1 Simultaneous 4-wire resistance measurement with ZOSHBI

This manual focuses on the nomenclature and the suitable physical connections in the case of performing 4-wire resistance and ZOSHBI oxygen sensor measurements simultaneously with default NORECS connector box for 10 channel scanner-card with Keithley 2000 or 6500 model desktop multimeter.

Further details of the measurement, calculations and the senor are in the ZOSHBI manual.

2 Physical connections

2.1 Resistance measurement

2.1.1 ProboStat

The 2-point 4-wire, or 4-point 4-wire resistance measurements occupy four pins of the outer chamber of the Probostat cell. These four pins correspond to the following connectors on the outside of Probostat: HC, HV, LC, LV. (Pins 15, 13, 6 and 8 accordingly).

2.1.2 Connector box

The switch card connects A and B to channel 4, and the C and D to channel 9. Each channel can be measured as such, each being 2-wire 2-point measurement for resistance or voltage. When the instrument is set for 4-probe mode (4-wire mode Kelvin probe mode) the channels 4 and 9 work together so as the current is sourced via channel 4, and the voltage ismeasured on channel 9.

Channels 5 and 10 are also connected to 4 and 9, but with inverse polarity, allowing the user to perform “reverse and average” to eliminate the contribution of thermovoltage to the measurement results. More on this subject can be found in the SeebSys manual.

On the box connect Probostat HC to box A, LC to B, HV to C, LV to D.

2.2 Oxygen sensor measurements

The oxygen sensor requires two voltages measured, the built-in S-type thermocouple and the sensor voltage itself.

The necessary connections occupy all four pins in the inner chamber inside the ProboStat cell. These pins correspond to the following connectors on the outside of Probostat: ILC, ILV, TCB/I (+ and -)

The sensor voltage is to be measured via ILC and ILV, and the sensor thermocouple voltage via the TCB/I positive and negative terminals.

Connect the ProboStat TCB/I to the connector box TCB with a thermocouple compensation cable (standard item from the ProboStat setup, one end of these cables needs to be assembled).

The ILC and ILV are BNC connectors, but the only available terminals left on the connector box are TCT and TCC. The system comes with a suitable adapter cable for connecting two BNC to TCC, as seen in the picture.

On ProboStat use two BNC to Banana adapters (from the adapters kit that comes with the ProboStat system). Connect the adapter cable (supplied with ZOSHBI) so that the thermocouple end is on the connector box TCB, and the banana ends connect to the BNC banana adapters on the ProboStat. The polarity of the cable is so that the yellow banana connects to positive and red banana to negative on the thermocouple plug. The polarity of the sensor is so that the reference gas side electrode is white, connected to pin 3 aka ILC, and the experiment side of the sensor is red, connected to pin 4 aka ILV.

While writing this I'm not sure of the correct polarity of connecting oxygen sensor to voltmeter, in specific what the convention is: reference side to instrument positive or to instrument negative. In any case, it is easy to adjust by inverting red and yellow on ILC and ILV.

NORECS AS
Engervannsveien 39
NO-1337 Sandvika
Norway

3 Omega

Omega can be used to obtain the required properties from the sensor as well as convert them to pO_2 and plot that on the graph section.

Omega has a built-in function to solve for pO_2 using Nernst equation: NERPO2(E,T,R) that returns partial pressure of oxygen in atmospheric pressure (ATM) when measured with zirconia electrolyte with reference gas. E is the sensor voltage, T is the temperature in Celsius, R is the reference gas pO2 in ATM.

3.1 Measuring parameter E

The E is easy to measure, make a node and make it measure voltage type. Let's assume this is measured with Node 1, so it's identifier prefix is $N1 and suffix is .MV in the expression parser, or $N1.MV as whole.

See Omega manual for more details on expression parser.

3.2 Parameter R

R is known from what gas is sent to flush the Oxygen sensor.

3.3 Parameter T

To obtain accurate T is important, as the Nernst equation is very sensitive to temperature inaccuracies.

Omega has two built-in functions to help with this task: TCS(V,T) and TT2(R) where TCS stands for Thermocouple S type and returns temperature in °C. V is the thermocouple voltage and T is the cold junction compensation temperature. TT2 is Thermistor Temperature (type 2) and R is for resistance.

They are used nested like TCS(V, TT2(R)), so the result of the TT2 function becomes the T parameter for the TCS function.

To get a temperature from S type thermocouple thermocouple voltage is needed along with cold junction compensation information. The former is easy as measuring a voltage, and the latter is made easy by the connector box and Omega, by allowing user to measure resistance of a specific type of thermistor inside the connector box, and using the TT2 function to convert the resistance to a temperature.

Let Node 2 be of voltage measurement type, and it's reference in expression parser therefore $N2.MV, and a Node 3 be of 2 wire resistance measurement type, and it's reference therefore $N3.M2.

The expression to get absolute temperature of the thermocouple in Omega would therefore be TCS($N2.MV, TT2($N3.M2))

3.4 Expression for pO_2

Combining all above into one expression results NERPO2($N1.MV, TCS($N2.MV, TT2($N3.M2)), R) where R is still to be replaced by the ATM pO2 of the reference/flush gas, such as 0.209 or 0.21 for bottled air.

This expression can be used in the graphs section to plot the pO_2 accordingly.

4 Use with Omega

This section is almost same as the ZOSHBI manual, but modified to account for the 4-w resistance measurement done simultaneously.

4.1 Measurement

Usage with immediate data feedback is often necessary to get the somewhat complicated process to work. Omega needs to be set to measure sensor voltage, electrolyte voltage, and a temperature used as cold junction compensation. The process is much like using MOSE sensor, except the function used to solve for pO_2 is different.

Say the sensor ZOSHBI thermocouple is connected to TCB/I (pins 1 & 2), the sensor voltage to pins ILC (pin 3) and ILV (Pin 4). If the measurement is done with ProboStat connection box (with DMM6500) these can be connected from ProboStat to TCB and C&D on the connector box. Corresponding channels to measure would be

	ZOSHBI thermocouple	ZOSHBI sensor voltage	Cold junction Temp
Pins on ProboStat	1+(black) & 2-(Red)	3 & 4	-
Connectors on ProboStat	TCB/I	ILC and ILV	-
Connector on connector box	TCB	With BNC to TC adapter connect to TCC	-
Channel on switch card	3	2	7 Channel terminates inside the box with a thermistor. It's resistance is accurately a function of temperature inside the box.
Node example name	Node 1 – Zoshbi TC	Node 2 – Zoshbi voltage	Node 3 – Box temp
Node variable prefix	$N1.	$N2.	$N3.
Node type	MV	MV	M2
Node full variable	$N1.MV	$N2.MV	$N3.M2
Instrument commands before measurement (DMM 6500 only)	*CLS :SENS:FUNC "VOLT:DC", (@**3**) :ROUT:DEL 1, (@**3**) :ROUT:CLOSE (@**3**) :READ?	*CLS :SENS:FUNC "VOLT:DC", (@**2**) :ROUT:DEL 1, (@**2**) :ROUT:CLOSE (@**2**) :READ?	*CLS :SENS:FUNC "RES", (@**7**) :ROUT:CLOSE (@**7**) :READ?
Instrument commands after measurement (DMM 6500 only)	:ROUT:OPEN:ALL	:ROUT:OPEN:ALL	:ROUT:OPEN:ALL

4.2 Calculations

With the above setup, in the graphs-section, the NERPO2(E,T,R) expression will calculate/plot the pO_2 of the cell. First however, we need the accurate temperature of the sensor tip: TCS($N2.MV, TT2($N3.M2))

NERPO2($N1.MV, TCS($N2.MV, TT2($N3.M2)), 0.209) where the 0.209 is the reference gas oxygen content in units of ATM.

NORECS AS
Engervannsveien 39
NO-1337 Sandvika
Norway

4.3 4w-resistance

A, B, C and D on the connector box are reserved for 4-wire resistance measurement. It is worth considering performing just 2-wire measurement unless the sample is highly conductive. This measurement uses the connector box channels 4 & 9

	Top probes	Bottom probes
Pins on ProboStat	15 & 13	8 & 6
Connectors on ProboStat	HC & HV	LV & LC
Pin, Role:Input/Current -> Connector on connector box	15, HC -> A	6, LC -> B
Pin, Role:Sense/Voltage -> Connector on connector box	13, HV -> C	8, LV -> D
Channel on switch card	4 (HC and LC)	9 (HV and LV)
Node example name	Node 4 - Top	Node 5 - Bottom
Node variable prefix	$N4.	
Node type	M4	
Node full variable	$N4.M4	
Comments	Do note that this being node 4 is coincidental, that this happens to measure channel 4 is also coincidental, and that the four wire node type is called M4, is also coincidental. This could just as well be node 9, measuring on channel 3.	
Instrument commands before measurement (DMM 6500 only)	*CLS :SENS:FUNC "FRES", (@4) :SENS:FRES:OCOM OFF :ROUT:CLOSE (@4) :READ?	The mode “FRES” automatically pairs channel @4 with +5 channel, i.e. @9, to get the sense, the voltages.
Instrument commands after measurement (DMM 6500 only)	:ROUT:OPEN:ALL	:ROUT:OPEN:ALL

Or the connection scheme for 4-wire/kelvin probe as a picture.

4.4 Reverse and average

Do note the thermal gradient contributes voltage as the Pt wires and the sample are dissimilar along the temperature gradient. To eliminate the contributionperform reverse and average by measuring “FRES” on channel 5 (and 10). And averaging the results from the two measurements. This method is explained in greater detail in other manuals. This can also be remedied by some instrument options.