

OPERATING INSTRUCTIONS AND SYSTEM DESCRIPTION FOR THE

MVCS / MVCC Series

IONTOPHORESIS MODULES FOR EPMS-07 SYSTEMS



VERSION 5.1

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About this Manual

Available Modules

MVCS-01	one channel without headstage, R_{EL} test and CAPACITY COMPENSATION
MVCS-02	two channels without headstage, R_{EL} test and CAPACITY COMPENSATION
MVCS-C-01	one channel with headstage, R_{EL} test and CAPACITY COMPENSATION
MVCS-C-02	two channels with headstage, R_{EL} test and CAPACITY COMPENSATION
MVCC-02	balance module for up to four channels.

This manual describes the MVCS-02 / MVCC-02 systems. The only difference between MVCS-01 and MVCS-02 systems are the number of channels. Therefore the MVCS-01 systems are not mentioned separately.

The manual should help you setup and use the MVCS-02 / MVCC-02 system correctly and to perform accurate experiments. With MVCS-02 the iontophoresis is performed and MVCC-02 is the balance module for the iontophoresis system used to compensate for the iontophoretic current (see also chapter 4.2). Unless otherwise noted, functions and settings that apply to MVCS-02 also apply to MVCC-02.

Generally, two different versions of the MVCS-02 / MVCC-02 system are available:

- System **without** headstage, R_{EL} test and CAPACITY COMPENSATION (MVCS-02 / MVCC-02 versions)
- System **with** headstage, R_{EL} test and CAPACITY COMPENSATION (MVCS-C-02 / MVCC-C-02 versions)

Note: In this manual, the slow MVCS-02 / MVCC-02 version is referred as MVCS / MVCC, whereas the fast MVCS-C-02 / MVCC-C-02 version is referred as MVCS-C / MVCC-C.

If you are not familiar with the use of instruments for iontophoretic application of substances, please read the manual completely. The experienced user should read at least chapters 1, 5, and 6.

Important: Please read chapter 1 carefully! It contains general information about safety regulations and how to handle highly sensitive electronic instruments.

Signs and conventions

In this manual names of all elements of the front panel are written in capital letters as they appear on the front panel.

System components that are shipped in the standard configuration are marked with 3 , optional components with | . In some chapters the user is guided step by step through a certain procedure. These steps are marked with o.

Important information, hints and special precautions are highlighted in gray.

Abbreviations

I_{EL}	current at electrode
R_{EL}	electrode resistance
V_{EL}	voltage at electrode

1. Safety Regulations

VERY IMPORTANT: 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 by trained staff only. 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.
- 6) **CURRENT INJECTION HIGH VOLTAGE HEADSTAGE:** The current injection headstages have an output compliance of ± 45 V up to ± 150 V. In addition, some headstages are equipped with a driven shield electrode connector (marked "Driven Shield" on the headstage enclosure). After turning on the instrument do not touch the interior contact or the shield of the electrode plug or of the cable that is connected to this plug. **In addition, it is extremely important that the instrument is turned off when changing or adjusting the electrode.**

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:

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

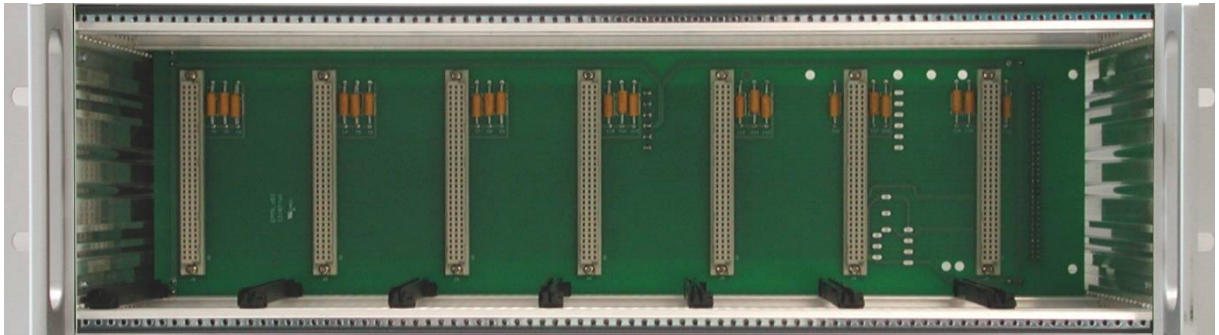


Figure 1: Left: front view of empty EPMS-07 housing.

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 (see Figure 2, right).

2.3. EPMS-H-07 Housing

In addition to the standard power supply of the EPMS-07, the EPMS-H-07 has a built-in high voltage power supply. This is necessary for all MVCS / MVCC modules, the HVA-100, HV-TR150 and HVC-03M modules. The output voltage depends on the modules in use.

2.4. EPMS-E-07 Housing

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

- 3 EPMS-E-07 cabinet
- 3 External Power supply PWR-03D
- 3 Power cord (PWR-03D to EPMS-E-07)
- 3 Mains chord
- 3 Fuse 1.6 A / 0.8 A, slow (inserted)
- 3 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.

2.5. EPMS-03

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

- 3 EPMS-07 cabinet with built-in power supply
- 3 Mains cord
- 3 Fuse 0,4 A / 0,2 A, slow (inserted)
- 3 Front covers

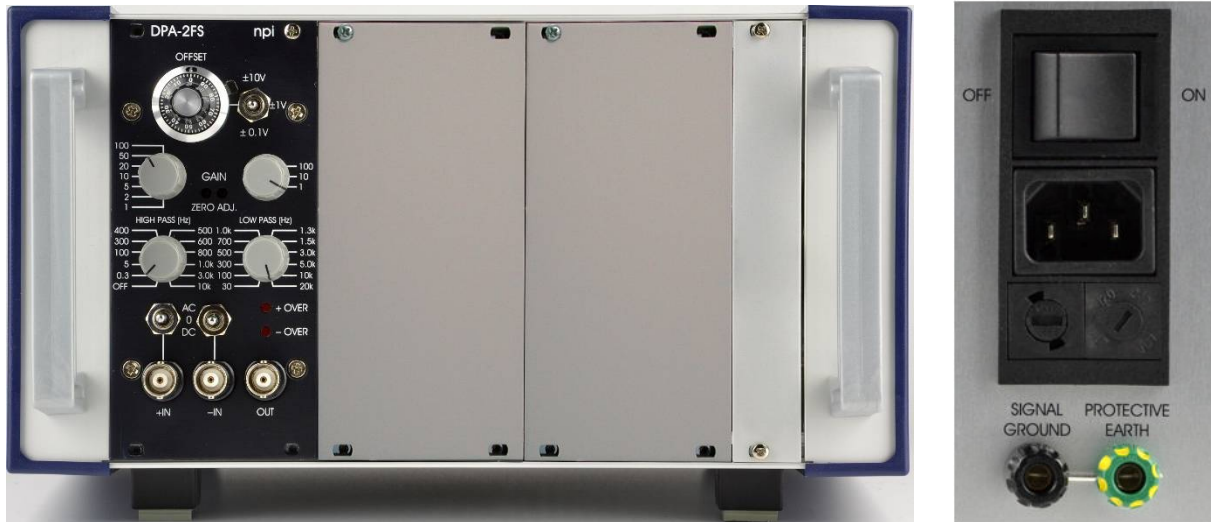


Figure 2: Left: front view of EPMS-03 housing. Right: rear panel detail of EPMS-03 and EPMS-07 housing.

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 (see Figure 2, right).

2.6. 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 one of three connectors on the front panel of the PWR-03D to the rear panel of the respective EPMS-E housing (see Figure 3, Figure 4). A POWER LED indicates that the PWR-03D is powered on (see Figure 3, left). Power switch, voltage selector and fuse are located at the rear panel (see Figure 3, right).

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 3: Left: PWR-03D front panel view Right: PWR-03D rear panel view.

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

2.7. System Grounding

EPMS-07/EPMS-03

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. It can be connected to the SYSTEM GROUND (SIGNAL GROUND) on the rear panel of the instrument (see Figure 4).

The chassis can be linked to PROTECTIVE EARTH by connecting it to the PWR-03D with the supplied 6-pole cable **and** by interconnecting the GROUND and PROTECTIVE EARTH connectors on the rear panel of the PWR-03D (see Figure 3). Best performance is generally achieved without connection of the chassis to protective earth.

Important: Always adhere to the appropriate safety measures.

Figure 4: Rear panel connectors of the EPMS-E-07

2.8. Technical Data

EPMS-07, EPMS-E-07 and EPMS-H-07

19" rackmount cabinet, for up to 7 plug-in units

Dimensions: 19" (483 mm) wide, 10" (254 mm) deep, 5.25" (133 mm) high

EPMS-07 and EPMS-H-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 (PWR-03D) 115/230 V AC, 60/50 Hz, fuse 1.6/0.8 A, slow

Dimensions of external power supply:

9.7" (247 mm) wide, 7.1" (180 mm) deep, 3.55" (90 mm) high

EPMS-03

Power supply: 115/230 V AC, 60/50 Hz, fuse 0.4 A / 0.2 A slow

Max. current supply: 500 mA

Dimensions: 10.4" (265 mm) wide, 9.65" (245 mm) deep, 5.25" (133 mm) high

3. MVCS / MVCC Components

The following items are shipped with a MVCS / MVCC system:

- MVCS / MVCC amplifier module
- Headstage (fast MVCS-C / MVCC-C systems only)
- GND connector for headstage (2.6 mm, fast MVCS-C / MVCC-C systems only)
- Electrode cables (“slow” MVCS / MVCC systems only)
- User manual

Optional accessories:

- Electrode holder
- Electrode adapter with BNC- and SMB connector



4. System Description

4.1. MVCS Iontophoresis Module

MVCS-02M systems are high-voltage current sources for iontophoresis or other applications, where constant currents in the nano- or microampere range are needed. Standard MVCS-02M systems have an output compliance of ± 45 V and can generate currents up to 450 nA into 100 M Ω while high-voltage MVCS-02M systems work with up to ± 150 V generating currents up to 1.5 μ A into 100 M Ω .

Generally, two different versions of the MVCS-02M system are available:

- System **without** headstage, R_{EL} test and CAPACITY COMPENSATION (MVCS-02M versions)
- Systems **with** headstage, R_{EL} test and CAPACITY COMPENSATION (MVCS-C-02M versions)

Note: In this manual the slow MVCS-02M version is referred as MVCS whereas the fast MVCS-C-02M version is referred as MVCS-C.

The operating and display elements of these instruments facilitate the application of drugs in physiological, pharmacological and biochemical studies. All systems allow very fast drug applications in the millisecond range, and even the sub-millisecond range, if equipped with the fast capacitance compensation option. Therefore, these systems can be used to simulate synaptic events (Behrends et al., 2002; Renger et al., 2001; Cottrell et al., 2000; Liu et al., 1999).

The MVCS systems are available as 19” instruments or as modules for the EPMS-07 modular system. The systems described here, are EPMS-07 modules. The MVCS-01M has one channel for current injection while the MVCS-02M consists of two independent injection channels. Each injection channel has digital ten-turn potentiometer for EJECT or RETAINING currents and CAPACITY COMPENSATION. Each injection channel also has a digital display, over

range LEDs and two switches for selection of the operating mode. The MVCC has the same controls, but no potentiometer for adjusting current.

In fast systems with CAPACITY COMPENSATION (MVCS-C / MVCC-C), the injecting electrodes are connected via small SMB or BNC shielded connectors that are mounted to a small headstage avoiding artifacts caused by long cables.

Systems for slow, long-lasting applications, in the second or minute range (MVCS / MVCC), need no headstages. In this case the electrodes are connected by special connectors at the front panel with shielded cables.

For EJECT or RETAIN currents modes of operation include manual activation and automatic control by digital TTL signals (HI = EJECT, LO = RETAIN). An automated electrode resistance test mode (MVCS-C / MVCC-C) is also available.

4.2. MVCC-02 Balance Module

To avoid artifacts caused by iontophoretic drug application, the MVCS-02M systems can be operated with the balance module MVCC-02. The balance (compensation) signal (inverted sum of current output signals), generated by the MVCC module, is applied to a separate compensation electrode, if the OPERATE mode is selected for the injection channel(s) and COMPENSATE mode is selected for the compensation channel. The MVCC module can compensate iontophoretic current for up to four injection channels.

4.3. Fast Capacitance Compensation

The MVCS-C / MVCC-C iontophoresis instruments have been designed for high-speed application of drugs in electrophysiological experiments. In addition to the standard features of the slow MVCS / MVCC devices each channel has a capacity compensation circuit and an R_{EL} test unit (see chapter 4.4). The capacity compensation circuit is operated by the control marked CAP. COMP.

The correct tuning of the capacity compensation is very important if high speed operation with high resistance microelectrodes is required. Uncompensated stray capacitances are charged from the iontophoretic current that is supplied by the instrument. Uncompensated stray capacitance therefore slows application. The tuning procedure is described in chapter 8.1.

The CAPACITY COMPENSATION control is based on the well-known conventional compensation: stray capacitances around the electrode are compensated by passing amounts of the electrode signal through a small capacitor. The circuit is set so that overshoots are avoided as far as possible.

Caution: Just like any feedback circuit, this circuit can cause overshoots or oscillations if it is overcompensated.

4.4. Electrode Resistance Test

MVCS-C / MVCC-C systems are equipped with an automatic electrode resistance test facility. By switching the V_{EL} , I_{EL} , R_{EL} switch to R_{EL} , the value of the electrode resistance is shown on the digital display in $M\Omega$, whether current is applied or not. This means that changes in electrode resistance caused by high currents ("rectification" effects) can be monitored directly. The electrode resistance test uses current pulses of ± 10 nA to measure the electrode resistance. These pulses are monitored at the current OUTPUT BNC and the voltage response can be seen on the $V_{EL}/10$ BNC. In this way, changes of electrode resistance can be recorded with a chart recorder or computer based data acquisition system. In addition, the electrode resistance test mode can be used to tune the fast capacity compensation (see chapter 8.1).

Important: The CAPACITY COMPENSATION unit must be tuned properly. Otherwise, the electrode resistance display may be inaccurate.

5. Description of the Front Panel

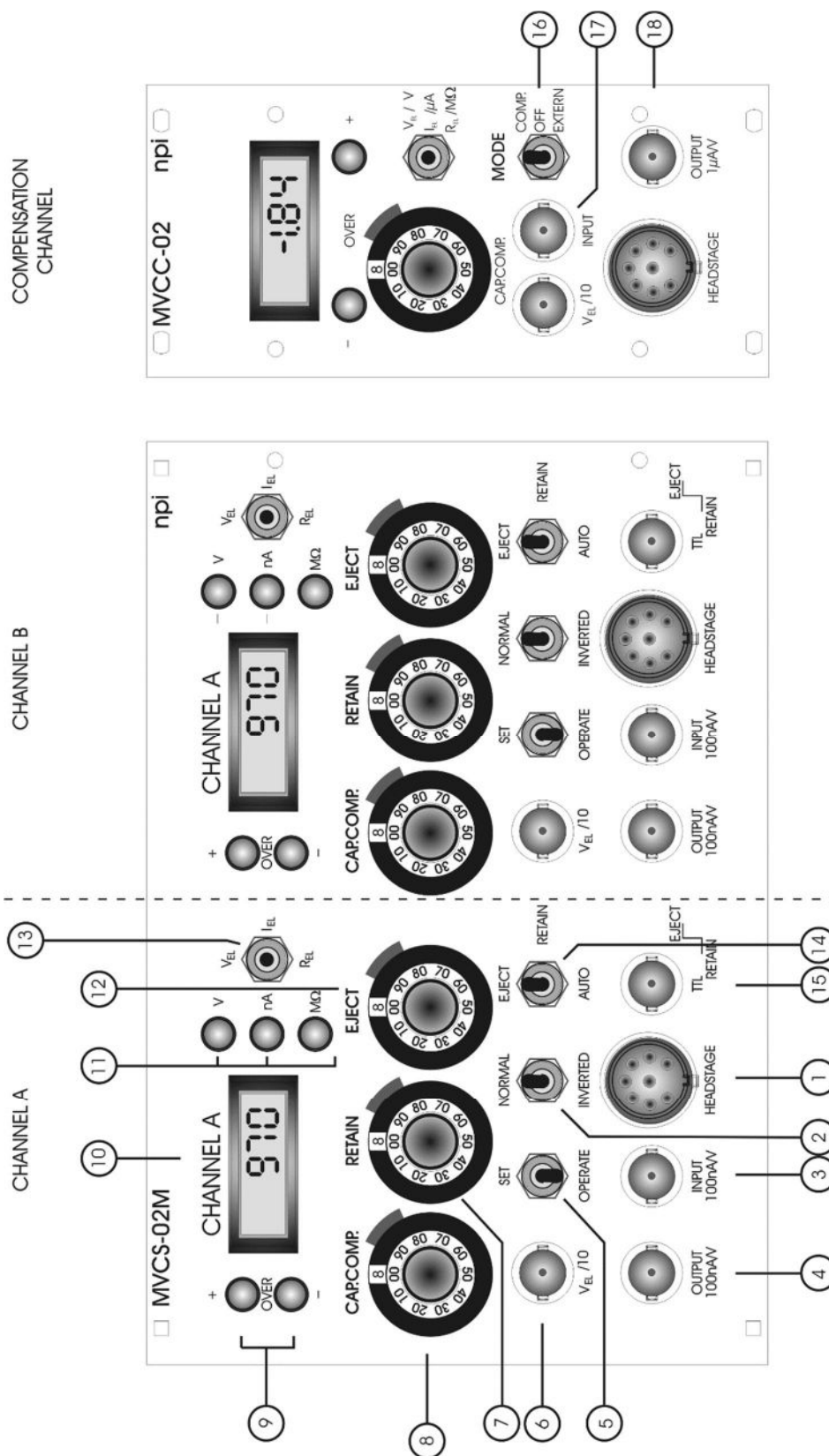


Figure 5: MVCS-C-02M / MVCC-C front panel view (the numbers are related to those in the text below)

5.1. Front Panel Elements

In the following description of the front panel elements, each element has a number that is related to that in Figure 5. 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.

The front panel of the MVCS-C-02M can be divided into two functional units: CHANNEL A and CHANNEL B.

The MVCC-C module serves for balancing the iontophoretic current for up to four injection channels.

Most of the elements are identical for each channel (with identical functions and labels) and therefore, are numbered and described only once (e.g. #1, HEADSTAGE connector that is also present for CHANNEL B and the MVCC).

Figure 5 shows the MCVS-C-02 / MVCC-C (fast systems) with capacity compensation and the automatic electrode resistance test facility. These two features are not present in the MVCS-02 / MVCC (slow systems). In slow systems the CAP. COMP. potentiometer is not installed and the function of R_{EL} is somewhat different (see below).

(1) HEADSTAGE connector



8 pole connector for the HEADSTAGE (MVCS-C systems) or for the cable directly connected to the injecting electrode (MVCS systems).

(2) NORMAL / INVERTED switch



Switch to set polarity of EJECT and RETAIN current: NORMAL = EJECT positive, RETAIN = negative.

(3, 17) INPUT connectors



BNC connectors for an auxiliary INPUT. These BNCs are directly connected to the output current source and are not isolated from ground.

Calibration for channels A and B: 100 nA / V

Calibration for the MVCC (17): 1 μ A / V

Note: The MVCC can be used as an additional injection channel by linking an external waveform to this connector and setting switch (16) to EXTERN.

(4, 18) OUTPUT connectors



BNC connector monitoring the EJECT or RETAIN current.

Calibration for channels A and B: 100 nA / V

Calibration for the MVCC (18): 1 μ A / V.

(The OUTPUT is not isolated from system ground.)

(5) SET / OPERATE switch

Two position switch to set the mode of operation. In SET position the electrode outputs are connected to an internally grounded load ($10\text{ M}\Omega$) and no compensation signal is generated. Thus, the SET position is used to preset the desired values at the EJECT / RETAIN controls on a well-defined basis. In the OPERATE position, the current preset at the EJECT / RETAIN controls will flow through the electrode and a compensation signal is generated at the MVCC.

(6) $V_{EL}/10$ connector

BNC connector monitoring the electrode potential divided by 10. Normally used to monitor the electrode resistance (scaling: $1\text{ mV} / \text{M}\Omega$, see also chapters 4.4 and 8.1).

(7) RETAIN potentiometer

Ten-turn control to set the RETAIN current, range 0-100 nA.

(8) CAP.COMP. potentiometer

Ten-turn control to set amount of compensation of electrode stray capacitance (see also chapter 8.1).

(9) + – OVER LEDS

LEDs indicating that the current source is out of linear range or that the electrode voltage / current is 10% below the maximum output voltage / current.

(10) CHANNEL A display

3 1/2 digit display for the electrode potential in V (XXX.X V), the electrode current in nA (XXXX nA for channels A and B, XX.XX μA for MVCC) or the electrode resistance in $\text{M}\Omega$ (XXXX $\text{M}\Omega$, i.e. 0100 correspond to $100\text{ M}\Omega$), selected by toggle switch (12). For the correct value of the electrode resistance display it is necessary to adjust the capacity compensation accurately (see chapter 8.1).

(11) V / nA / $\text{M}\Omega$ LEDS

LEDs indicating the unit of the reading of the DISPLAY (10).

(12) EJECT potentiometer



Ten-turn control to set the EJECT current, range 0-1 μ A.

(13) V_{EL} , I_{EL} , R_{EL} switch

3 position toggle switch to set the mode of display CHANNEL A (10).

Position V_{EL} : the electrode potential is displayed. Position I_{EL} : the current flowing through the electrode is displayed. Position R_{EL} : the electrode resistance is displayed.

Important: The R_{EL} mode is an option that is only implemented in MVCS-C / MVCC-C (fast) systems. In MVCS / MVCC (slow) systems, the R_{EL} position of the switch has the same function as the I_{EL} position (middle position).

(14) EJECT / RETAIN / AUTO switch



Switch to select the mode of operation. EJECT: the EJECT current set with (11) is applied to the electrode. RETAIN: the RETAIN current set with (7) is applied to the electrode. AUTO: Operation controlled by a TTL pulse at (15).

Remember: Current is applied to the electrode only if switch (5) is set to OPERATE.

(15) TTL connector



BNC connector for external control in the AUTO mode (see also 14). LO = RETAIN, HI = EJECT.

MVCC-C Only(16) MODE switch, (17) INPUT connector, (18) OUTPUT 1 μ A/V connector

For 17 and 18 see above

(16) MODE switch



Switch to select the operation mode of the MVCC-C.

COMP.: The inverted sum of all injection channels is applied to the compensation electrode.

OFF: No current is applied to the electrode.

EXTERN: The output current source is connected directly to INPUT BNC (17). In this mode the MVCC can be used as an additional injection channel with a scaling of 1 μ A / V, i.e. if 1 V is connected at (17), an injection current of 1 μ A is applied to the electrode connected to the MVCC.

6. Headstage (MVCS-C / MVCC-C Systems)

The headstage is housed in a small box that can be mounted directly onto a micromanipulator. It is connected to the main amplifier by means of a shielded flexible cable and a multi-pole connector.

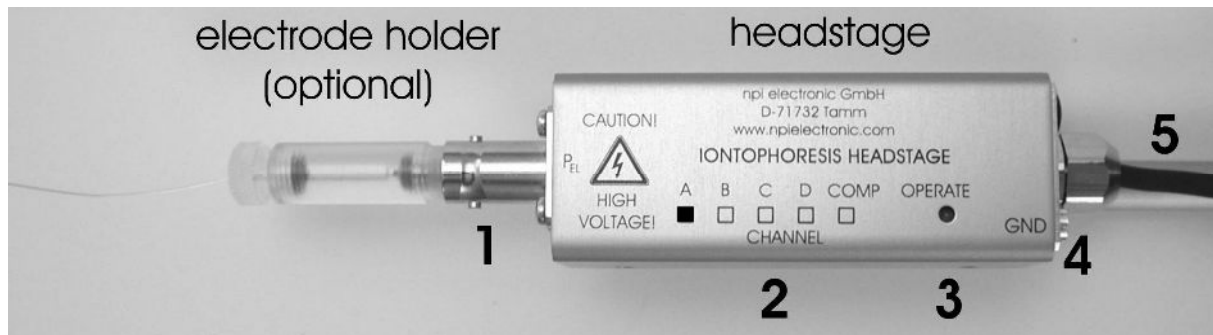


Figure 6: MVCS-C-02C headstage

- 1 PEL: BNC connector for the electrode holder, grounded shield
- 2 CHANNEL indicator: marker show for which CHANNEL the headstage is configured, in the example shown for CHANNEL A (see also hint below)
- 3 holding bar and headstage cable to amplifier
- 4 GND: ground connector
- 5 OPERATE LED: indicates that injection takes place

GND (GROUND) connector

The bath (or reference) of the recording chamber is connected to GND. This is the "lowest" signal level in the recording system, i.e. all signals are related to this signal. This connector must be connected to the ground signal of the recording amplifier / chamber.

PEL

In order to avoid disturbances on the recording amplifier, the microelectrode holder is connected via a BNC connector with a grounded shield.

Caution: The current injection headstages have an output compliance of ± 45 V up to ± 150 V. In addition, all headstages are equipped with sensitive FET amplifiers that can be damaged by electrostatic charge and must therefore be handled with care (see also chapter 1).

Very Important: Always turn power off when connecting or disconnecting headstages from the 19" cabinet. For changing electrodes it is sufficient to switch the respective channel to SET mode.

Also very important: Each headstage is adjusted for a specific channel and instrument. They are labeled A and B (or A, B, C, D for a four eject-channel system formed by two MVCS-C-02M modules) for the EJECT channels, and COMP for the COMPENSATION channel. Please **do not exchange headstages** for a respective instrument or between different MVCS instruments.

Hint: If one channel is not used the headstage can be left unconnected, but then the display for this channel will show arbitrary values. So, we recommend connecting the headstage even if it is not used and set channel to SET mode using switch #5, Figure 5).

Systems for slow, long-lasting applications (in the second or minute range) need no headstages (MVCS systems). In these systems the electrodes are connected from special connectors on the front panel with shielded cables:

Pin 2: white/blue wire = ground

Pin 5: yellow/red wire = electrode

7. Setting up the Iontophoresis System

The following steps should help you set up the iontophoresis system correctly. Always adhere to the appropriate safety measures (see chapter 1).

Usually the module(s) are shipped mounted in an EPMS-H-07 housing. If a single module is delivered the user has to mount the module in the EPMS-H-07 housing. This is done by performing the basic installation steps.

⌘ Basic installation

- Turn off the EPMS-07 system.
- Remove front covers from the EPMS-07 housing.
- Plug in the MVCS / MVCC and fasten the iontophoresis / balance module with four screws. The screws are important not only for mechanical stability but also for proper electrical connection to the EPMS-07 housing.

After installation, MVCS / MVCS-C / MVCC-C / MVCC are attached to the setup by assembling the electrical connections.

⌘ Electrical connections

- Turn POWER off.
- MVCS / MVCC: Connect your injection electrodes to the special connectors with shielded cables at the front panel of the MVCS module. Connect your compensation electrode to the special connector with shielded cables at the front panel of the MVCC module.
Pin 2: white/blue wire = ground
Pin 5: yellow/red wire = electrode

MVCS-C / MVCC-C: Connect the headstages to the HEADSTAGE connectors (#1, Figure 5) at the front panel of the respective module.

- If the recording chamber is not grounded, connect GND of the headstage (MVCS-C).

Note: System ground is isolated from mains ground. The 19" cabinet (EPMS-H-07 housing) is connected to mains ground (see also chapter 2), headstage enclosures are connected to the internal system ground.

- MVCS-C / MVCC-C: Connect the $V_{EL}/10$ connectors and the current OUTPUT (#4, Figure 5) to an oscilloscope or to a data acquisition system.
- If you intend to control the MVCS / MVCS-C system externally (e.g. by a computer) connect the gating signal to TTL (#15, Figure 5), the stimulus waveform to INPUT (#3, Figure 5) and the current OUTPUT (#4, Figure 5) to the analog input of the data acquisition system.

8. Operation

MVCS / MVCS-C / MVCC / MVCC-C systems are modules for the npI EPMS-07 system.

Important: These modules require an EPMS-07 housing with high voltage power supply!! Users of systems delivered before April 2002 will recognize a built-in high voltage power supply by the fact that the EPMS-07 housing is 354 mm deep (instead of 245 mm with low voltage power supply). Systems delivered after September 2006 have a yellow warning label above the respective channels.

Additionally, each channel has a mark (A, B, C, D, COMP) and the related headstages are labeled accordingly. Please use headstage A for channel A, headstage B for channel B and so on, because each headstage is dedicated to a particular channel.

Each system is composed of one (MVCS-01 / MVCS-C-01) or two independent injection channels (MVCS-02 / MVCS-C-02) marked A and B. MVCC / MVCC-C systems serve as compensation (balance) channels and can compensate iontophoretic current for up to four injection channels.

Each channel has an auxiliary analog input and an output which monitors the current flowing through the electrode. Each channel is equipped with a digital display and two overload LEDs.

All numbered items refer to Figure 5, page 12, in the following discussion.

The systems can be operated manually by means of a toggle switch on the front panel (#14) or by an external digital pulse (TTL) connected to #15.

- Turn CAP.COMP. (#8) for all channels to less than 1 to avoid oscillations.
- Turn POWER on.
- Set the operation mode of all channels to SET using switch #5 to disable current output.
- Set the EJECT and/or RETAIN current amplitude to the desired values using #12 and #7.
- MVCS-C: First, compensate the stray capacitances of the electrodes and second, check the electrode resistances by switching #13 to R_{EL} (see also chapter 8.1 below).

Important: The values of the ELECTRODE RESISTANCE are accurate only if the capacitances of the electrodes are compensated properly.

- Put the injection- and compensation electrodes to the desired positions.
- Start iontophoresis either manually by setting switch #14 to EJECT and switch #5 to OPERATE or remotely by setting switch #14 to AUTO and applying a TTL pulse to #15.

8.1. Capacity Compensation Tuning Procedure (MVCS-C / MVCC-C Systems)

The tuning of the capacity compensation controls is performed with the help of the electrode potential monitor BNC marked $V_{EL}/10$ (#6) and square pulses applied to the electrode. This pulse can originate from the built-in ELECTRODE RESISTANCE TEST circuit or from an external signal source. The pulses generated internally by the ELECTRODE RESISTANCE test unit have an amplitude of ± 10 nA.

The following tuning procedure is described for the MVCS-C channels A or B only. The tuning of the capacity compensation for the MVCC-C module is done analogue.

The tuning must be performed with the electrode in the bath immersed to the maximal depth required during the experiment. Square pulses (positive and negative) of a few nA and 0.1-10 ms duration are applied to one of the INPUT BNCs (#3) or by activating the ELECTRODE RESISTANCE test unit (#13). The signals from the $V_{EL}/10$ and CURRENT OUTPUT BNCs (#4) are monitored on an oscilloscope. The SET / OPERATE switch (#5) must be in OPERATE position.

The CAP.COMP. control (#8) is turned on clockwise until the signal at the $V_{EL}/10$ BNC is as square as possible.

The CAPACITY COMPENSATION is based on the well-known conventional compensation: stray capacitances around the electrode are compensated by passing amounts of the electrode signal through a small capacitor. The circuit is designed to minimize oscillations.

Caution: As in any feedback circuit, this circuit can cause overshoots or oscillations, if it is overcompensated.

8.2. Electrode Resistance Test Procedure (MVCS-C / MVCC-C Systems)

MVCS-C modules and MVCC-C modules have an electrode resistance test unit built-in. It works by application of rectangular current pulses (± 10 nA) to the electrode. This will cause an voltage drop at the electrode which is proportional to the electrode resistance. This voltage drop is measured, the resulting electrode resistance calculated and shown at the digital display (#10).

- Set switch #5 to OPERATE.
- Immerse the electrode into the bath and compensate for stray capacities (see chapter 8.1 above).
- Set V_{EL} , I_{EL} , R_{EL} switch to R_{EL} . The resistance of the electrode is shown at display #10.

Note: If #5 is switched to SET the internal resistor of 10 M Ω is measured and displayed. If a different value is shown (within a tolerance of 10%) it is likely the amplifier or the headstage is damaged. Please contact npi electronic in this case.

Important: The electrode resistance is displayed correctly only if the electrode capacity is compensated accurately!

Note: The electrode resistance test is functional also if an iontophoresis current is generated. This feature can be used to test the resistance at different current levels.

For testing rectification, the EJECT potentiometer or a ramp signal at the INPUT connector can be used for setting a current level.

Testing of rectification of the electrode is done, e.g. by application of different current levels both, positive and negative to the electrode (using the EJECT potentiometer) and testing the resistance of the electrode.

If the resistance changes at a certain level the electrode rectifies and should not be used for application of currents above or below this level, i.e. the resistance must not change over the range of current which is used during the experiment.

Also Important: Testing the electrode resistance at different current levels will cause the substance in the electrode to leak out of the electrode! Therefore, don't test the electrode resistance intensively within your preparation in order to avoid i.e. desensitization.

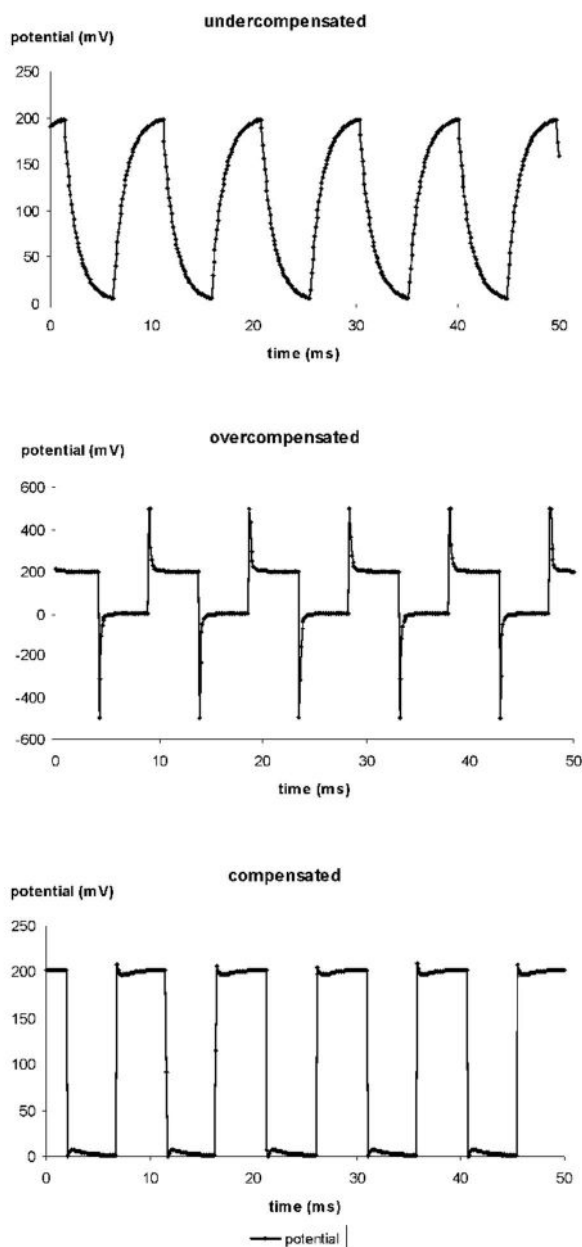


Figure 7: Capacity compensation of the electrode

9. Literature

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10. Technical Data

Electrode output:	floating current source, output impedance $>10^{12} \Omega$
Maximum current:	450 nA [1.5 μ A] into 100 M Ω load
Display:	current: XXXX nA, compensation: XX.XX μ A, voltage: XXX.X V, R_{el} : XXXX M Ω , displayed value is set by a three-position toggle switch, separate displays for each channel
Over LEDs:	activated 10% below maximum current / voltage
Eject:	adjustable by ten-turn control
Minimum pulse duration:	50 μ s
Retain:	adjustable by ten-turn control, maximum 100 nA
Capacity compensation:	adjustable by ten-turn control, range 0-30 pF
Output current polarity:	selected by INVERTED/NORMAL toggle switch
Modes of operation:	set by two toggle switches EJECT/RETAIN/AUTO switch enables manual or TTL controlled operation SET/OPERATE switch connects automatically electrode outputs via a 10 M Ω resistor to ground (SET position)
TTL input (AUTO mode):	LO = RETAIN, HI = EJECT, isolated
Analog input:	sensitivity 100 nA / V, $R_{in} > 100 \text{ k}\Omega$, range $\pm 10 \text{ V}$
Current monitor:	sensitivity 100 nA / V, $R_{out} = 50 \Omega$
Voltage monitor:	$V_{EL} / 10$, $R_{out} = 50 \Omega$
Electrode resistance test:	1 mV / M Ω at voltage monitor $V_{EL} / 10$
MVCC output:	inverted sum of all injection currents (up to four channels) sensitivity 1 μ A / V
Output connector pins and cable colors: (for systems without headstage)	Pin 2: white/blue wire = ground Pin 5: yellow/red wire = electrode

Dimensions

MVCS-01:	front panel: 18 HP (91.1 mm) wide x 3U (128,5 mm) high, corresponds to 1.5 Units housing: 7" (175 mm) deep
MVCS-02:	front panel: 36 HP (182.5 mm) wide x 3U (128,5 mm) high, corresponds to 3 Units housing: 7" (175 mm) deep
MVCC-02:	front panel: 12 HP (60.6 mm) wide x 3U (128,5 mm) high, corresponds to 1 Unit housing: 7" (175 mm) deep
Headstage size:	approx. 70x25x25 mm