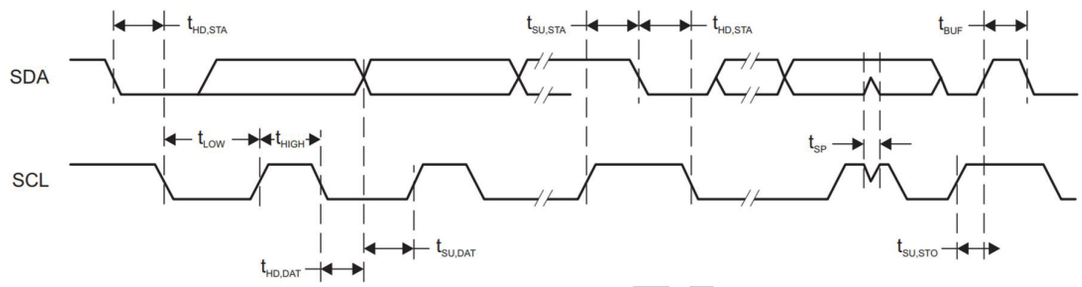
Pin Assignment

Pin 1	GND	
Pin 2	SCL	
Pin 3	VCC	Voltage supply
Pin 4	SDA	

I²C-protocol

For integration with a micro-controller, the OOL module has an I²C-compatible interface which supports both 100 kHz and 400 kHz bit rates. The default I²C slave address is programmed to 0x28 and can be adjusted in the entire 7-bit address range (0x00 to 0x7F).

Parameter	Min	Max	Unit
f_{SCL}	100	400	kHz
$t_{HD, STA}$	0.6		µs
$t_{SU, STA}$	0.6		µs
$t_{HD, DAT}$	0		µs
$t_{SU, DAT}$	250		µs
$t_{ST, STO}$	0.6		µs
	50	600	ns



Reading the data from OOL module

During normal operation OOL module is ready to transmit: heater power, temperature of liquid and temperature of microcontroller. Typical transmissions:

Start	Address	R	ACK	Data[7]	ACK	Data[6]	ACK	...	Data[0]	ACK	Stop

Start	Address	R	ACK	Data[7]	ACK	Data[6]	Stop

Data		Parameter	Unit
Data[7]	higher byte	Flow	kg/h
Data[6]	lower byte		
Data[5]	higher byte	Heater power	mW
Data[4]	lower byte		
Data[3]	higher byte	Temperature of liquid	°C
Data[2]	lower byte		
Data[1]	higher byte	Temperature of microcontroller	°C
Data[0]	lower byte		

All values read from the module are in unsigned fixed-point integer Q5 format. In order to convert them to decimal format, the read value has to be divided by $2^5 = 32$. The minimum value is 0, the maximum value is 2048. The resolution of each value is 1/25 = 0.03125.

MSB																LSB
Integer bits														Fractional bits		

Entering Command Mode

To read, write or remotely reboot the OOL module must be set to command mode by sending 0xA0.

Start	Address	W	ACK	Data = 0xA0	ACK	Stop

In the command mode OOL module switches off flow measurement and waits for further communication. If the transmission is unsuccessful, the module shall automatically reboot after 0.6 second of being idle. The module requires up to 1 ms to enter the command mode (counted form stop bit).

Entering commands

In the command mode user can transmit a 1-byte instruction to the module. The module requires up to 1 ms to process the instruction.

Start	Address	W	ACK	Data = Instruction's code	ACK	Stop

0x0b:	Read Delta_T – temperature difference between heater and sensor
0x0e:	Read I2C_address – own address on I²C bus
0x2b:	Write Delta_T – temperature difference between heater and sensor
0x2e:	Write I²C_address – own address on I²C bus, applies after reset
0xa1:	Exit command mode (without reset)
0xa2:	Reboot

Reading parameters from the module

After receiving a read instruction the module fills the I²C buffer with the selected parameter. All parameters read from the module, except I²C_address, are in signed fixed-point long IQ22 format (4 bytes). To convert them to decimal format divide read value by 2^{22} = 4 194 304. The minimum value is -512, the maximum value is 511.999 999 762. The resolution of each parameter is $1/2^{22}$ = 0.000 000 238. I2C_address parameter is read in unsigned long format and internally masked with 0x3F.

Start	Address	R	ACK	Data[3]	ACK	Data[2]	ACK	...	Data[0]	ACK	Stop

Data		Parameter
Data[3]	1st byte (highest)	Parameter
Data[2]	2nd byte	
Data[1]	3rd byte	
Data[0]	4th byte (lowest)	

After transmitting 4 bytes the module resets it's internal timer and waits in command mode for the next command. The module will reboot automatically after 0.6 second if idle or unsuccessful transmission.

Writing parameters to the module

After successful write instruction the module waits for 4 bytes with the new parameter. All parameters, except I²C_address, are in signed fixed-point long IQ22 format (4 bytes). In order to convert decimal format to IQ22, the decimal value has to be multiplied by 2^{22} = 4 194 304. To reduce the error, this calculation should be done as double precision floating point number. The minimum value is -512, the maximum value is 511.999 999 762. The resolution of each parameter is $1/2^{22}$ = 0.000 000 238. I²C_address parameter is written in unsigned long format and internally masked with 0x3F. Please mind that the new I²C address applies after reboot. The module requires up to 60 ms after stop bit to flash the internal memory with the new parameter. Internal flash memory is rated for minimum 10^4 programming cycles (typically 10^5).

Start	Address	W	ACK	Data[3]	ACK	Data[2]	ACK	...	Data[0]	ACK	Stop

Data		Parameter
Data[3]	1st byte (highest)	Parameter
Data[2]	2nd byte	
Data[1]	3rd byte	
Data[0]	4th byte (lowest)	

After receiving 4 bytes the module resets internal timer and waits in command mode for next command. The module will reboot automatically after 0.6 second of idle or unsuccessful transmission.

Exit command mode

After receiving this command, the module returns to normal operation, taking new parameters' values except the I²C address.

Start	Address	W	ACK	Data = 0xA1	ACK	Stop

Reboot

After receiving this command, the module reboots.

Start	Address	W	ACK	Data = 0xA2	ACK	Stop

Typical parameter's read sequence

To read parameter(s) form the flash memory please follow steps:

1. Write 0xA0 to the module – start the command mode
2. Wait 1 ms
3. Write 0x20…0x2f to the module – an address of the parameter
4. Wait 1 ms
5. Write 4 bytes to the module
6. Wait 60 ms
7. If needed repeat steps 3-6 for another parameter
8. Write 0xA1 to the module – exit command mode or 0xA2 – reboot the module

Recommendation for connecting the OOL Module

Based on a plastic tube with an 6.0 mm outer diameter and a 1.0 mm wall thickness:

- Ear clamps with insert ring: One-Ear clamp with insert ring 5.6-6.5

Product Photo

Order Information

Order code	Product name
153331	OOL Module V1.2.1
153332*	EvaKit OOL Module V1.2.1

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