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 recordings 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.
Features:

- four modes of operation by default
  - Bridge mode (BR)
  - Current Clamp mode (CC)
  - Voltage Clamp mode (VC)
  - Electrode resistance test mode ($R_e$)

- three additional modes optional
  - Voltage Clamp controlled Current Clamp mode (VCcCC)
    Allows Current Clamp experiments at controlled resting potentials
  - Dynamic Hybrid Clamp mode (DHC)
    Allows precise measurement of conductances after action potentials
  - Linear (unswitched) mode (LIN), optional with series resistance compensation
    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 synchronized SEC amplifiers (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:

Theory:

SEC-SYNC:

DHC:

Juxtacellular filling:
SEC-03M module for EPMS-07 system

SEC low-noise headstage with electrode holder

SEC standard headstage with electrode holder and adapter

SEC headstage for extracellular recording

SEC mini headstage set

SEC passive cell model
**Technical Data**

### MODES OF OPERATION

- **R.**: Electrode resistance test
- **BR**: Bridge mode
- **CC**: Current Clamp mode
- **VC**: Voltage Clamp mode
- **DHC**: Dynamic Hybrid Clamp mode (option)
- **VCC**: Voltage Clamp controlled Current Clamp mode (option)
- **LIN**: Linear mode
- **LIN**: Linear mode with series resistance compensation
- **Mode selection**:
  - rotary switch with six positions (SEC 05X)
  - four pushbuttons (SEC 10X)
  - rotary switch with five positions (SEC 03)
  - Linear mode with switch

### HEADSTAGES

- **Standard headstage (SH)**, **low-noise Headstages (HSP)**
- Operation voltage: ±15 V
- Size: 100x40x25 mm, HSP: 77x37x20 mm
- Headstage enclosure connected to ground: gold plated 3M (SH)
- BNC connector (HSP), both with driven shield ground: 2.6 mm connector or headstage enclosure input resistance: >10^5 Ohms
  - Current range (continuous mode):
    - 150 nA (SH): 15 nA into 1000 Ohms (HSP)
  - CC control: Coarse control for cap. comp. holding bar (SH): diameter 8 mm, length 10 cm
  - Headstage enclosure: 60x50 mm
  - EXT: headstage: 1 mm connector, differential high impedance input, gain of ten cap. comp. for the non-inverting input
  - High pass filter with six corner frequencies:
    - 1/10 kHz
  - Current range (continuous mode): 150 nA (SH): 15 nA into 1000 Ohms (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 connector, differential high impedance input, gain of ten cap. comp. for the non-inverting input
  - Current range (continuous mode): 150 nA (SH): 15 nA into 1000 Ohms (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 connector, differential high impedance input, gain of ten cap. comp. for the non-inverting input

### BANDWIDTH AND SPEED OF RESPONSE

- Full power bandwidth (Re = 0): >10 kHz
- Rise time (10-90%, Re = 1000 Ohms): <30 ms
- Rise time (10-90%, Re = 5000 Ohms): <8 µs
- Electrode artifact decay (switched modes 10 nA signal) <1 µs (Re = 5000 Ohms)
- Cap. comp. tuned with no overshoot

### ELECTRODE RESISTANCE TEST

- 10 mV/Ohm, obtained by application of square current pulses ±1 nA, display ±500 mV

### 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)

### ELECTRODE 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
- 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)

### SWITCH 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

### CURRENT OUTPUT

- Electrode potential: max. ±15 V
- Output impedance 250 Ohms
- Current output: ±400 pA

### VOLTAGE CLAMP

- Inputs: ±10 mV or ±40 mV
- Input resistance > 100 kOhms
- Hold: X.XX nA ten-turn digital control, -/0/+ switch

### BRIDGE BALANCE

- Inputs: ±10 mV or ±40 mV
- Input resistance > 100 kOhms
- Hold: X.XX nA ten-turn digital control, -/0/+ switch
- 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)

- % settling time: <80 µs for 10 mV step
- <800 µs for 50 mV step applied to cell model
- Gain: 1000 mV
- Rise time limit: 0-2 ms (SEC-05 / SEC-10 only)
- Potential output: <400 µV pp
- Current output: <400 pA pp

### AUDIO MONITOR

- Pitch correlated with potential signal

### Optional accessories:

- **SEC-MOD**: passive cell model
- **SEC-MODA**: active cell model
- **SEC-EH-SET**: electrode holder set
- **SEC-PRS**: remote switch for penetration
- **Headstages**: SEC-HSP low-noise recording, SEC-EXT extracellular recording, SEC-HSD differential measurement

### Technical Support

For more information contact:

**General**
- npi electronic GmbH
  - Phone: +49-7141-9730230
  - Fax: +49-7141-9730240
  - sales@npi-electronic.com
  - www.npi-electronic.com

**Switzerland**
- Science Products AG
  - Phone: +41-61-3013570
  - Fax: +41-61-3033555
  - info@science-products.com
  - www.science-products.com