Electronic Instruments for the Life Sciences

made to measure

OPERATING INSTRUCTIONS AND SYSTEM DESCRIPTION FOR THE

TEC-B-01M

VOLTAGE CLAMP MODULE FOR EPMS SYSTEMS

VERSION 1.2
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1. Safety Regulations

<u>VERY IMPORTANT</u>: Instruments and components supplied by npi electronic are NOT intended for clinical use or medical purposes (e.g. for diagnosis or treatment of humans), or for any other life-supporting system. npi electronic disclaims any warranties for such purpose. Equipment supplied by npi electronic must be operated only by selected, trained and adequately instructed personnel. For details please consult the GENERAL TERMS OF DELIVERY AND CONDITIONS OF BUSINESS of npi electronic, D-71732 Tamm, Germany.

1) GENERAL: This system is designed for use in scientific laboratories and must be operated only by trained staff. General safety regulations for operating electrical devices should be followed.

2) AC MAINS CONNECTION: While working with the npi systems, always adhere to the appropriate safety measures for handling electronic devices. Before using any device please read manuals and instructions carefully.
   The device is to be operated only at 115/230 Volt 60/50 Hz AC. Please check for appropriate line voltage before connecting any system to mains.
   Always use a three-wire line cord and a mains power-plug with a protection contact connected to ground (protective earth).
   Before opening the cabinet, unplug the instrument.
   Unplug the instrument when replacing the fuse or changing line voltage. Replace fuse only with an appropriate specified type.

3) STATIC ELECTRICITY: Electronic equipment is sensitive to static discharges. Some devices such as sensor inputs are equipped with very sensitive FET amplifiers, which can be damaged by electrostatic charge and must therefore be handled with care. Electrostatic discharge can be avoided by touching a grounded metal surface when changing or adjusting sensors. **Always turn power off when adding or removing modules, connecting or disconnecting sensors, headstages or other components from the instrument or 19” cabinet.**

4) TEMPERATURE DRIFT / WARM-UP TIME: All analog electronic systems are sensitive to temperature changes. Therefore, all electronic instruments containing analog circuits should be used only in a warmed-up condition (i.e. after internal temperature has reached steady-state values). In most cases a warm-up period of 20-30 minutes is sufficient.

5) HANDLING: Please protect the device from moisture, heat, radiation and corrosive chemicals.

2. EPMS-07 Modular Plug-In System

2.1. General System Description / Operation

The npi EPMS-07 is a modular system for processing of bioelectrical signals in electrophysiology. The system is housed in a 19” rackmount cabinet (3U) has room for up to 7 plug-in units. The plug-in units are connected to power by a bus at the rear panel.

The plug-in units must be kept in position by four screws (M 2,5 x 10). The screws are important not only for mechanical stability but also for proper electrical connection to the system housing. Free area must be protected with covers.

2.2. EPMS-07 Housing

The following items are shipped with the EPMS-07 housing:

- ✓ EPMS-07 cabinet with built-in power supply
- ✓ Mains cord
- ✓ Fuse 2 A / 1 A, slow
- ✓ Front covers

In order to avoid induction of electromagnetic noise the power supply unit, the power switch and the fuse are located at the rear of the housing.

2.3. EPMS-E-07 Housing

The following items are shipped with the EPMS-E-07 housing:

- ✓ EPMS-E-07 cabinet
- ✓ External Power supply PWR-03D
- ✓ Power cord (PWR-03D to EPMS-E-07)
- ✓ Mains chord
- ✓ Fuse 1.6 A / 0.8 A, slow
- ✓ Front covers

The EPMS-E-07 housing is designed for low-noise operation, especially for extracellular and multi channel amplifiers with plugged in filters. It operates with an external power supply to minimize distortions of the signals caused by the power supply.

2.4. PWR-03D

The external power supply PWR-03D is capable of driving up to 3 EPMS-E housings. Each housing is connected by a 6-pole cable from the one of the three connectors on the front panel of the PWR-03D to the rear panel of the respective EPMS-E housing. (see Figure 1, Figure 3). A POWER LED indicates that the PWR-03D is powered on (see Figure 1). Power switch, voltage selector and fuse are located at the rear panel (see Figure 2).

Note: The chassis of the PWR-03D is connected to protective earth, and it provides protective earth to the EPMS-E housing if connected.

Figure 1: PWR-03D front panel view

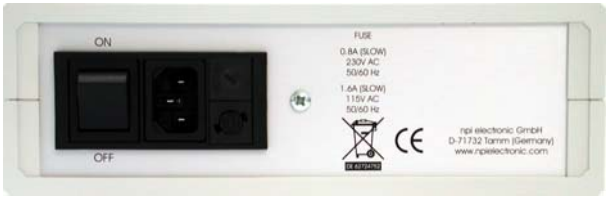

Figure 2: PWR-03D rear panel view

Note: This power supply is intended to be used with npi EPMS-E systems only.

2.5. System Grounding

EPMS-07

The 19" cabinet is grounded by the power cable through the ground pin of the mains connector (= protective earth). In order to avoid ground loops the internal ground is isolated from the protective earth. The internal ground is used on the BNC connectors or GROUND plugs of the modules that are inserted into the EPMS-07 housing. The internal ground and mains ground (= protective earth) can be connected by a wire using the ground plugs on the rear panel of the instrument. It is not possible to predict whether measurements will be less or more noisy with the internal ground and mains ground connected. We recommend that you try both arrangements to determine the best configuration.

EPMS-E-07

The 19" cabinet is connected to the CHASSIS connector at the rear panel. The CHASSIS is linked to protective earth as soon as the PWR-03D is connected. It can be connected also to the SYSTEM GROUND (SIGNAL GROUND) on the rear panel of the instrument (see Figure 3).

Important:: Always adhere to the appropriate safety measures.

Figure 3: Rear panel connectors of the EPMS-E-07

2.6. Technical Data

19” rackmount cabinet, for up to 7 plug-in units
Dimensions: 3U high (1U=1 3/4” = 44.45 mm), 254 mm deep

EPMS-07

Power supply: 115/230 V AC, 60/50 Hz, fuse 2 A / 1 A slow, 45-60 W

EPMS-E-07

External power supply (for EPMS-E): 115/230 V AC, 60/50 Hz, fuse 1.6/0.8 A, slow

Dimensions of External power supply: (W x D x H) 225 mm x 210 mm x 85 mm

3. TEC-B-01M

3.1. System Description

The TEC-B-01M amplifier module is designed to be used together with the modified BA-01M bridge amplifier. In two-electrode CC or VC mode the current is applied through the current electrode connected to the TEC-B-01M and potential measurement is performed through the BA-01M. The active connection of the two amplifiers is indicated by the DUAL LED. The BA-01M has also an LED above the display indicating two-electrode operation.
But it is also possible to use the BA-01M only with the electrode connected the BA-01M in bridge mode. For operation of the BA-01M in bridge mode using only one electrode, the MODE OF OPERATION switch of the TEC-B-01M has to be set into EXT or OFF position. In EXT position the TEC-B-01M can be used as current pump, e.g. for iontophoresis.
In one EPMS housing always a pair (one BA-01M and one TEC-B-01M) is used for two electrode operation. The corresponding amplifiers are labeled at the front panel (A-A, B-B, C-C). The corresponding headstages are labeled as well, i.e. BRAMP headstage A belongs BRAMP A amplifier, TEC-B-01M headstage A belongs to TEC-B-01M amplifier, and so on. Swapping headstages is not recommended, but nothing will be damaged.

Note: It is mechanically not possible to put a BA-01M headstage in a TEC-B-01M headstage connector!

If two non-corresponding amplifiers are put into one housing two electrode operation is not possible, but the amplifiers will not be damaged.

3.2. Description of the Front Panel

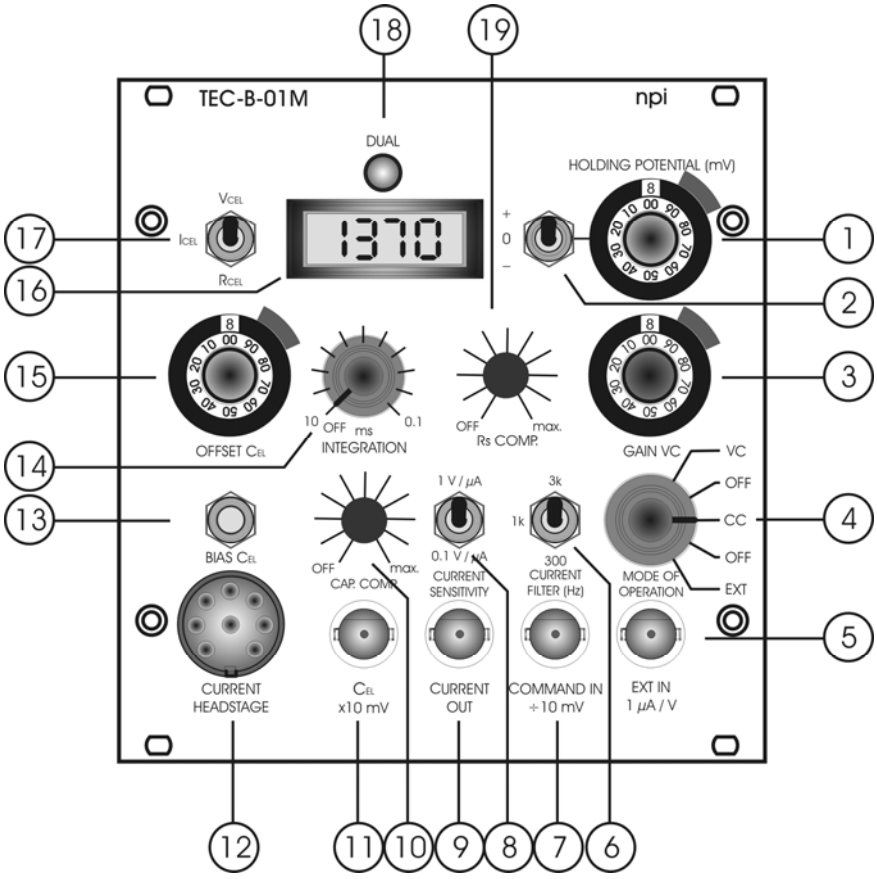

Figure 4: front panel view of the TEC-B-01M

In the following description of the front panel elements each element has a number that is related to that in Figure 4. The number is followed by the name (in uppercase letters) written on the front panel and the type of the element (in lowercase letters). Then, a short description of the element is given.

(1) HOLDING POTENTIAL potentiometer

10-turn potentiometer for setting the HOLDING POTENTIAL in VC mode; range max. ±1000 mV.

(2) + /0 /- switch

Switch for setting the polarity of the HOLDING POTENTIAL in VC mode. In 0 position the HOLDING POTENTIAL is disabled, i.e. set to 0 mV.

(3) GAIN VC potentiometer

10-turn potentiometer to set amplification factor (GAIN) of the VC error signal. To keep the VC error as small as possible it is necessary to use high GAIN settings, but the system becomes unstable and begins to oscillate if the GAIN is set too high.

(4) MODE OF OPERATION switch

Switch to select the MODE OF OPERATION:

VC: **V**oltage **C**lamp
OFF: In this position the current injection of the amplifier is switched OFF, e.g. for operating the BA-01M as bridge amplifier.
CC: **C**urrent **C**lamp with current injection through the current headstage.

Note: In CC operation the current stimulus input of the BA-01M is used!

EXT.: EXTernal control. For operating the TEC-B-01M module as a constant current source, e.g. for iontophoresis, or for operating the BA-01M as bridge amplifier.

(5) EXT IN 10 µA/V connector

BNC connector for connecting an external voltage signal. This can be used to operate the TEC-B-01M module as a constant current source, e.g. for iontophoresis. Scaling is 10 µA / V, i.e. 1 V connected at EXT IN leads to a current of 10 µA at the current electrode.

(6) CURRENT FILTER (Hz) switch

3-position switch to set the corner frequency of the CURRENT FILTER (300 Hz, 1 kHz or 3 kHz).

Important: If switched to 0.1 V / µA the current signal is always unfiltered, regardless of the position of the CURRENT FILTER switch #**6**!

(7) COMMAND IN ÷10 mV connector

BNC connector for an external COMMAND voltage in VC mode (sensitivity: ÷10 mV). The signal form remains unchanged.

(8) CURRENT SENSITIVITY switch

Switch to set the amplification of the current signal at #**9** (1 V / µA or 0.1 V / µA).

Important: If switched to 0.1 V / µA the current signal is always unfiltered, regardless of the position of the CURRENT FILTER switch #**6**!

(9) CURRENT OUT connector

BNC connector providing the current signal. The scaling is set by switch #**8**.

(10) CAP.COMP. potentiometer

Not installed.

(11) C_{EL} x10 mV connector

BNC connector providing the potential of the current electrode.

(12) CURRENT HEADSTAGE connector

Connector for the current headstage.

(13) BIAS C_{EL} trim pot.

Trim pot for adjusting the current headstage BIAS current; range: ±0.5 µA.

Current Headstage Bias Current Adjustment for TEC-B-01M

Caution: It is important that this tuning procedure is performed ONLY after a warm-up period of at least 30 minutes!

The tuning procedure must be performed regularly (at least once a month) with great care since the bias current changes over time and it determines the accuracy of the TEC system.

The TEC-B-01M is equipped with a high-voltage current source that is connected to the current injecting electrode and performs the current injection. This current source has a high-impedance floating output. Therefore the zero point (the zero of the bias current) of the current source must be defined, i.e. without an input signal there should not be an output current.
The tuning procedure is done using the BIAS C_{EL} trim pot and one resistance of a few kΩ and one of a few MΩ. It is based on Ohm's Law (U = R * I).

If the headstage generates an output current, this current will cause a voltage deflection at a test resistor. If this test resistor has a low resistance of only a few kΩ, this voltage deflection originates only from a possible offset of the electrode, that can be cancelled using the OFFSET C_{EL} (#**15,** Figure 4) potentiometer.
Replacing the low resistance resistor by one of a much higher resistance may lead to another voltage reading at the digital display. This voltage deflection then originates only from the BIAS output current and is proportional to this output current according to Ohm's law. Using the BIAS C_{EL} trim pot. the monitored voltage can be set to 0. This cancelled the BIAS current.

Tuning procedure:

The tuning procedure is performed using high-value resistors or a cell model. It cannot be performed with an electrode, since there are always unknown potentials involved (tip potential, junction potentials etc.).

Warning: **High voltage!** Always turn power off when working directly on the current headstage output.

- ❑ If you use a cell model, connect only the C_{EL} and GND.
- ❑ Set the MODE OF OPERATION switch to OFF.

Important: The tuning procedure **must not** be done in VC mode!!

- ❑ Connect the electrode connector of the TEC-B-01M headstage to ground. If parasitic oscillations occur use a 10 kΩ resistor for grounding. If you use a cell model set the ON / GND switch to GND.
- ❑ Switch the digital display (#**16**) to V_{CEL} (potential output of the current electrode) using switch #**17**. Set the reading of the display to 0 using the OFFSET potentiometer (#**15**).
- ❑ After tuning the current electrode potential OFFSET set the set the ON / GND switch of the cell model to ON. If you do not use a cell model simulate an electrode by replacing the 10 kΩ resistor with a much larger resistor (1 MΩ).
- ❑ The digital display (and the CURRENT ELECTRODE potential connector (CEL x10mV) (#**11**)) now shows a voltage deflection that is related to the BIAS current of the headstage according to Ohm's Law. Cancel this voltage by tuning the BIAS C_{EL} trim pot (#**13**). The current is 0 if the voltage deflection is 0.

Note: Due to the characteristics of the high voltage OPs the V_{CEL} display may fluctuate around the baseline of 0 mV by some mV. With a 1 MΩ resistor (as used in the cell model) 1 mV corresponds to 1 nA. Keeping in mind that the display accuracy of the current is 100 nA in the last digit this is insignificant.

Important: Since the BA-01M is a bridge amplifier it has a BIAS current as well and must be adjusted as described in the BA-01M user manual.

(14) ms INTEGRATION potentiometer

The integrator improves control performance for slower signals, e.g. during recording of ligand-gated currents. Position OFF disables the integrator. Setting a time constant by turning the potentiometer clockwise converts the controller into a PI (proportional-integral) system. Time constant range is 10…0.1 ms.

(15) OFFSET potentiometer

10-turn potentiometer to cancel potential OFFSETs at the current electrode; range: ±500 mV.

(16) Display

LC-Display for the CURRENT passed through the CURRENT electrode in µA (XX.X µA, switch #**17** in I_{CEL} position) or the potential at the current electrode in mV XXXX mV (switch #**17** in V_{CEL} position) or the resistance of the current electrode XX.X MΩ (switch #**17** in R_{CEL} position).

(17) V_{CEL} / I_{CEL} / R_{CEL} / switch

3-position switch for selection of the display mode:

V_{CEL}: potential of the current electrode is displayed
I_{CEL}: CURRENT value is displayed
R_{CEL}: resistance of the current electrode is displayed

(18) DUAL LED

LED indicating operation with the BA-01M amplifier in CC or VC mode.

(19) Rs COMP. potentiometer

Not installed.

4. Technical Data

Modes of Operation

CC:	Current Clamp mode
VC:	Voltage Clamp mode
OFF:	Current- and Voltage Clamp disabled, BA-01M operational
EXT:	External mode
MODE selection:	by rotary switch

Headstage

Potential headstage

BA-01M headstage is used for potential measurement

Current headstage

Operating voltage:	±45 V
Input resistance:	$>10^{12}$ Ω
Electrode connector:	BNC, shield is grounded
Ground:	2.3 mm connector or headstage enclosure
Size:	23 x 70 x 26 mm, enclosure grounded
Holding bar:	diameter 8 mm, length 10 cm

Current range:

450 nA / 100 MΩ or 4.5 µA / 10 MΩ

Current electrode parameter controls:

Offset compensation:	ten-turn control, ±500 mV
BIAS compensation:	trim pot.; ±0.5 µA
C_{EL}:	x10 mV; max. ±1400 mV

Electrode Resistance Test:

100 mV / MΩ, obtained by application of square current pulses ±10 nA, display XX.X MΩ, selected by switch

Current Outputs:

Unfiltered output:	sensitivity: 0.1 V / µA, output impedance 50 Ω
Filtered output:	sensitivity: 1 V / µA, with low-pass Bessel filter, output impedance 50 Ω
DISPLAY:	XX.X µA

Current Output Filters:

One-pole low-pass Bessel filter
3 corner frequencies: 300, 1k or 3k Hz.

Current Clamp (current stimulus input from BA-01M):

Inputs:	1 µA / V
Input resistance:	>100 kΩ
HOLD:	X.XX µA, ten-turn digital control with -/0/+ switch, maximum 10 µA.

Voltage Clamp:

Input sensitivity:	÷10 mV
Input resistance	>100 kΩ
HOLD:	XXX mV, ten-turn digital control with +/0/- switch, maximum 1000 mV

External Input:

EXT. IN:	sensitivity: 10 µA / V