Operating Instructions

for the

PLUGSYS®

Electrometer Modul EMM Typ 696
(Version: 1.0 Printed: 29.05.02 from Ser.No. 96001 / T. Beha)

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1. Introduction, manufacturer's details

These Operating Instructions describe the operation and use of the **EMM** Module Type 696. It is part of the equipment and should be kept close to it.

All the information in these Instructions has been drawn up after careful examination but does not represent a warranty of product properties. Alterations in line with technical progress are reserved.

This PLUGSYS module is manufactured by:

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Trademark

PLUGSYS is a registered trademark of Hugo Sachs Elektronik, March/Hugstetten, Germany.

2. Safety note

Important: This equipment is not suitable for operation in hazardous areas and/or in a flammable atmosphere.

The equipment is not approved for measurement on humans!

3. General description, applications

The HSE Electrometer module **EMM** Type 696 is a high-impedance electrometer plug-in amplifier for the PLUGSYS measuring system. It is used to measure concentrations with potentiometric electrochemical sensing electrodes. The main application is recording of pCO_2 or Na^+, K^+, Mg^{++}, Cl^- and Ca^{++} concentrations in biological fluids such as perfusate for isolated perfused organs, using the corresponding electrodes e.g. model 501, 625 , 601 and 603. Using this special electrodes mounted in a flow-through chamber it is possible to make continuous measurements over hours or days. Changes or fluctuations in these parameters can be recorded continuously.
In order to avoid interaction where several electrochemical parameters (such as pO_2, pH, Na^+, K^+ or Ca^{++}) are being measured continuously, this module incorporates an input with isolating amplifier. This also avoid possible hum interference. The input circuit is isolated from the output circuit and the housing through the isolating amplifier.

The measurement of all these parameters is based on a potentiometric princip, this means that all electrodes deliver a voltage, depending of the specific ion concentration at the tip of the electrode. The measured voltage is indicated on a 3 1/2 digit LED display.

The amplified mV signal is available as analogue voltage at a BNC socket on the front panel and also internally on the PLUGSYS system bus for recording or data acquisition. Gain can be changed internally with a jumper in the following ranges: x10, x20, x50, x100.

Using ion selective Elektrodes for Na^+, K^+ or Ca^{++} with logarithmic caracteristic, requires a calculation to receive the exakt concentration of Ions in the solution. This has already be done in the HSE software ISOHEART, HAEMODYN and PULMODYN.
For calibration a recorder or computer data acqisition system a simulating device which can simulate two fixed mV values is provided.

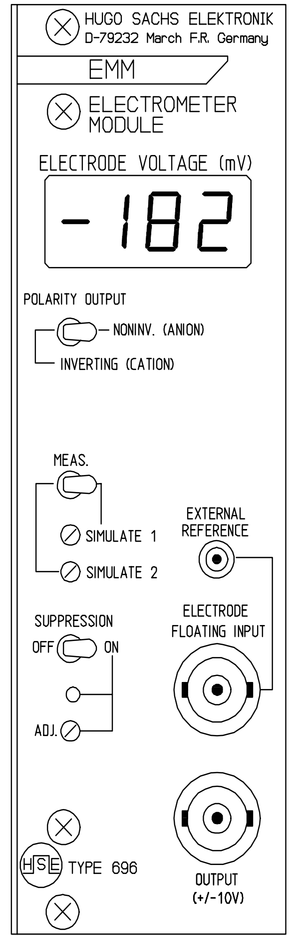


Fig. 1 Front panel

For using the **EMM** module it has to be installed in a PLUGSYS housing Series 600.

4. Installing the module in a housing

(If the module has been supplied already installed you can omit Section 4 and continue with Section 5. If you have received the module as a separate unit you should continue here.)

Before you can use the **EMM** module it has to be installed in a suitable HSE PLUGSYS housing Series 600 (April. 96: 601 to 607). If the module is supplied as part of a completely installed PLUGSYS measuring system the work described below has already been carried out and the selected signal paths have been entered in the bus diagram.

Before the module is installed in a housing the connections of the module to the bus lines have to be determined by plugging in links as described in the next section (Section 4.1).

Do not forget to enter the selected connections in the bus diagram (in the white Operating Manual folder under Section 1).

Brief procedure (for full details see the Operating Manual of the housing):

• Pull out the mains plug on the housing.
• Remove the blank panel at the housing slot position intended for the **EMM** module.
• Prepare module according to Section 4.1 (set lines and links).
• Insert the **EMM** module, note the guide rails.
• Push the module firmly into the bus connector.
• Screw on the front panel.
• Connect up the pH electrode.
• Reconnect the mains plug to the housing.
• Switch on the housing.

4.1 Internal instrument settings, links

Warning: the **EMM** module must be protected against electrostatic discharges while it is outside the housing! The **EMM** module contains highly sensitive MOS components which can be damaged or destroyed by electrostatic discharges. If you dismantle the module or if you carry out any operations on the dismantled module you must ensure potential equilibration before touching any part of the printed circuit (by touching some grounded metal part, e.g. water tap, central heating radiator. grounded housing, PLUGSYS housing or similar).

Before you install the **EMM** module into the PLUGSYS housing it is necessary to set a link on the circuit board in order that the output signal is linked to the appropriate or required bus line. The module can only be used in conjunction with the complete system if the bus lines have been connected up correctly.

Do not forget to enter the selected signal assignment in the bus diagram for the PLUGSYS housing (the bus diagram is filed in the Operating Manual folder under Section 1).

If the module is supplied as part of a completely installed PLUGSYS measuring system, the operations described below have already been completed and the selected signal paths have been entered in the bus diagram.

The location of the link is shown in the illustration next page. The following linkages can be set:

- Signal output AV_MV to transfer the mV value to the PLUGSYS bus system
- Signal output AV_MV_SU to transfer the mV value with suppression to the PLUGSYS bus system, selected by switch

4.11 Signal output AV_MV to transfer mV signal to PLUGSYS bus system

The link AV_MV transfers the potential measured at the electrode to the PLUGSYS bus after multiplication by a factor of 10.
If this voltage is required the link must be set to the required channel (AV1 - AV16). When the module is supplied alone, this link is in the parking position. If the module comes mounted in a PLUGSYS basic system case all these settings are done. The signal is transmitted through the PLUGSYS bus to a recorder or a data acquisition system. **(See Fig. 2 D)** In this example AV_MV is not used. The mainly used output is AV_MV_SU.

Please note:
This signal is affected by the Jumper J2 **(Fig. 2 C)**. With this jumper the mV signal from the eletrode can be reversed. This signal is **not** affected by the **"SUPPRESSION"** switch and also not by the **"NONINV.(ANION) / INVERTING (CATION)** switch. It gives the direct reading of the electrode in mV x10.

Jumper right --> signal not reversed (normal setting on delivery)
Jumper left --> signal reversed
See also Fig 2 C.

Input Voltage [mV]	Outp. AV_MV not reversed [V] Jumper right	Output AV_MV reversed [V] Jumper left
+110	+1.10	-1.10
0	0	0
-110	-1.10	+1.10

Note:

When selecting the bus line (AV1...16) be sure to use a free line and check this in the bus diagram. If there is no appropriate information in the bus diagram you can determine the bus line assignment only by removing all the modules and determining the signal paths selected on them using the corresponding operating instructions.

4.12 Output AV_MV_SU for transfer suppressed analog mV signal to the bus system with SUPPRESSION and selectable gain

The link AV_MV_SU transfers the measured voltage of the electrode multiplied with the gain to one of the 16 possible analogue lines. The gain is set by jumper GAIN (see Fig. 2 B).
Is SUPPRESSION switched ON so the output voltage is suppressed according to the settings of the ADJ. trimmer.
If electrodes with high offset voltages are used or the experiment requires ranges, where relative small changes with some 100mV electrode voltages should be measured, the SUPPRESSION is absolutely required. The second advantage of output AV_MV_SU is that the gain can be changed.

Here again the link must be plugged in the required channel AV1 - AV16. The signal is then passed through the PLUGSYS bus to a recorder or data capture system. When the module is supplied alone, the link is in the parking position. (See Fig. 2D)

Please note:
This signal is affected by the **"SUPPRESSION"** switch and also by the **"NONINV.(ANION) / INVERTING (CATION)** switch. Each change on one of these switches changes also the output signal. This signal is also available on the BNC output on the front panel.

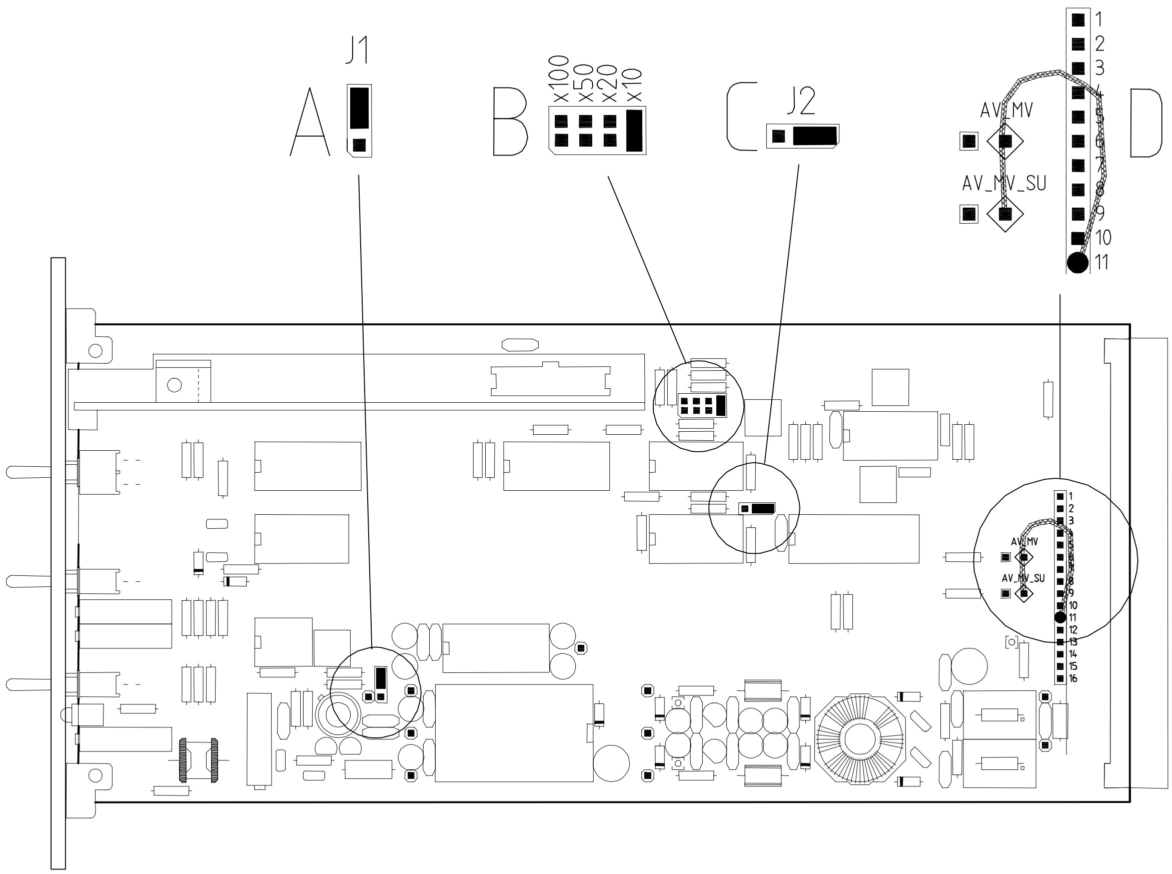


Fig. 2: Position of the internal links

In example Fig. 2 D the signal output AV_MV is not used. The signal output AV_MV_SU is set to channel AV11. The jumper J1 (A) is set so that the input filter is set to 0.2 Hz. The gain is set to x10 (B). The mV signal is not reversed, Jumper J2 (C).

4.2 Setting GAIN for internal output AV_MV_SUP (Fig.: 2B)

With this jumper the Gain can be set in the following ranges: x10, x20, x50, x100

Electrode voltage [mV]	GAIN Jumper	Output AV_MV_SUP [V] SUPPRESSION OFF	Output AV_MV_SUP [V] SUPPRESSION ON

+10	10	0.1	0.1 + SUP.-value
+10	20	0.2	0.2 + SUP.-value
+10	50	0.5	0.5 + SUP.-value
+10	100	1.0	1.0 * SUP.-value

4.3 Filtering the electrode signal, filter setting with Jumper J1 (Fig.: 2A)

Two low-pass filters are available for use with the electrode signal:

Jumper J1 up --> filter 0.2 Hz (time constant 5 seconds)
Jumper J1 down --> filter 0.8 Hz (time constant 1.25 seconds)

As the average reaction time of mini electrodes is about 30 seconds both ranges can be used. It is recommended to use the 0.2 Hz setting (factory setting) since the indication is more stable here and does not jump continually. See Fig 2 A.

5. Starting up

After the electrode has been prepared and the electrode cable has been connected to the input socket the housing can be switched on and measurement can begin.

5.1 Calibrating the pCO_2 electrode

The description below assumes that a pCO_2 electrode Type 501 and a thermostated flow-through chamber (HSE Chemical Electrode Chamber) are being used.

Basic principle of calibrating electrodes:
In order to avoid measurement errors it is important that calibration takes place at the same temperature as the subsequent measurements. The entire measurement in the electrode chamber depends on flow rate and it is therefore important that the pumping speed of the roller pump is the same during calibration and during measurement. The recommended flow rate through the chamber should be between 1 and 2 ml/min (check pump output volumetrically). In principle the calibration should be repeated daily.

Procedure:
It is assumed that the circulation thermostat has already been operating for at least 5 min and the electrode chamber has warmed up. In order to ensure chemical stability the electrode should already have been stored in electrolyte solution for at least 24 hours.

(1) Connect the pCO_2 electrode to the EMM module. Switch **"NONINV.(ANION) / INVERTING (CATION)"** in position **NONINV.(ANION)** (pCO_2 electrode has a caracteristic with positiv slope, so inverting is not necessary).

(2) Place a little perfusion solution into two small conical flasks (50 ml). Pass Carbogen (95% O_2, 5% CO_2) through one of the flasks, and a mixture of carbogen and room air through the other (use frits). This operation is best performed using a multi-channel roller pump. One channel pumps Carbogen, the second one room air. The mixture of room air with 0.03% CO_2 and Carbogen with 5% CO_2 produces a content of approx. 2.5% CO_2. See also Fig. 3.

In this way two solutions are obtained, one containing 5% CO_2 and the other 2.5% CO_2; using these solutions the calibration can readily be performed.
The solutions should be warmed to the temperature of the chamber in order to achieve the same temperature conditions for calibration as for the measurement.

It is also possible to perform the calibration using Carbogen (95% O_2, 5% CO_2) and nitrogen (100% N); it would however take a long time (more than 30 min) until the solution is 100% saturated with nitrogen.

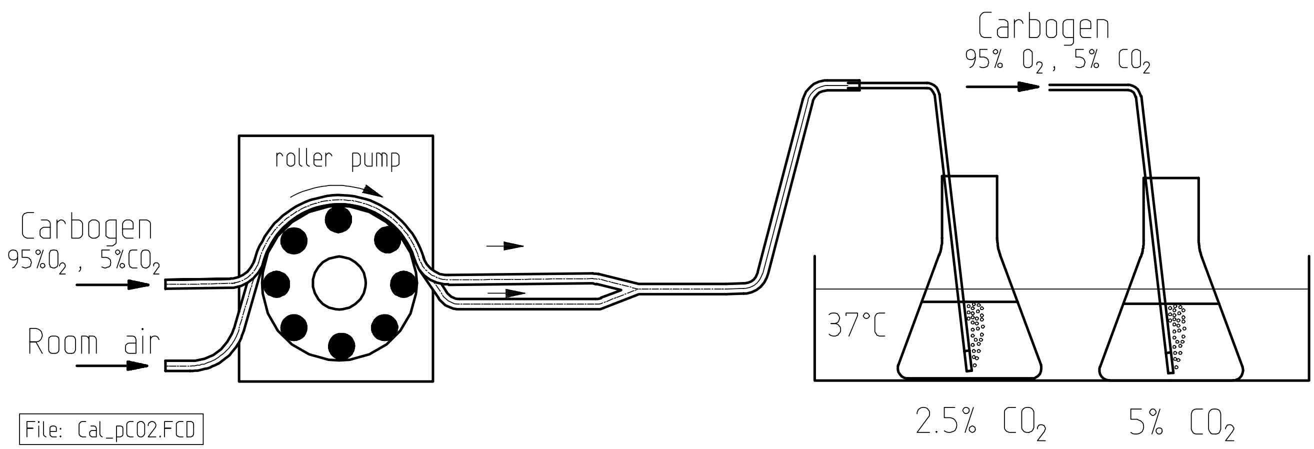


Fig. 3: Calibration setup for pCO_2 electrodes

(3) Prepare the chamber with the electrodes for measurement.

(4) Start up the roller pump. Hold the suction tubing of the chamber into air until an air bubble approx. 30 mm long has been formed in the tubing. Stop the roller pump again.

(5) After gas has been passed through the two calibration solutions for about 15 min, hold the inlet tubing of the chamber into the flask with 2.5% CO_2. Start the roller pump.
As soon as the system (chamber + tubing) contains only gassed pCO_2 solution, pump this solution in a closed loop.

(6) After the pCO_2 reading (mV) has become steady (approx. 30 - 60 sec) set the same mV value with SIMULATE 1. Hold switch **"SIMULATE 1 / MEAS. / SIMULATE 2"** in position **"SIMULATE 1"** and adjust with trimmer **"SIMULATE 1"** the display until it shows the same value as measured with 2.5% CO_2.
This means that now switching to **"SIMULATE 1"** simulates the same output voltage as measured with the pCO_2 electrode in solution with 2.5% CO_2 or a pCO_2 value with 19mmHg.

(7) Hold the chamber suction tubing again into the air until an air bubble approx. 30 mm long has been formed in the tubing. Then hold the tubing into the flask with 5% CO_2. The air bubble separates the two solutions.

(8) As soon as the system contains only solution gassed with 5% CO_2, pump this solution in a closed loop.

(9) After the pCO_2 reading on the meter has become stable at the new value (after approx. 30 sec), set the same mV value with SIMULATE 2. Hold switch **"SIMULATE 1 / MEAS. / SIMULATE 2"** in position **"SIMULATE 2"** and adjust with trimmer **"SIMULATE 2"** the display until it shows the same value as measured before.

This means that now switching to **"SIMULATE 2"** simulates the same output voltage as measured with the pCO_2 electrode in solution with 5% CO_2 or a pCO_2 value with 38mmHg.

Note: If pO_2 is also being measured at the same time, the 95% value for pO_2 measurement can be calibrated at the same time provided calibration is performed with Carbogen (95% O_2, 5% CO_2).

The measured mV values for the two calibration solutions are roughly as follows:

pCO_2	mV
2.5%	-160 to -180
5%	-130 to -150

As a check the two calibration points should be re-checked alternatively. If there are larger deviations, steps 4 to 9 have to be repeated.

When the EMM has been calibrated to the pCO_2 electrode the measurement can be started under the same conditions (constant temperature, constant flow).
The reaction time of the electrode type 501 is approx. 30 seconds. The electrode slope is approx. 0.4mV/mmHg pCO_2 or 3mV/% CO_2. The slope is positiv, i.e. the mV value becomes less negative as the CO_2 percentage increases. During the experiment, check that the chamber is free from bubbles.

5.2 Arranging a pCO_2 scale on the recorder

After the simulation values have been set as indicated in Section 5.1 the recorder can readily be calibrated.
It is now assumed that the PLUGSYS housing is switched on and ready for use and that a recorder with 8 cm writing width per channel is connected up.
It is of course possible to use some other recorder with a different writing width and chart scaling. It is however necessary to have adequate sensitivity of at least 1 Volt for full-scale deflection.

Assumptions:	
Required pCO_2 range:	2.5% to 5% (19mmHg to 38mmHg)
Writing width:	80 mm
Chart scale grid:	every cm and mm

The simulation values have been set in the calibration (See Cap. 5.1) to 2.5%CO_2 and 5% CO_2.
In the following examples four differend recorder calibrations are described:

I) 2,5m pen deflection corresponds to 2.5%, 5 cm pen deflection corresponds to 5%, this means 1% is 1cm. The whole scale goes from 0 to 8% CO_2.

II) 0 corresponds to 2,5% CO_2, 5cm corresponds to 5% CO_2 (using the suppression gives the possibility that at 2.5% the pen is on Zero position and at 5% the pen has a deflection of 5cm. In this case the whole scale goes from 2.5% to 6.5% CO_2.

III) 19mmHg pCO_2 correspond to 38mm pen deflection, 38mmHg correspond to 76mm pen deflection. In this case the whole scale goes from 0 to 40 mmHg pCO_2.

IV) 19mmHg pCO_2 correspond to 8mm pen deflection, 38mmHg correspond to 46mm pen deflection. In this case the whole scale goes from 15mmHg to 55 mmHg pCO_2.

Procedure according example I:

(A) Position the recorder pen at the bottom edge of the chart. Zero the recorder input. Set with position the pen to 2.5 cm from the bottom line.

(B) On the EMM set the **SUPPRESSION** switch to **ON**. The green LED **"ADJ"** is alight.

(C) Start the chart drive (e.g. 100mm/min). Move switch **SIMULATE 1 / MEAS / SIMULATE 2** to **SIMULATE 1** and hold it there. The display shows the mV value for 2.5% CO_2 or 19mmHg pCO_2.
Now adjust again the pen to 2.5cm with trimmer ADJ. using a screwdriver. The zero line now corresponds to 2.5% CO_2.
When you release the switch the value is hold for further 10 seconds.

(D) Move switch **SIMULATE 1 / MEAS / SIMULATE 2** to **SIMULATE 2** and hold it there. The display shows the mV value for 5% CO_2 or 38mmHg pCO_2.
Now adjust the recorder gain so that the pen has a deflection of 5cm. This value corresponds to 5% CO_2 and 1cm correspond to 1% CO_2

(E) Checking the adjustment:
Run the recorder at a slow speed. Switch **SIMULATE 1 / MEAS / SIMULATE 2** on **MEAS**. The value present measured value of the electrode is being indicated and shown on the chart. Move the switch briefly to **SIMULATE 1**. The value for 2.5% CO_2 is now being simulated for 10 sec, the pen deflection is 2.5cm. Next move the switch to **SIMULATE 2**. 5% CO_2 is now being simulated for 10 sec, the pen deflection is 5cm.

By quickly keying in the simulation values it is possible at any time (also during an experiment) to check the recorder settings.

Please note:
Simulation does not replace the calibration! Simulation only provides output values for a recorder. During a measurement these are only correct if the electrode has been calibrated correctly!
A pCO_2 electrode can only be calibrated by the use of bubbling a solution with calibrated CO_2 gasses ! See Section 5.1.
Calibration or checking of calibrated values should be performed at least once a day. The better method is to follow GLP and check before and after each experiment.

Procedure according example II:

(A) Position the recorder pen at the bottom edge of the chart. Zero the recorder input. Set with positon the pen to zero line.

(B) On the EMM set the **SUPPRESSION** switch to **ON**. The green LED **"ADJ"** is alight.

(C) Start the chart drive (e.g. 100mm/min). Move switch **SIMULATE 1 / MEAS / SIMULATE 2** to **SIMULATE 1** and hold it there. The display shows the mV value for 2.5% CO_2 or 19mmHg pCO_2.
Now adjust the pen to zero with trimmer ADJ. using a screwdriver. The zero line now corresponds to 2.5% CO_2.
When you release the switch the value is hold for further 10 seconds.

(D) Move switch **SIMULATE 1 / MEAS / SIMULATE 2** to **SIMULATE 2** and hold it there. The display shows the mV value for 5% CO_2 or 38mmHg pCO_2.
Now adjust the recorder gain so that the pen has a deflection of 5cm. This value corresponds to 5% CO_2, so 1cm corresponds to 0.5% CO_2

(E) Checking the adjustment:
Run the recorder at a slow speed. Switch **SIMULATE 1 / MEAS / SIMULATE 2** on **MEAS**. The value present measured value of the electrode is being indicated and shown on the chart. Move the switch briefly to **SIMULATE 1**. The value for 2.5% CO_2 is now being simulated for 10 sec, the pen deflection is zero. Next move the switch to **SIMULATE 2**. 5% CO_2 is now being simulated for 10 sec, the pen deflection is 5cm.

By quickly keying in the simulation values it is possible at any time (also during an experiment) to check the recorder settings.

Please note:
Simulation does not replace the calibration! Simulation only provides output values for a recorder. During a measurement these are only correct if the electrode has been calibrated correctly!
A pCO_2 electrode can only be calibrated by the use of bubbling a solution with calibrated CO_2 gasses ! See Section 5.1.
Calibration or checking of calibrated values should be performed at least once a day. The better method is to follow GLP and check before and after each experiment.

Procedure according example III:

(A) Zero the recorder input. Set the pen to 38mm pen deflection with position knob.

(B) On the EMM set the **SUPPRESSION** switch to **ON**. The green LED **"ADJ"** is alight.

(C) Start the chart drive (e.g. 1mmm/s). Move switch **SIMULATE 1 / MEAS / SIMULATE 2** to **SIMULATE 1** and hold it there. The display shows the mV value for 2.5% CO_2 or 19mmHg pCO_2.
Now adjust the pen to 38mm with trimmer ADJ using a screwdriver. The 38mm line now corresponds to 19 mmHg CO_2.
When you release the switch the value is hold for further 10 seconds.

(D) Move switch **SIMULATE 1 / MEAS / SIMULATE 2** to **SIMULATE 2** and hold it there. The display shows the mV value for 5% CO_2 or 38mmHg pCO_2.
Now adjust the recorder gain so that the pen has a deflection of 76mm. This value corresponds to 5% CO_2, so 1cm corresponds to 5mHg pCO_2

(E) Checking the adjustment:

Run the recorder at a slow speed. Switch **SIMULATE 1 / MEAS / SIMULATE 2** on **MEAS**. The value present measured value of the electrode is being indicated and shown on the chart. Move the switch briefly to **SIMULATE 1**. The value for 2.5% CO_2 is now being simulated for 10 sec, the pen deflection is 38mm. Next move the switch to **SIMULATE 2**. 5% CO_2 is now being simulated for 10 sec, the pen deflection is 76mm.

By quickly keying in the simulation values it is possible at any time (also during an experiment) to check the recorder settings.

Please note:
Simulation does not replace the calibration! Simulation only provides output values for a recorder. During a measurement these are only correct if the electrode has been calibrated correctly!
A pCO_2 electrode can only be calibrated by the use of bubbling a solution with calibrated CO_2 gasses ! See Section 5.1.
Calibration or checking of calibrated values should be performed at least once a day. The better method is to follow GLP and check before and after each experiment.

Procedure according example IV:

(A) Zero the recorder input. Set the pen to 8mm pen deflection with position knob.

(B) On the EMM set the **SUPPRESSION** switch to **ON**. The green LED **"ADJ"** is alight.

(C) Start the chart drive (e.g. 100mm/min). Move switch **SIMULATE 1 / MEAS / SIMULATE 2** to **SIMULATE 1** and hold it there. The display shows the mV value for 2.5% CO_2 or 19mmHg pCO_2.
Now adjust the pen to 8mm with trimmer ADJ using a screwdriver. The 8mm line now corresponds to 19 mmHg CO_2.
When you release the switch the value is hold for further 10 seconds.

(D) Move switch **SIMULATE 1 / MEAS / SIMULATE 2** to **SIMULATE 2** and hold it there. The display shows the mV value for 5% CO_2 or 38mmHg pCO_2.
Now adjust the recorder gain so that the pen has a deflection of 46mm. This value corresponds to 39 mmHg pCO_2, so 1cm corresponds to 5mHg pCO_2 but the scale is
-compared to example III- shifted down by 3 cm.

(E) Checking the adjustment:
Run the recorder at a slow speed. Switch **SIMULATE 1 / MEAS / SIMULATE 2** on **MEAS**. The value present measured value of the electrode is being indicated and shown on the chart. Move the switch briefly to **SIMULATE 1**. The value for 2.5% CO_2 is now being simulated for 10 sec, the pen deflection is 8mm. Next move the switch to **SIMULATE 2**. 5% CO_2 is now being simulated for 10 sec, the pen deflection is 46mm.

By quickly keying in the simulation values it is possible at any time (also during an experiment) to check the recorder settings.

Please note:
Simulation does not replace the calibration! Simulation only provides output values for a recorder. During a measurement these are only correct if the electrode has been calibrated correctly!
A pCO_2 electrode can only be calibrated by the use of bubbling a solution with calibrated CO_2 gasses ! See Section 5.1.
Calibration or checking of calibrated values should be performed at least once a day. The better method is to follow

GLP and check before and after each experiment.

5.3 Calibration of ion selective electrodes as K^+, Na^+, Ca^{++}, Mg^{++}, Cl^-

To calibrate ion selective electrodes calibration solutions have to be made. For example for K^+ three concentrations with 2, 4 and 6 mmol/l have to be prepared. The two point calibration is performed with 2mmol/l and 6mmol/l. The 4 mmol/l concentration can be used to check the electrode. See also operating instructions of the particular electrode.

Because ion selective electrodes generally have a logarithmic characteristic a delogarithmic calculation has to be performed to receive the exakt concentration of Ions in the solution. This has already be done in the HSE software ISOHEART, HAEMODYN and PULMODYN.

Calculation of the concentration of ions in a solution:

The main formula for the electrode slope is:

$$m = \frac{E - E_0}{\log C / C_0}$$

where m is the slope of the electrode
E is the electrode voltage at concentration C
E_0 is the electrode voltage at concentration C_0
log is the decadic logarithm

From this formula we get the formula to calculate the concentration:

$$C = C_1 * 10^{\left(\frac{E * \log C_1 / C_2}{E_{C1} - E_{C2}} - \frac{E_{C1} * \log C_1 / C_2}{E_{C1} - E_{C2}}\right)}$$

where C is the calculated concentration
E is the electrode voltage at the calculated concentration
C_1 and C_2 are the concentrations used for the two point calibration
E_{C1} and E_{C2} are the electrode voltages got with the calibration concentrations

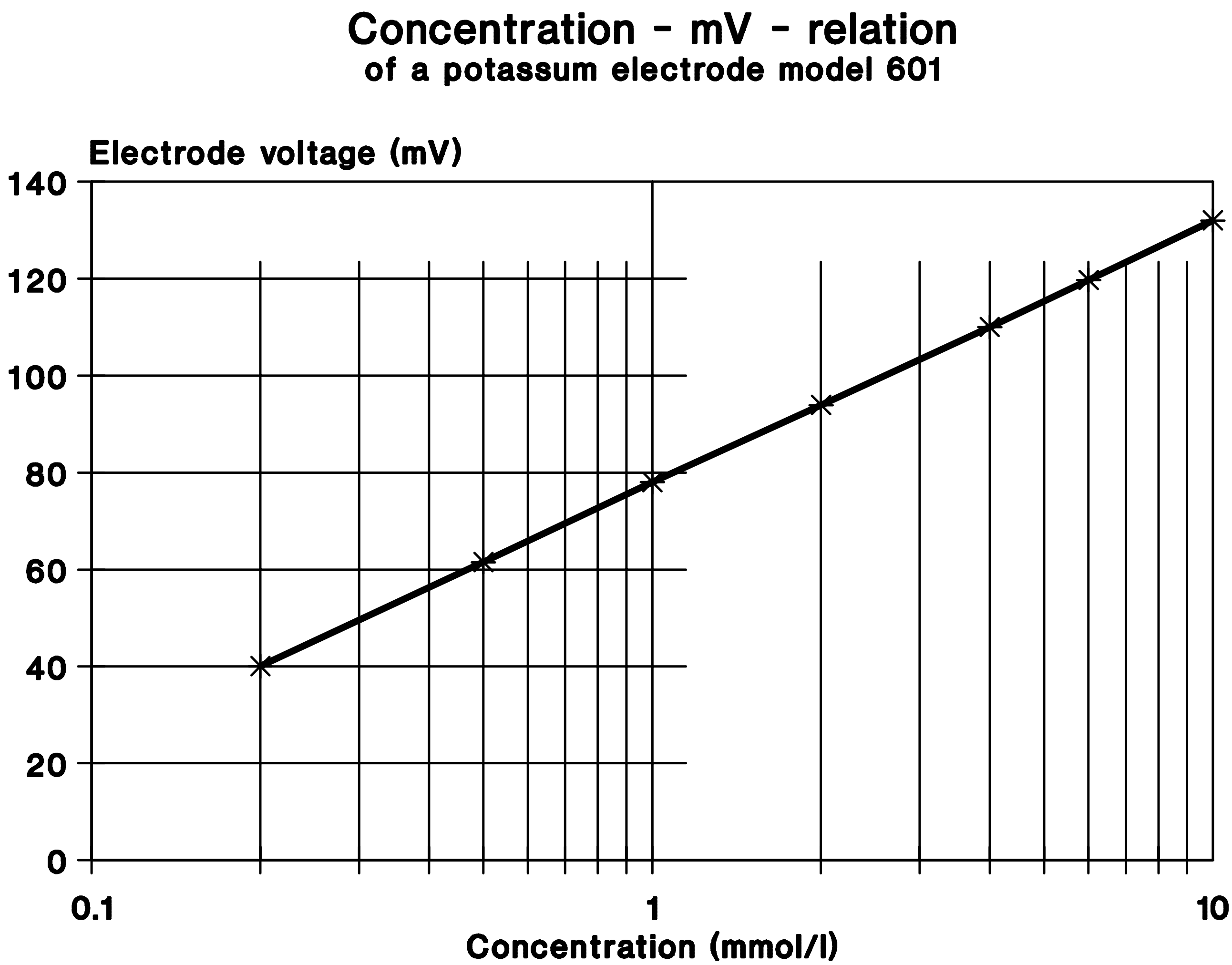


Fig. 3 Concentration - mV relation of a K^+ electrode model 601

For recorder applications the voltage of the electrodes has to be measured and the calculation of the concentration has to be made from the chart.

5.4 Experiment

If the pCO_2 electrode has been calibrated the measurement can now be started under the same conditions (constant temperature, constant flow).
The reaction time of the electrodes is about 30 to 60 seconds (combination pCO_2 electrode model 501). The electrode sensitivity is approx. 0.4mV/mmHg CO_2 that results in 20mV voltage change from 2,5% to 5% CO_2 or. from 19mmHg to 38mmHg.

6. Input

The **EMM** module carries a BNC input socket for combination electrodes. Alternatively, electrodes with an external

reference electrode can be used; the reference electrode is connected to the black input socket EXTERNAL REFERENCE (2 mm socket).
The input is floating, i.e. isolated from ground. This is necessary in order to prevent mutual interference if several electrochemical values such as pO_2, pH, Na^+, K^+ oder Ca^{++} are being measured continuously at the same time. Isolation also prevents hum interference. The input circuit is isolated from the output circuit and the housing by an isolating amplifier.

7. Description of the controls

(1) Display to indicate mV value.

(2) POLARITY OUTPUT switch. This switch sets the polarity of the output. **NONINV.(ANION)** is used for electrodes with positive slope, **INVERTING (CATION)** is used for electrodes with negative slope. The BNC socket **OUTPUT** (9) carries, depending on the switch setting the voltage corresponding to the measured mV.

(3) Switch **SIMULATE 1 / MEAS / SIMULATE 2**. This switch automatically returns to the central **MEAS** position and is used to simulate two freely selected mV values in order to simplify the calibration of a recorder or data acquisition system. If the switch is pushed to the right to **SIMULATE 1**, the mV value set on the trimmer **SIMULATE 1 (4)** is shown on the display and appears at the output. After releasing the switch it jumps back to its central position; the simulated mV value is however held for a further 10 sec approx. in order to permit readjustment of the recorder without having to hold down the switch continuously. In the left position **SIMULATE 2** the mV value set on the trimmer **SIMULATE 2 (5)** is shown on the display and appears at the output. Here again the simulated mV value is held for a further 10 sec approx.

(4) Trimmer **SIMULATE 1**: This trimmer is used to set the first mV simulation value. To do this, push the switch **SIMULATE 1 / MEAS / SIMULATE 2** to the **right**, hold it there and, using a screwdriver, set the required value as shown on the display. See also Section 5.1

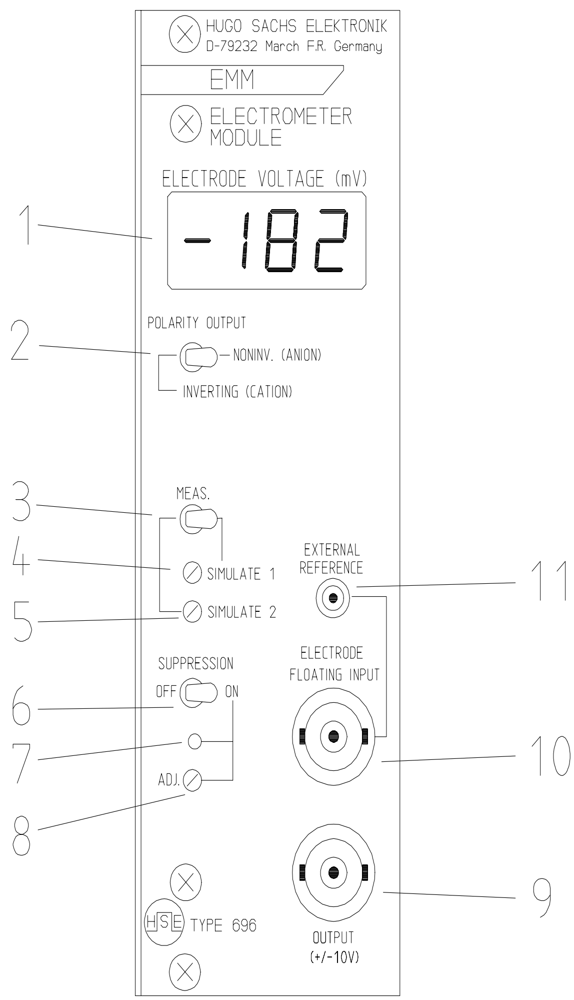


Fig.3 Controls on the front panel

(5) Trimmer **SIMULATE 2**: This trimmer is used to set the second mV simulation value. To do this, push the switch **SIMULATE 1 / MEAS / SIMULATE 2** to the **left**, hold it there and, using a screwdriver, set the required value as shown on the display. See also Section 5.1

(6) Switch **SUPPRESSION OFF/ON**. Using this switch the range suppression can be switched on and off. This function is required when using a recorder or data acquisition software.

If the **SUPPRESSION is OFF**, at the internal output AV_MV_SU and at the BNC socket on the frontpanel the displayed mV value amplified with the internal gain (selectable x10, x20, x50, x100) appeares.

For example: with 5% CO_2 (38mmHg pCO_2) a voltage of -160mV is measured and with 2,5% CO_2 (19mmHg) a voltage of -185mV is measured. In this case with gain 50 we receive for 5%CO_2 a voltage of -8V and for 2.5% CO_2 we receive -9V.
Now the problem appeares that the chart recorder can not be adjusted far enough so that 2.5% can be shown at chart zero. This problem is avoided by switching on the SUPPRESSION function. If the **SUPPRESSION** switch is set to **ON** the output voltage range can be shifted with the **ADJ trimmer**; 2.5% can then be placed on 0 Volt. In this way the range from 2.5% to 5% can be shown enlarged on the recorder. See also Section 5.2.

(7) LED **"SUPPRESSION ON"**. This LED lights up as soon as SUPPRESSION is switched on.

(8) Trimmer **ADJ**. This trimmer is used to adjust the range suppression. To set CO_2 concentration to recorder zero, the **SUPPRESSION** must be switched on. Then a mV value can be simulated with **SIMULATE 1**. Using the **ADJ** trimmer the recorder pen is then set to the required position.

(9) BNC socket **OUTPUT**. This output socket carries, the amplified electrode voltage.
If **SUPPRESSION** is switched on, this socket carries the mV signal with range suppression.

(10) BNC socket **ELETRODE FLOATING INPUT**. This socket is used to connect the electrode.

(11) 2 mm socket **EXTERNAL REFERENCE**. This socket is used to connect an external reference electrode when using a pH electrode with separate reference electrode.

8. Faults, causes and remedies

Fault:
pCO_2 fluctuates strongly or appears unrealistic.
Cause:
Air bubble at the electrode tip, electrode chamber not grounded.
Remedy:
Produce a large air bubble, e.g. by briefly opening the supply tubing. The large air bubble produced (approx. 20 - 30 mm long in the supply tubing) then joins up with the undesirable bubbles in the chamber and can be pushed out by the liquid following behind. Connect the chamber to the central ground point.

Fault:
Measurement completely incorrect, instrument overloaded.
Cause:
Ground not connected.
Remedy:
Connect ground cables to central ground point.

9. Maintenance and cleaning

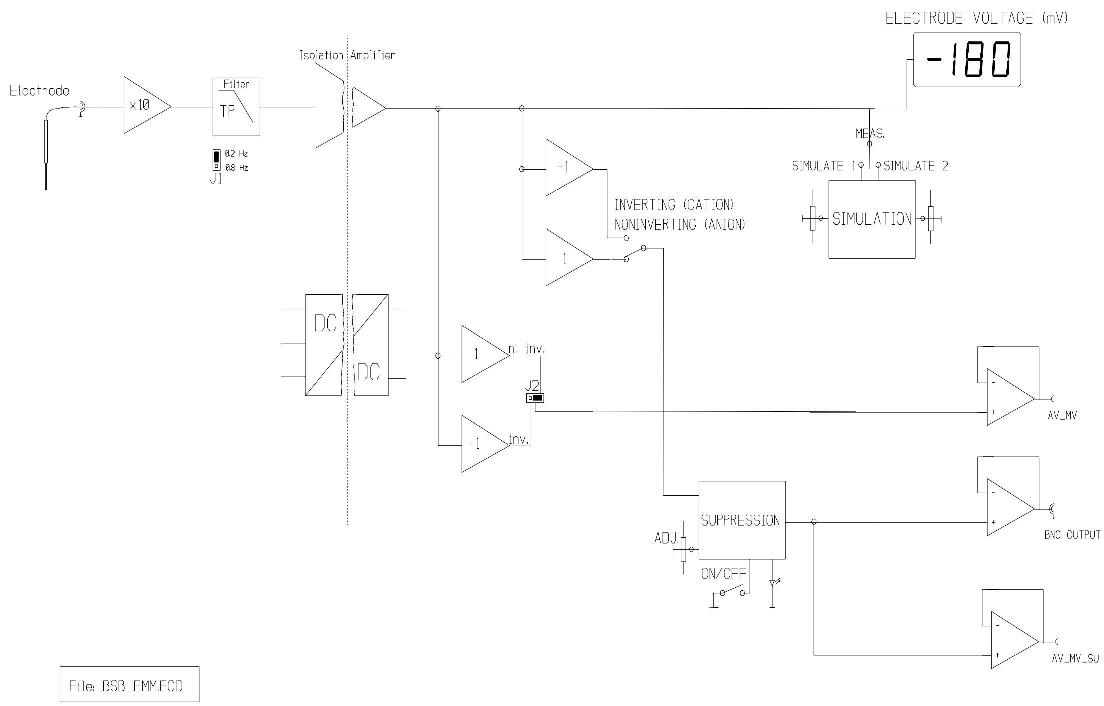
The PLUGSYS module does not really require any maintenance. The **EMM** module is supplied fully calibrated, only the pH electrode still requires calibration. Any operation on or modification of the electronic circuit invalidates the warranty and the manufacturer's product liability.
The front panel can be cleaned if necessary with a lightly moistened (not a wet) cloth. Before cleaning always pull out

the mains supply plug!
No moisture must find its way into the unit and especially not into the switches and keys, since this leads to corrosion at the switch contacts resulting in faulty operation. In general the PLUGSYS housing should be protected against splash water and salt solutions as this may damage individual components and may cause a short-circuit!

10. Transport and storage

In order to avoid transport damage when returning the unit to the factory, the PLUGSYS housing should be packed in a suitably large carton (the carton should allow a spacing of about 10 cm all round so that sufficient packing material such as polystyrene, hard foam panel or similar can be included to protect against impact damage). When shipping individual modules these should also be well packed, preferable enclosed in antistatic foil or envelope.

11. Block diagram of the EMM module



12. Technical data

Input:	isolated differential input, max isolation voltage 500 V
Input socket:	BNC
Input impedance:	10^{15} Ohm
Input current:	±300 fA
Indication:	3 1/2 digit LED display
Millivolt range:	±600 mV
Output:	input voltage x10, x20, x50,x100 at BNC socket OUTPUT on front panel (±10 V 5 mA max.) The output voltage is also available internally on the PLUGSYS bus.
Suppression:	in range of ± 10V
Calibration:	2-point calibration with two bubbled solutions
Simulation:	two physiological measurement points for calibrating a recorder can be set A switch is used to switch the simulation values to the display and the output.
Recorder outputs:	the internal output AV_MV_SUP is connected through a link to the PLUGSYS bus system. The signal can be connected to a recorder through the Recorder Output Module installed in the PLUGSYS system. Direct connection at the BNC socket on the front panel is also possible.
Ambient conditions:	Operating temperature: 10 to 40°C
Relative humidity:	20 to 80% without condensation
Storage temperature:	-20 to +60°C
Supply:	5 V 450 mA, supply via the PLUGSYS system bus
Mechanical data:	
Dimensions:	module for PLUGSYS housing width 8 E (40.8 mm) height 3 U (128.7 mm) depth Eurocard (220 mm)
Connectors:	DIN 41612, 64-pin VG connector BNC
Weight:	400 g
Accessories:	BNC output cable and Operating Instructions