Galvanic oxygen micro-sensor

O2-L Manual

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1 Preface

This OEM version of the galvanic AMT-O_2-micro-sensor has been developed above all for the very fast measurement of dissolved oxygen.

The sensor has very short response times and streaming as it is well known from nearly all kind of Clark-type oxygen sensors is not necessary. So profiling and stationary measurements without stirring the analyte become possible with very high signal and local resolution.

The sensor is ready for use immediately without any polarization or warm-up time. The sensor includes an integrated electronic device for the transformation of the sensor current into a voltage of 0...+ 3 V (DC) and an exchangeable sensor tip. The exchange of the sensor tip is very easy and could be done by the customer himself.

All sensors are delivered with temperature compensation data and also with mathematics to calculate the oxygen concentration or the saturation index.

Please take note, that the micro-sensor should be calibrated immediate before using (see also chapter 5 of this instruction manual) in air saturated water only (not in air !).

The perfect functioning and operational safety of the measuring device can only be ensured if the user observes the safety precautions as well as the specific safety guidelines stated in the present operating instruction.

2 Technical Data*)

sensor type:	galvanic membrane covered micro-sensor tip
power supply:	9 ... 30 V DC (not included)
polarisation:	polarizes itself
streaming of the membrane:	not necessary
stirring of the analyte:	not necessary
output:	0 ... + 3 VDC
connector:	Fischer-type
materials:	titanium (housing), silicone (membrane), glass (sensor), epoxy resin
dimensions:	total length (without connector): 205.0 mm diameter housing (main body): 12.7 mm diameter housing (largest part): 16.7 mm
concentration range:	variable, approx. 0 ... 150%
accuracy:	± 2% (measuring value) ± 1 digit
temperature range:	0°C ... 30°C (for measurement and storage)
response time ($t_{90\%}$):	down to some hundred milliseconds
life time:	approx. 3000 measuring hours at 100% saturation
signal interferences:	H_2S (sensor may be destroyed)
special features:	exchangeable sensor tip, integrated electronic device for transformation of pA-current into 0 ... + 3 V DC

*) Changes for technical improvement are reserved.

3 Structure of the O_2 micro-sensor

4 Putting into operation

Please use only the delivered adapter kit, power supply and cable connections. For putting into operation please act as follows:

1. Link the sensor with the sensor cable. Do not twist. Make sure by means of the red points at the sensor plug and cable socket which have to face each other, that the connection is safe and correct.
2. Link the plastic box with the delivered cables to the voltage measuring instrument.
3. Select a suitable voltage range.
4. Link the power supply unit with the plastic box and switch on the power supply. The sensor is now ready for measurements. The observed following adjustment time is only due to temperature and concentration equilibrium adjustments.
5. Remove the protection cap from the sensor tip (without pull off of the sensor electronic housing !). Make sure that the glassy tip will not be destroyed mechanically by any solids or by handling or by cross forces near the sensor tip. This is not covered by the warranty.

5 Measurement and calibration

Measurement

The sensor output shows a signal in the range of 0 ... + 3 V DC (main working range: approx. 400 ... 2.000 mV) depending upon the partial pressure of oxygen in the analyte solution and the temperature. Therefore the calculation of the oxygen concentration or of the oxygen saturation is possible by means of the following equations:

oxygen concentration:

$$c = a_{20^\circ C}\, x\, (U - U_G)\, x\, E_T\, x\, \frac{c_S}{X_{O2}\,(p_N - p_W)}\, x\, K_T$$

oxygen saturation index without consideration of salinity:

$$s = a_{20^\circ C}\, x\, (U - U_G)\, x\, E_T\, x\, \frac{100\%}{X_{O2}\,(p_L - p_W)}\, x\, K_T$$

formula for p_w with unit bar (water vapour pressure at measuring temperature):

$$\ln p_W = 11{,}8571 - (\frac{3840{,}7}{T}) - (\frac{216961}{T^2})$$

oxygen saturation concentration with consideration of salinity, temperature and depth:

$$c_S = e^{-173{,}4292 + 249{,}6339(\frac{100}{T}) + 143{,}3483\ln(\frac{T}{100}) - 21{,}8492(\frac{T}{100}) + S x\left[-0{,}033096 + 0{,}014259(\frac{T}{100}) - 0{,}0017(\frac{T}{100})^2\right]}\; x\, 1{,}4289$$

depth correction factor K_T:

$$K_T = e^{-(0{,}03775 x \frac{d}{273{,}15 + t})}$$

For laboratory purposes the consideration of depth correction is not required.

T	temperature in Kelvin (273,15 + x °C)
t	temperature in °C
d	depth in meter
K_T	depth correction factor (no unit)
c	oxygen concentration in mg/l
$a_{20°C}$	sensor slope at 20°C
U	measured output voltage
U_G	voltage at 0 mg/l O_2
E_T	temperature compensation factor E_T =f(t)=f(temperature in °C) $E_T = a_3t^3 + a_2t^2 + a_1t^1 + a_0$ a_3 ... a_0 are sensor specific and delivered by the manufacturer with every sensor
c_S	oxygen saturation concentration in mg/l at 1013 mbar and measuring temperature
p_N	1013 mbar
p_w	water vapour pressure at measuring temperature
p_L	air pressure
s	oxygen saturation index in per cent %
S	salinity in per mille
X_{O2}	0,2095

Attention ! Make sure, that you use the same units for all the calculation. Be carefully especially with the pressure units.

Calibration

The galvanic oxygen micro-sensor has been developed above all for very fast measurement with the main aim of fast response times. Caused by technical reasons the optimization of the long time stability for some weeks or months was not possible. How often the sensor has to be calibrated depends on the requested accuracy of the measurements.

Please take note, that in every case accurate measuring values are only possible with an accurate calibration. Therefore we recommend for accurate calibrations and with high demanding concerning to accuracy the use of an electrochemical generator for the stepless online generation of oxygen standard solutions. This device is also available from AMT Analysenmesstechnik GmbH. The generator has been developed for the generation of well-defined oxygen standard solutions with constant quality and without any consumption of chemicals for the degassing of the carrier solution. The calibration happens in a flow through system with the integrated oxygen sensor. For more information please do not hesitate to contact AMT.

For lower demandings concerning to the accuracy we recommend the two-point calibration with inert gases (argon or nitrogen) and with air saturated water (not with water vapour saturated air - in the most cases these values are 10-20% higher !!). The one-point calibration could be used too, because it is known, that the residual current is nearly constant during the whole sensor life. Only at the end of the sensors life the residual current increases. As a general rule, the residual current (U_G) is between 0 and 10 mV in the most cases. You will find the residual/zero current on top of the attached calibration sheet (last page).

If you want to calibrate your sensor, you have to determine the slope $a_{20°C}$ following this equation:

$$a_{20°C} = \frac{x_{O2}(p_L - p_W)}{E_T(U - U_G)}$$

6 Maintenance

Mechanical stress of the sensor tip, especially cross forces, unintentional touch downs or strong vibrations have to be avoided. The sensor tip is very weak. Do not touch it. Mechanical damage of the sensor tip excludes that the repair is covered by the guarantee.

For cleaning the sensor tip rinse it in water only. Do not use organic solutions. If there should be any biofouling at the sensor tip, it is recommended to clean the sensor tip by immersing it into very diluted acetic acid (2-5%) or diluted 0.02 mol/l NaOH (up to maximum of 24 hours). Higher concentrations may damage the sensor tip.

Protect the sensor tip with the wetting cap during long breaks. You can fill the wetting cap with less than ¼ with distilled water. Also a dry storage is possible.

p_W-table according to German DIN

Water vapour pressure of water in mbar with dependence of temperature (DIN 24163 part 2)

Temperature in °C	0	,1	,2	,3	,4	,5	,6	,7	,8	,9
0	6,11	6,16	6,19	6,24	6,29	6,33	6,37	6,43	6,47	6,52
1	6,56	6,61	6,67	6,71	6,76	6,80	6,85	6,91	6,96	7,00
2	7,05	7,11	7,16	7,21	7,25	7,31	7,36	7,41	7,47	7,52
3	7,57	7,63	7,68	7,73	7,79	7,85	7,91	7,96	8,01	8,08
4	8,13	8,19	8,24	8,31	8,36	8,43	8,48	8,53	8,60	8,65
5	8,72	8,79	8,84	8,91	8,96	9,03	9,09	9,16	9,21	9,28
6	9,35	9,41	9,48	9,53	9,61	9,68	9,75	9,81	9,88	9,95
7	10,01	10,08	10,15	10,23	10,29	10,36	10,43	10,51	10,57	10,65
8	10,72	10,80	10,87	10,95	11,01	11,09	11,17	11,24	11,32	11,40
9	11,48	11,55	11,63	11,71	11,79	11,87	11,95	12,03	12,11	12,19
10	12,27	12,36	12,44	12,52	12,61	12,69	12,77	12,87	12,95	13,04
11	13,12	13,21	13,29	13,39	13,47	13,56	13,65	13,75	13,84	13,93
12	14,01	14,11	14,20	14,29	14,39	14,48	14,59	14,68	14,77	14,87
13	14,97	15,07	15,17	15,27	15,36	15,47	15,57	15,67	15,77	15,88
14	15,97	16,08	16,19	16,29	16,40	16,51	16,61	16,72	16,83	16,93
15	17,04	17,16	17,27	17,37	17,49	17,60	17,72	17,83	17,95	18,05
16	18,17	18,29	18,41	18,52	18,64	18,76	18,88	19,00	19,12	19,25
17	19,37	19,49	19,61	19,73	19,87	19,99	20,12	20,24	20,37	20,51
18	20,63	20,76	20,89	21,03	21,16	21,29	21,43	21,56	21,69	21,83
19	21,96	22,11	22,24	22,39	22,52	22,67	22,80	22,95	23,09	23,23
20	23,37	23,52	23,67	23,81	23,96	23,11	24,25	24,41	24,56	24,71
21	24,87	25,01	25,17	25,32	25,48	25,64	25,80	25,95	26,11	26,27
22	26,43	26,60	26,76	26,92	27,08	27,25	27,41	27,59	27,75	27,92
23	28,09	28,25	28,43	28,60	28,77	28,95	29,12	29,31	29,48	29,65
24	29,84	30,01	30,19	30,37	30,56	30,75	30,92	31,11	31,29	31,48
25	31,68	31,87	32,05	32,24	32,44	32,63	32,83	33,01	33,21	33,41
26	33,61	33,81	34,01	34,21	34,41	34,61	34,83	35,03	35,24	35,44
27	35,65	35,87	36,08	36,28	36,49	36,71	36,93	37,15	37,36	37,57
28	37,80	38,03	38,24	38,47	38,69	38,92	39,15	39,37	39,60	39,83
29	40,05	40,29	40,52	40,76	41,00	41,23	41,47	41,71	41,95	42,19
30	42,43	42,68	42,92	43,17	43,41	43,67	43,92	44,17	44,43	44,68

Formula for p_W with unit **bar**:

$$\ln p_W = 11{,}8571 - \left(\frac{3840{,}7}{T}\right) - \left(\frac{216961}{T^2}\right) \quad T \text{...} \textit{temperature in Kelvin}$$

C_S-table according to German DIN

oxygen saturation concentration c_S (mg/l) for water in equilibrium with air at a total pressure of the water vapour saturated atmosphere of 1013 mbar in dependence of the temperature after German DIN 38408, part 22.

Temperature in °C	0	,1	,2	,3	,4	,5	,6	,7	,8	,9
0	14,64	14,60	14,55	15,51	14,47	14,43	14,39	14,35	14,31	14,27
1	14,23	14,19	14,15	14,10	14,06	14,03	13,99	13,95	13,91	13,87
2	13,83	13,79	13,75	13,71	13,68	13,64	13,60	13,56	13,52	13,49
3	13,45	13,41	13,38	13,34	13,30	13,27	13,23	13,20	13,16	13,12
4	13,09	13,05	13,02	12,98	12,95	12,92	12,88	12,85	12,81	12,78
5	12,75	12,71	12,68	12,65	12,61	12,58	12,55	12,52	12,48	12,45
6	12,42	12,39	12,36	12,32	12,29	12,26	12,23	12,20	12,17	12,14
7	12,11	12,08	12,05	12,02	11,99	11,96	11,93	11,90	11,87	11,84
8	11,81	11,78	11,75	11,72	11,69	11,67	11,64	11,61	11,58	11,55
9	11,53	11,50	11,47	11,44	11,42	11,39	11,36	11,33	11,31	11,28
10	11,25	11,23	11,20	11,18	11,15	11,12	11,10	11,07	11,05	11,02
11	10,99	10,97	10,94	10,92	10,89	10,87	10,84	10,82	10,79	10,77
12	10,75	10,72	10,70	10,67	10,65	10,63	10,60	10,58	10,55	10,53
13	10,51	10,48	10,46	10,44	10,41	10,39	10,37	10,35	10,32	10,30
14	10,28	10,26	10,23	10,21	10,19	10,17	10,15	10,12	10,10	10,08
15	10,06	10,04	10,02	9,99	9,97	9,95	9,93	9,91	9,89	9,87
16	9,85	9,83	9,81	9,70	9,76	9,74	9,72	9,70	9,68	9,66
17	9,64	9,62	9,60	9,58	9,56	9,54	9,53	9,51	9,49	9,47
18	9,45	9,43	9,41	9,39	9,37	9,35	9,33	9,31	9,30	9,28
19	9,26	9,24	9,22	9,20	9,19	9,17	8,15	8,13	9,11	9,09
20	9,08	9,06	9,04	9,02	9,01	8,99	8,97	8,95	8,94	8,92
21	8,90	8,88	8,87	8,85	8,83	8,82	8,80	8,78	8,76	8,75
22	8,73	8,71	8,70	8,68	8,66	8,65	8,63	8,62	8,60	8,58
23	8,57	8,55	8,53	8,52	8,50	8,49	8,47	8,46	8,44	8,42
24	8,41	8,39	8,38	8,36	8,35	8,33	8,32	8,30	8,28	8,27
25	8,25	8,24	8,22	8,21	8,19	8,18	8,16	8,15	8,14	8,12
26	8,11	8,09	8,08	8,06	8,05	8,03	8,02	8,00	7,99	7,98
27	7,96	7,95	7,93	7,92	7,90	7,89	7,88	7,86	7,85	7,83
28	7,82	7,81	7,79	7,78	7,77	7,75	7,74	7,73	7,71	7,70
29	7,69	7,67	7,66	7,65	7,63	7,62	7,61	7,59	7,58	7,57
30	7,55	7,54	7,53	7,51	7,50	7,49	7,48	7,46	7,45	7,44

$\ln C_S = 7{,}7117 - 1{,}31403 \ln (t + 45{,}93)$ t...temperature in °C