npi
Electronic Instruments
for the Life Sciences

made to measure

# OPERATING INSTRUCTIONS AND SYSTEM DESCRIPTION FOR THE

# ELECTROPORATOR

# ELECTROPORATION AMPLIFIER

**±100 V / ±10 mA max.**

VERSION 1.2
npi 2020

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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 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.

## 2. Special Safety Notice for High Voltage Instruments


HIGH VOLTAGE!!
RISK OF ELECTROCUTION!!

Observe extreme caution when working with this instrument!!!

1) Always connect high voltage power supplies to protective earth!!

2) Do not touch connections unless the instrument is turned off and the capacitance of both the load and power supply are earthed!!

3) Allow adequate time for discharge of internal capacitance of the power supply!!

4) Do not ground yourself or work under wet or damp conditions!!

5) Servicing should be only done by qualified personnel aware of the hazards!!

6) If in doubt, return to supplier for servicing!!

# 3. ELP-02D Electroporator Unit

## *3.1. System Description*

The ELectroPORATOR unit is designed for application of voltage and current pulses for electroporation of cells.

The output signal is not isolated from ground and can either be a voltage up to ±100 V or a current up to ±10 mA.

The ELectroPORATOR will reproduce a waveform applied to its SIGNAL INPUT according to the scaling chosen on the OUTPUT SCALING switch.

The output current, voltage or power can be read at the displays of the device, the applied waveforms can be monitored through BNC connectors at the rear panel by using an oscilloscope or a data acquisition system.
The output at the connected electrode can be corrected by the OFFSET VOLTAGE, OFFSET CURRENT and the CAPACITANCE COMPENSATION control (if displays or oscilloscope show not the expected values/waveform).

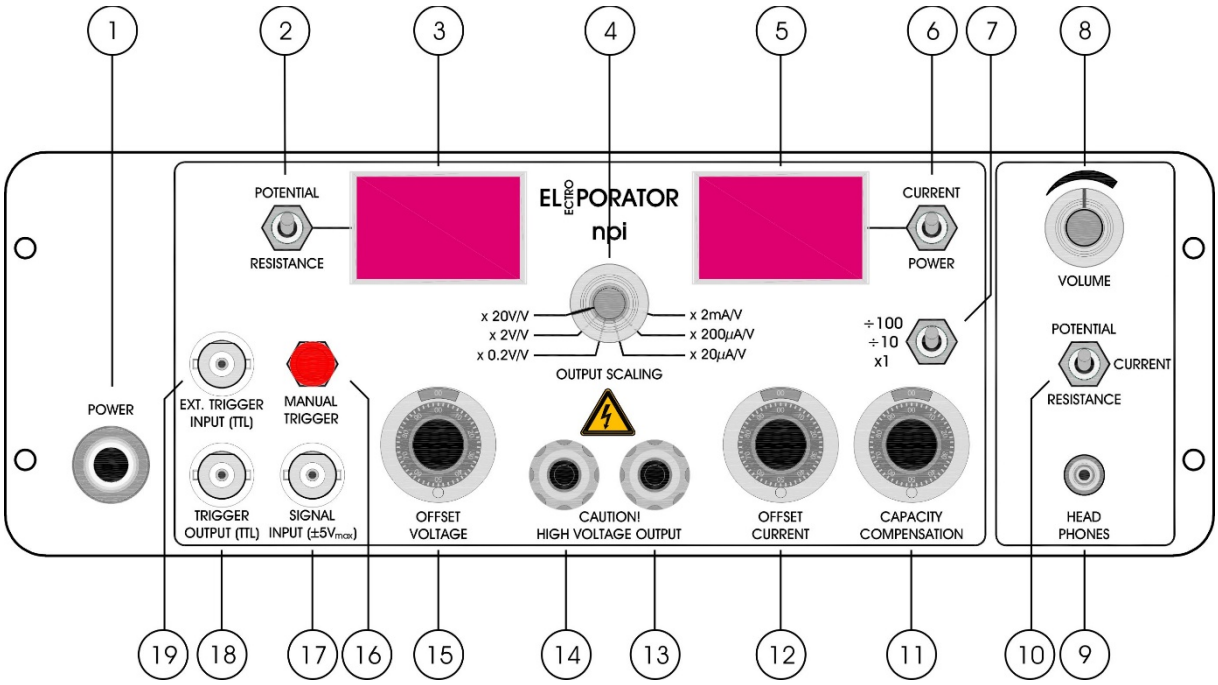


Figure 1: ELectroPORATOR front panel view

***Important***: The input voltage at SIGNAL INPUT (**#17**) must not exceed ±5V

### 3.2. Description of the Front Panel

(**1**) POWER switch

Pushbutton to switch the amplifier ON (pushed) or OFF (released).

(**2**) POTENTIAL/RESISTANCE switch

This switch selects whether the POTENTIAL or the RESISTANCE is displayed at #**3**. The electrode resistance is determined by square pulses of ±1 µA.

(**3**) POTENTIAL/RESISTANCE display

This display shows either the POTENTIAL or the electrode RESISTANCE, as set by switch **#2.** The resolution depends on setting of OUTPUT SCALING switch. See also technical data.

(**4**) OUTPUT SCALING rotary switch

Rotary switch for selecting how the output signal is scaled relative to the input signal at #**17**.

| | |
|---|---|
| Voltage output: | x 20 V/V |
| | x 2 V/V |
| | x 0.2 V/V |
| Current output: | x 2 mA/V |
| | x 200 µA/V |
| | x 20 µA/V |

(**5**) CURRENT/POWER display

This display shows either the CURRENT or the POWER, as set by switch **#6.** The resolution depends on setting of OUTPUT SCALING switch. See also technical data.

(**6**) CURRENT/POWER switch

This switch selects whether the CURRENT or the POWER is displayed at #**3**.

(**7**) ÷100, ÷10, x1 switch

Three position switch for pre-selecting the voltage and current output range (x 1, ÷10, ÷100). Activating this switch will alter the output scaling of the **#13 #14** output plugs as well as the capacity compensation **#11**, and the rear panel monitor BNCs (see below). In table 1 there is an overview over all possible states and scaling.

CURRENT output rear panel: ±10 V correspond to ±maximum current range

POTENTIAL output rear panel: 100 mV/V (not changed compared to standard)

RESISTANCE output rear panel: scaled 1 V/MΩ (except in ÷100 mode: 0.1 V/MΩ).

POWER output rear panel: 10 V/W (not changed compared to standard)

**AUDIO MONITOR unit**

(**8**) VOLUME potentiometer

Potentiometer for adjusting the output volume for the internal loudspeaker and the headphone jack #9.

(**9**) HEADPHONES connector

3.5 mm headphone connector providing the audio monitor signal. The internal loudspeaker is disabled if a headphone is connected.

(**10**) SOURCE SELECT switch

Toggle switch for selecting the signal source for the audio monitor:
POTENTIAL, CURRENT or RESISTANCE.

***Caution***: THIS INSTRUMENT HAS A HIGH VOLTAGE OUTPUT (UP TO ±100 V)!!! Do not touch these pins or bare wires connected to these pins. Always turn power off if you manipulate devices connected to these pins.

(**11**) CAPACITY COMPENSATION potentiometer

The CAPACITY COMPENSATION potentiometer compensates for the input capacitances in CURRENT output operation only. Capacity compensation is achieved by turning the potentiometer clockwise, until the current signal at the oscilloscope is as square as possible.
The signal can be monitored at the CURRENT 100/10/1 mV/µA connector on the real panel.

***Important***: If the CAPACITY COMPENSATION is overcompensated in CURRENT MODE the electroporator will ring and not work properly!

(**12**) OFFSET CURRENT potentiometer

Potentiometer compensate for the CURRENT OFFSET of the electroporation electrode. It is recommended to compensate the offsets only in a completely warmed up condition, i.e. after 30 minutes warm-up time (see below). Offset range is dependent on current scaling. See also technical data. The signal can be monitored at the CURRENT 100/10/1 mV/µA connector on the real panel.

(**13, 14**) HIGH VOLTAGE OUTPUT plugs

The output signal is available at two banana plugs (red and black, 4 mm).

(**15**) OFFSET VOLTAGE potentiometer

Potentiometer to compensate for the VOLTAGE OFFSET of the electroporation electrode. It is recommended to compensate the offsets only in a completely warmed up condition i.e. after 30 minutes warm-up time. Offset range: is ±1 V, The signal can be monitored at the POTENTIAL 0.1 V/V connector on the real panel.

(**16**) MANUAL TRIGGER button

Button for triggering the function generator or data acquisition system connected to SIGNAL INPUT manually.

(**17**) SIGNAL INPUT (±5 Vmax) connector

BNC connector for the input of an analog signal. Please do not exceed ±5 V

(**18**) TRIGGER OUTPUT (TTL) connector

BNC connector providing a TTL HIGH signal (length: 400 µs) when the electroporator's trigger unit is activated. This TTL signal is used for triggering the function generator or data acquisition system.

(**19**) EXT. TRIGGER INPUT (TTL) connector

BNC connector for the input of a TTL external trigger signal for triggering the function generator or data acquisition system connected to SIGNAL INPUT.

### 3.3. Description of the Rear Panel

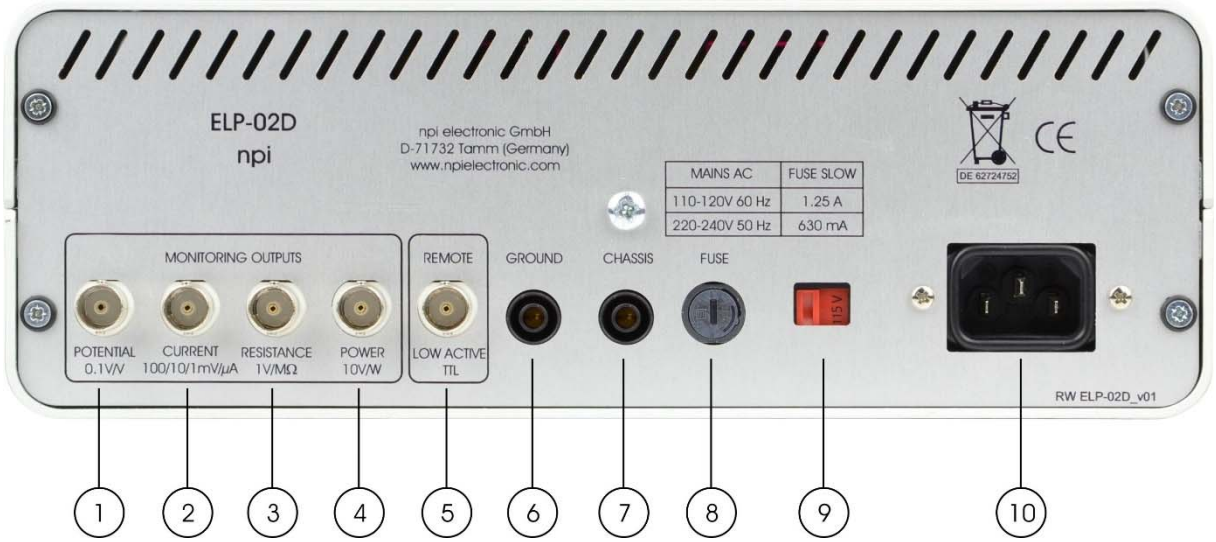


Figure 2: ELectroPORATOR rear panel view

**MONITORING OUTPUT** connectors

Scaling of the MONITORING OUTPUTS for current and resistance depends on the setting at the current range switch (**#7** front panel).

(**1**) POTENTIAL: scaling 0.1 V/V

(**2**) CURRENT: ±10 V correspond to ±maximum current range (scaling also dependent on current scaling, **#4**, front panel)

(**3**) RESISTANCE: scaling 1 V/MΩ (except in ÷100 mode: 0,1 V/MΩ)

(**4**) POWER: scaling10 V/W

(**5**) REMOTE connector

BNC connector with active low logic. A passive footswitch or a remote button can be connected here.

(**6**) GROUND connector

Banana plug providing internal ground (see below).

(**7**) CHASSIS connector

Banana plug providing mains ground (see below).

(**8**) FUSE holder

Holder for the line fuse. For changing the fuse rotate the holder counter-clockwise using a screw driver.

(**9**) LINE SELECT switch

Switch for selecting the line voltage. Switch to the right for 230 V AC, to the left for 115 V AC. The selected voltage is indicated on the switch.

***Caution***: Before turning on the instrument, make sure that the correct line voltage is selected.

(**10**) Mains connector

Plug socket for the mains power-plug.

***Important***: Check line voltage before connecting the ELectroPOATOR to power. Always use a three-wire line cord and a mains power-plug with a protection contact connected to ground. Disconnect mains power-plug when replacing the fuse or changing line voltage. Replace fuse only by appropriate specified type (one spare fuse is supplied). Before opening the cabinet unplug the instrument.

### *3.4. Description of the headstage*

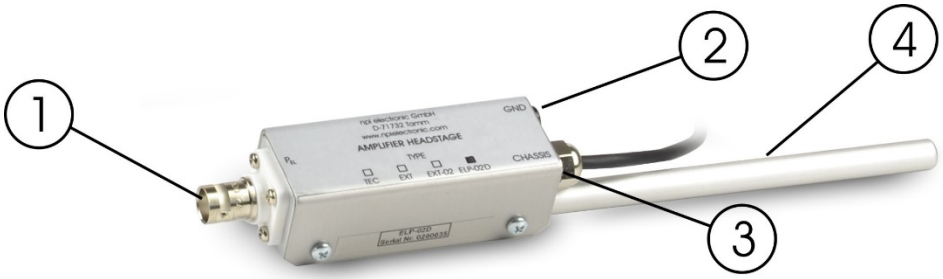


Figure 3: Headstage of the ELectroPORATOR.

**(1)** $P_{EL}$ BNC connector

The pipette holder with the micropipette for electroporation is connected here.

**(2)** GNC connector

2.4 mm connector for connecting the bath electrode.

**(3)** CHASSIS connector

2.4 mm connector for grounding the headstage's housing. This might be useful in case of electrical noise.

**(4)** Mounting rod

The headstage can be mounted with this 8 mm rod to a micromanipulator. Alternatively, a dovetail plate can be installed.

# 4. Operation

## 4.1. General

The instrument is operated by connecting a signal generator or data acquisition analog output to SIGNAL INPUT. This signal can have a maximum range of ±5 V. This signal is transformed into an output signal at HIGH VOLTAGE OUTPUT and scaled according to the settings at the OUTPUT SCALING switch.

The ELectroPORATOR has a trigger unit for starting the function generator or data acquisition system connected to SIGNAL INPUT. This trigger can be set manually by the MANUAL TRIGGER or a footswitch/button connected to REMOTE LOW ACTIVE TTL at the rear panel. It can also be set externally by connecting an external trigger to TIGGER INPUT (TTL). Activating the trigger unit leads to a TTL HIGH signal at TIGGER OUTPUT (TTL).

SIGNAL INPUT and HIGH VOLTAGE OUTPUT are always connected and an electroporation signal is generated as soon as the function generator or data acquisition system connected to SIGNAL INPUT is activated.

Before using the ELectroPORATOR compensate for OFFSETS (VOLTAGE and CURRENT separately) and for electrode capacity (in current output mode).
Output signals can be monitored by connecting an oscilloscope or a data acquisition system to the monitoring outputs on the rear panel.

## 4.2. Approaching cells in RESISTANCE mode

RESISTANCE mode (switch **#2**) can be used in combination with the audio monitor for approaching cells. When a cell is found and the pipette gets close to its membrane, this can be heard as a change in resistance.

Pushing the FOOTSWITCH in this situation, this will change the mode of the amplifier from resistance measurement to application (depending on the setting at the OUTPUT SCALING rotary switch **#4**) for as long as the footswitch is pushed. It also sends a signal to the TRIGGER OUTPUT. After releasing the FOOTSWITCH the amplifier immediately returns to resistance measurement mode.

## 4.3. Approaching cells in POTENTIAL mode

VOLTAGE mode (switch **#2**) can also be used for approaching cells. Pushing the FOOTSWITCH in this situation will only send a trigger to the TRIGGER OUTPUT, since the amplifier already is in voltage mode and ready for stimulation.

# 5. Technical Data

**Output modes**:
Voltage source or current source,
selectable with rotary switch

**Scaling**:
For output scaling see Table 1 below.

**Displays**:
For Potential and Current Display, see Table 1 below.

Resistance:
XXX.X MΩ

Power:
XXXX mW in all scalings (voltage output)
XX.XX mW in x20 µA/V scaling (current output)
XXX.X mW in x200 µA/V scaling (current output)
XXXX mW in x2 mA/V scaling (current output)

**Trigger Unit**:
Trigger Input front panel: TTL, active high, 10 kΩ, max. 2 kHz
Trigger Input rear panel (REMOTE): TTL, active low
Push button
Trigger Output front panel: TTL, active high, 50 Ω, length: 400 µs

**Offset Ranges**:
Potential: ±1 V
Current: ±400 nA in x20 µA/V scaling (current output)
Current: ±4 µA in x200 µA/V scaling (current output)
Current: ±40 µA in x2 mA/V scaling (current output)

**Monitors Scaling**:
Potential: 100 mV/V
Resistance: 1 V/MΩ (except in ÷100 mode: 0.1 V/MΩ)
Current (depending on mode and scaling):
In VOLTAGE mode: 1V/mA
In CURRENT mode: ±10 V correspond to ±maximum current range
Power: 10 V/W

**Input voltage range:** ±5 V

**Max. output voltage:** ±100 V max.

**Max. output current:** ±10 mA max.

**Dimensions:** 245 x 260 x 90 mm³

Table 1: Scaling and Display settings for all possible current ranges.

**x1 Mode**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XXX.X V | XX.XX mA |
| x 200µA/V | XXX.X V | XXXX µA |
| x 20 µA/V | XXX.X V | XXX.X µA |
| x 0.2 V/V | XX.XX V | XX.XX mA |
| x 2 V/V | XXX.X V | XXX.X mA |
| x 20V/V | XXX.X V | XXX.X mA |

**÷10 Mode**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XXX.X V | XXXX µA |
| x 200µA/V | XXX.X V | XXX.X µA |
| x 20 µA/V | XXX.X V | XX.XX µA |
| x 0.2 V/V | XX.XX V | XX.XX mA |
| x 2 V/V | XXX.X V | XX.XX mA |
| x 20V/V | XXX.X V | XX.XX mA |

**÷100 Mode**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XXX.X V | XXX.X µA |
| x 200µA/V | XXX.X V | XX.XX µA |
| x 20 µA/V | XXX.X V | XXXX nA |
| x 0.2 V/V | XX.XX V | XX.XX mA |
| x 2 V/V | XXX.X V | XX.XX mA |
| x 20V/V | XXX.X V | XX.XX mA |

**x1 Mode & RESISTANCE**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XXX.X MΩ | 1.0 µA |
| x 200µA/V | XXX.X MΩ | 1.0 µA |
| x 20 µA/V | XXX.X MΩ | 1.0 µA |
| x 0.2 V/V | XXX.X MΩ | 1.0 µA |
| x 2 V/V | XXX.X MΩ | 1.0 µA |
| x 20V/V | XXX.X MΩ | 1.0 µA |

**÷10 Mode & RESISTANCE**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XX.XX MΩ | 100 nA |
| x 200µA/V | XX.XX MΩ | 100 nA |
| x 20 µA/V | XX.XX MΩ | 100 nA |
| x 0.2 V/V | XX.XX MΩ | 100 nA |
| x 2 V/V | XX.XX MΩ | 100 nA |
| x 20V/V | XX.XX MΩ | 100 nA |

**÷100 Mode & RESISTANCE**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XXX.X MΩ | 10 nA |
| x 200µA/V | XXX.X MΩ | 10 nA |
| x 20 µA/V | XXX.X MΩ | 10 nA |
| x 0.2 V/V | XXX.X MΩ | 10 nA |
| x 2 V/V | XXX.X MΩ | 10 nA |
| x 20V/V | XXX.X MΩ | 10 nA |

**x1 Mode & POWER**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XXX.X V | XXXX mW |
| x 200µA/V | XXX.X V | XX.XX mW |
| x 20 µA/V | XXX.X V | XXXX µW |
| x 0.2 V/V | XX.XX V | XXXX mW |
| x 2 V/V | XXX.X V | XXXX mW |
| x 20V/V | XXX.X V | XXXX mW |

**÷10 Mode & POWER**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XXX.X V | XX.XX mW |
| x 200µA/V | XXX.X V | XXXX µW |
| x 20 µA/V | XXX.X V | XXX.X µW |
| x 0.2 V/V | XX.XX V | XXXX mW |
| x 2 V/V | XXX.X V | XXXX mW |
| x 20V/V | XXX.X V | XXXX mW |

**÷100 Mode & POWER**

| OUTPUT SCALING switch | Display POTENTIAL | Display CURRENT |
|---|---|---|
| x 2 mA/V | XXX.X V | XX.XX mW |
| x 200µA/V | XXX.X V | XXXX µW |
| x 20 µA/V | XXX.X V | XXX.X µW |
| x 0.2 V/V | XX.XX V | XXXX mW |
| x 2 V/V | XXX.X V | XXXX mW |
| x 20V/V | XXX.X V | XX.XX mW |