Electronic Instruments
for the Life Sciences

# SEC Series

## Single Electrode Voltage and Current Clamp Amplifiers


SEC-05X


SEC-10LX

npi SEC amplifiers are versatile intracellular recording systems. They are the fastest and most accurate single electrode current- and voltage-clamp amplifiers available. SEC devices are suitable for recordings with high resistance microelectrodes, and for tight-seal perforated patch or whole-cell recording techniques with patch pipettes. SEC systems can be used for extracellular recording as well. They also allow artifact-free simultaneous recordings from two cells (double-cell VC technique) or intracellular recordings during voltammetry experiments.

The SEC amplifiers fully compensate the recording microelectrode. This is a significant improvement over other time-sharing amplifiers, and makes possible single electrode recordings with the same accuracy and speed of response as with the standard two electrode voltage clamp approach. Moreover, the time-sharing principle of SEC amplifiers completely eliminates series resistance errors.

All amplifiers include at least four modes of operation, many automatic functions, protection circuits, versatile I/O signal conditioning units, and digitally controlled operation. Furthermore, a lot of accessories and additional options are available. All of these features make these amplifiers the ideal research instruments for all electrophysiological investigations that utilize intracellular microelectrodes.

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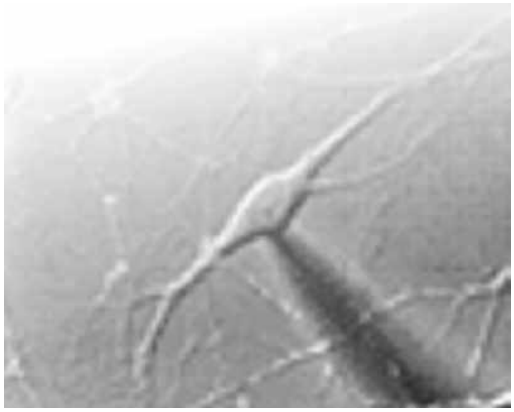
# Features:



- four modes of operation by default
  - Bridge mode (BR)
  - Current Clamp mode (CC)
  - Voltage Clamp mode (VC)
  - Electrode resistance test mode ($R_{EL}$)
- three additional modes optional
  - **V**oltage **C**lamp **c**ontrolled **C**urrent **C**lamp mode (VCcCC)
    Allows Current Clamp experiments at controlled resting potentials
  - **D**ynamic **H**ybrid **C**lamp mode (DHC)
    Allows precise measurement of conductances after action potentials
  - Linear (unswitched) mode (LIN)
    x1: Allows low-noise recordings of small currents, and approaching the cell and seal formation in VC mode
    x10: Provides 10 times more current in CC and 10 times more voltage in VC mode for non-invasive (juxtacellular) filling of cells
- complete compensation of electrode artifacts allowing high (>30 kHz) switching frequencies
- no series resistance errors
- perfect for recording also from coupled cells with two syncronized SEC amplifers (SEC-SYNC)
- recordings with sharp microelectrodes or patch pipettes
- true current clamp in switched and bridge mode
- fast switched voltage clamp with proportional-integral (PI) controller
- versatile and configurable penetration unit
- BESSEL filters for current and voltage (16 corner frequencies)
- monitors for filters and current output sensitivity

## References:


**Books:** Polder, H.R., M. Weskamp, K. Linz and R. Meyer (2005). Voltage-Clamp and Patch-Clamp Techniques. (2005) Chapter 3.4, in: Dhein, St.; Mohr, FW; Delmar, M. (eds.) Practical Methods in Cardiovascular Research, Springer, Berlin Heidelberg New York.

Lalley, P. M., Moschovakis, A. K. and Windhorst, U. (1999). Electrical Activity of Individual Neurons in Situ: Extra- and Intracellular Recording, in: U. Windhorst and H. Johansson (eds.) Modern Techniques in Neuroscience Research, Springer, Berlin, New York

**Theory:** Polder, H.R. and D. Swandulla (2001). The use of control theory for the design of voltage clamp systems: A Simple and standardized procedure for evaluating system parameters, J. Neurosci. Meth., 109: 97-109.

**VCcCC:** Sutor, B., Ch. Grimm and H.R. Polder (2003). Voltage-Clamp controlled Current-Clamp Recordings ..., Pflügers Arch. 446, 133-141.

**DHC:** Dietrich, D. et al. (2002). Improved hybrid clamp: resolution of tail currents following single action potentials. J.Neurosci.Meth. 116, 55-63.

**SEC-SYNC:** Müller, A., M. Lauven, R. Berkels, S. Dhein, H.R. Polder and W. Klaus (1999). Switched single electrode amplifiers allow precise measurement of gap junction conductance, Am. J. Physiol. (Cell) 276, C980-88.

**Juxtacell. filling:** Both M, Bähner F, von Bohlen, Halbach O, und Draguhn A. (2008.) Propagation of specific network patterns through the mouse hippocampus. Hippocampus. May 2008, DOI: 10.1002/hipo.20446.

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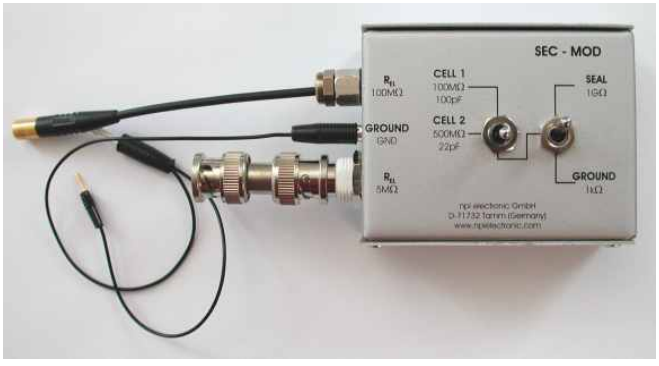
SEC-03M module for
EPMS-07 system

SEC low-noise headstage
with electrode holder


SEC headstage for
extracellular recording


SEC standard headstage
with electrode holder
and adapter




SEC passive
cell model

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# Technical Data

MODES of OPERATION
$R_{EL}$: Electrode Resistance Test
BR: Bridge Mode
CC: Current Clamp Mode
VC: Voltage Clamp Mode
DHC: Dynamic Hybrid Clamp Mode (option)
VCcCC: Voltage Clamp controlled
Current Clamp Mode (option)
LIN: Linear Mode (x1 and x10)
Mode selection:
rotary switch with six positions (SEC 05X)
four pushbuttons (SEC 10LX)
rotary switch with five positions (SEC 03)
Linear Mode with switch

HEADSTAGES
**Standard** headstage(SH), **low-noise** Headstages(HSP)
operation voltage: ±15 V
size: 100x40x25mm, HSP: **XXXX**
headstage enclosure connected to ground
electrode connector: gold plated SMB (SH)
BNC connector (HSP), both with driven shield
ground: 2.6 mm connector or headstage enclosure
input resistance: $>10^{13}$ Ohms
current range (continuous mode):
150 nA (SH); 15 nA into 100 MOhms (HSP)
CC control: Coarse control for cap. comp.
holding bar (SH): diameter 8 mm, length 10 cm
mounting plate (HSP headstage) 60x50 mm
**EXT** headstage: 1 mm connectors,
differential high impedance input, gain of ten
cap. comp. for the non-inverting input
high pass filter with six corner frequencies
(1; 3; 10; 30; 100; 300 Hz)

BANDWIDTH AND SPEED OF RESPONSE
Full power bandwidth (Re=0): >100 kHz
rise time (10-90%, Re = 100 MOhms) <30 µs
rise time (10-90%, Re = 5 MOhms) <8 µs
Electrode artifact decay (switched modes
10 nA signal) <1 µs (Re = 5 MOhms)
<1.5 µs (Re = 100 MOhms)
cap. comp. tuned with no overshoot

ELECTRODE RESISTANCE TEST
10 mV/MOhm, obtained by application of square
current pulses ±1 nA, display XXX MOhm

OSCILLATION SHUT-OFF
Turns off current injection and cap. comp. function
indicated by red/green LED,
disabled / off / reset switch
threshold set with linear control (0-1200 mV).
SEC-03: no oscillation shut-off

CELL PENETRATION
Overcompensation of cap. comp.,
timer controlled,with remote switch
connected via BNC connector.
Application of DC pulses, variable frequency and
amplitude, timer controlled, with remote switch
connected via BNC connector (SEC-10).
Application of max. continuous DC current, BUZZ,
with push button or remote switch connected via
BNC connector (SEC-05).
No cell penetration unit (SEC-03)
(modular penetration unit available)

SWITCHED MODES PARAMETERS
Switching frequency: linear control
1.5 to >50 kHz; display: XX.XX kHz.
duty cycles: 1/2, 1/4, 1/8
selected by toggle switch.
SEC-03: fixed 1/4 duty cycle

CURRENT RANGE vs. DUTY CYCLE
1/8 - 15 nA; 1/4 - 30 nA, 1/2 - 60 nA
(standard 15 V headstage)
1/8 - 1.5 nA; 1/4 - 3 nA, 1/2 - 6 nA
(low noise headstage)

SWITCHED MODE OUTPUTS
Electrode potential: max. ±15 V,
output impedance 250 Ohms.
switching frequency: TTL (5 V),
output impedance 250 Ohms.

CURRENT OUTPUT
Sensitivity: 0.1...10 V/nA in 1-2-5 steps
with lowpass Bessel filter
output impedance 250 Ohms
sensitivity monitor: 1...7 V, 1V/switch position
output impedance 250 Ohms
current display: X.XX nA
SEC-03: fix 0.1V/nA

POTENTIAL OUPUT
Sensitivity x10 mV, with lowpass Bessel filter
output impedance 250 Ohms
potential display: XXX mV

AUDIO MONITOR
Pitch correlated with potential signal

OUTPUT FILTERS
SEC-05: two-pole (standard version) or
four-pole lowpass Bessel filters (SEC-05X-BF) with
16 corner frequencies, 20 Hz - 20 kHz
frequency monitor: -8...+7 V, 1 V/switch position
output impedance 250 Ohms.
SEC-10: four-pole lowpass Bessel filter with
16 corner frequencies, 20 Hz - 20 kHz
output impedance 250 Ohms.
SEC-03: unfiltered or 5 kHz, internally adjustable

CURRENT CLAMP
Inputs: 1 nA/V, 0.1 nA/V with ON/OFF switches
SEC-03: 1 nA/V
input resistance >100 kOhms
hold: X.XX nA ten-turn digital control, -/0/+ switch
max. 10 nA.
Gated input (SEC-10 systems only): X.XX nA
with +/0/- switch, TTL input (HI >2.5 V, input
resistance 10 kOhm).
BRIDGE balance: XXX MOhms with
ten-turn digital control.
noise (BRIDGE MODE): 400µV pp / pA pp
with 100 MOhms resistance at 10 kHz bandwidth
(internal four-pole Bessel filters)

VOLTAGE CLAMP
Inputs: ÷10 mV or ÷40 mV
SEC-03: ÷10mV
input resistance >100 kOhms
hold: XXX mV, ten-turn digital control
with +/0/- switch, max. 1000 mV
rise time limit: 0-2 ms (SEC-05 / SEC-10 only)
gain: 100 nA/V - 10 µA/V ten-turn linear control
noise (filters set to 10 kHz, SEC-05 / SEC-10)
Potential output: <400 µV pp
current output: <400 pA pp

SPEED of RESPONSE (VC Mode)
1 % settling time: <80 µs for 10 mV step
<800 µs for 50 mV step applied to cell model
(Re= 100 MOhms, Rm= 50 MOhms, Cm= 470 pF
duty cycle = 1/4, switching frequency = 30 kHz
standard headstage)
<400 µs with 1/2 duty cycle.

DIMENSIONS
SEC-05 / SEC-10 systems:
19" (483 mm) wide
14" (355 mm) deep
5.25" (132.5 mm) high,
SEC-03 (two slots):
24 HP (121 mm) x 3U (128 mm) x 7 inch (175 mm)

## Optional accessories:

**SEC-MOD**: passive cell model
**SEC-MODA**: active cell model
**SEC-EH-SET**: electrode holder set
(1 with port, 1 without port, 1 holding bar)
**SEC-PRS**: remote switch for penetration
**Headstages**: SEC-HSP low-noise recording
SEC-EXT extracellular recording
SEC-HSD differential measurement

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