A-M Systems

Neuroprobe Amplifier

1600

INSTRUCTION MANUAL

FOR

NEUROPROBE AMPLIFIER

MODEL 1600

Serial #__________

Date____________

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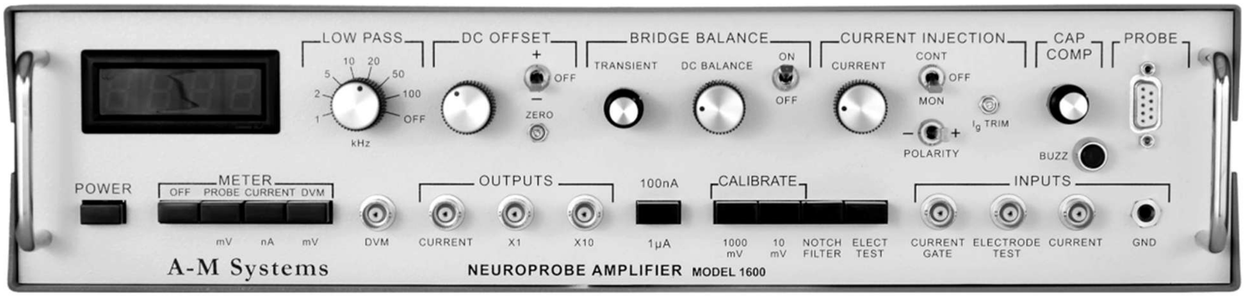
Each Neuroprobe Amplifier
is delivered complete with:

One Head Stage with a 5 Foot Cable
Rack Mount Hardware

NOTE

This instrument is not intended for clinical measurements using human subjects. A-M Systems, Inc. does not assume responsibility for injury or damage due to the misuse of this instrument.

General Description



Instrument Features

The *Neuroprobe Amplifier Model 1600* is designed for intracellular recording and stimulation. The instrument consists of a high-input-impedance electrometer amplifier combined with current injection and balance circuitry, allowing simultaneous stimulation and recording through the same electrode. A digital panel meter allows direct display of membrane potential, injected current, and electrode impedance.

Additional features include a variety of current-control modes, signal-conditioning filters, and an internally-generated square-wave current source for adjusting compensation and measuring electrode impedance. An *Iontophoresis Adapter Model 6820* is also available to allow for the application of high voltages for iontophoretic injection of drugs or dyes, or any other application where greater current levels are required.

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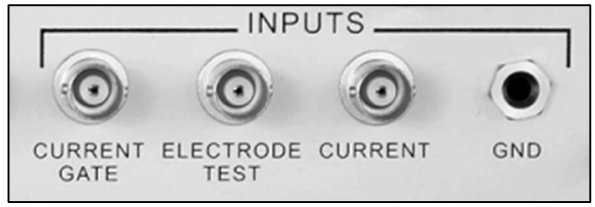
Controls and Connectors

INPUTS



CURRENT GATE: This BNC connector provides control over the timing of current injection. A signal greater than +2.5 V (optimal results will be obtained with a signal of +5 V) at this input triggers injection of the preset current and a signal less than +0.6 V (optimal results will be obtained with a signal of 0.0 V) turns the injection current off. When not connected, the current gate is in an off state and current gating is manually controlled via the **CURRENT INJECTION (CONT-OFF-MOMEN)** switch.

ELECTRODE TEST: This BNC connector enables a current to be injected through the electrode for periodically checking the electrode resistance in situ. The injection current, which is proportional to the voltage applied to this input, results in a voltage drop across the electrode which is proportional to the electrode resistance. (The membrane impedance is also involved, but is typically much smaller than that of the electrode.) Unlike the injected current regularly used, this electrode test current is not affected by the **CURRENT GATE** input or the **DC BALANCE** knob, allowing the full voltage drop to appear at the **OUTPUTS**. Thus, the output signal may be recorded as a measure of electrode resistance. This feature may also be used to periodically document the integrity of the electrode tip without disturbing the preparation. The sensitivity of the **ELECTRODE TEST** input is 1 mV/MΩ/(input voltage) in Low Range Mode and 10 mV/MΩ/(input voltage) in High Range Mode. For example, in Low Range Mode with 5 V applied to the **ELECTRODE TEST** connector, if the **X**1 **OUTPUT** reads 50 mV, we can calculate 50 MΩ divided by 5 V, yielding an electrode impedance of 10 MΩ.

CURRENT: This BNC connector provides control over the magnitude of the injected current via an external signal applied at this input. The current applied here is summed with the current set by the **CURRENT INJECTION: CURRENT** knob. The total current magnitude can be monitored at the **METER** or at the **OUTPUT: CURRENT** connector. Sensitivity is 10 nA/V in Low Range Mode and 100 nA/V in High Range Mode. Current injection is triggered via the **CURRENT INJECTION (CONT-OFF-MOMEN)** switch or the **CURRENT GATE** connector.

GND: This connector provides a ground or reference point for measuring probe potential.

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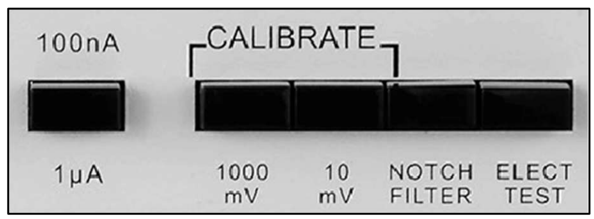
Capacity Controls

COMP.: This knob is used to adjust an active feedback circuit to compensate for up to 30 pF of electrode capacitance. The capacitance compensation can be accurately adjusted with the electrode in the experimental preparation using the internal square-wave generator and an oscilloscope connected to either the **X1 OUTPUT** or the **X10 OUTPUT**. This control should be adjusted to obtain the sharpest corners possible on the square-wave with very little overshoot. Clockwise rotation of both parts of this control increases the capacity compensation. The outer ring provides a coarse adjustment and the inner knob allows for fine control.

BUZZ: This button provides a capacitance override to send the circuit into positive feedback and cause the electrode to vibrate. This is commonly called a "tickler." When the electrode vibrates rapidly it sometimes will aid in the penetration of the cell membrane, or clearing of a clogged electrode.

Miscellaneous Functions

100nA \ 1uA (HIGH RANGE): This button activates High Range Mode when pressed, changing the available range of injection currents. The maximum injection current is the lesser of 2.5 V /(electrode resistance) and either 100 nA in Low Range Mode or 1000 nA in High Range Mode. The key criterion for current range selection is the ability to balance the voltage drop across the electrode. The *Model 1600* can balance up to 500 MΩ in Low Range Mode and 50 MΩ in High Range Mode.



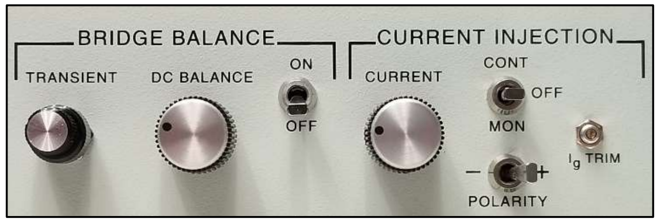
1000 mV CALIBRATE: This button provides an accurate reference signal for calibrating external recording instruments. It causes 1000 mV to appear at the **X1 OUTPUT** and 10 V at the **X10 OUTPUT**, in which case these two connectors are disconnected from other signal sources within the instrument.

10 mV CALIBRATE: This button provides an accurate reference signal for calibrating external recording instruments. It causes 10 mV to appear at the **X1 OUTPUT** and 100 mV at the **X10 OUTPUT**, in which case these two connectors are disconnected from other signal sources within the instrument.

NOTCH FILTER: This button activates filtering of power line frequency interference from the signal. Use this filter only when absolutely necessary, since it can cause signal distortion if the frequency of the recorded signal lies in the rejection band of the Notch Filter (50 or 60 Hz). Adequate shielding and grounding procedures should always be used.

ELECT TEST: This button activates a 100 Hz square-wave current source used to test electrode resistance and to adjust the capacitance compensation. With the **ELECT TEST** and the **METER: PROBE** buttons pressed, the **METER** displays the electrode resistance in MΩ. *(Note: Recording and reference electrodes should be in a saline solution for resistance testing.)* When the electrode resistance is less than 100 MΩ, High Range Mode should be used to maximize the signal-to-noise ratio and increase measurement accuracy. In Low Range Mode 1 nA peak-to-peak produces 1mV/MΩ and in High Range Mode 10 nA peak-to-peak produces 10 mV/MΩ.

Current Injection



TRANSIENT: This knob is a dual-function transient control which adjusts the transient response of the balance circuit to duplicate that of the Headstage Probe, allowing maximum suppression of the transient when balancing out the electrode response for current injection. The smaller knob is the **SLOPE** control; the larger is the **PEAK** control. The effect of both controls is increased as they are rotated clockwise. The **ON\OFF** switch deactivates the entire balance circuit. This is the preferred setting for any experiment not involving current injection, as the balance circuit creates a slight increase in noise level.

DC BALANCE: This knob controls a 10-turn potentiometer which nulls voltage drop across the electrode due to current injection when recording and stimulating through the same electrode. This function is disabled when the **ON\OFF** switch is set to the **OFF** position.

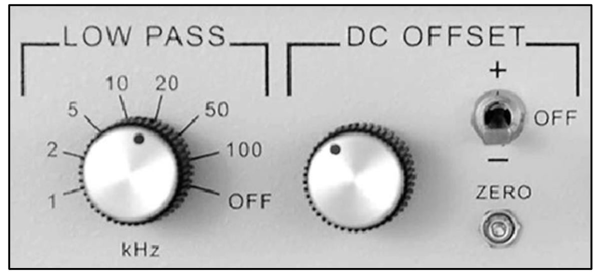
CURRENT: This knob sets the level of the injection current supplied by the internal source. This level can be measured on the **METER** prior to injection.

POLARITY: This switch sets the output polarity of the internal current source.

CURRENT INJECTION (CONT-OFF-MOMEN): This switch triggers injection of the preset injection current. The **CONT** setting triggers continuous current injection which lasts until the switch is manually returned to the **OFF** position. The **MOMEN** setting triggers continuous current injection which lasts only as long as the switch is held in this position. The switch will automatically return to the **OFF** position after being released from the **MOMEN** position.

IG TRIM: This control nulls the input bias current to the Headstage Probe to less than 10^{-13} Amp for high input impedance.

Low Pass Filter



LOW PASS: This knob controls a low pass filter which provides adjustable bandwidth limiting. Attenuation above the cutoff frequency is -12 dB/octave. When the switch is set to **OFF**, the filter is removed from the circuit.

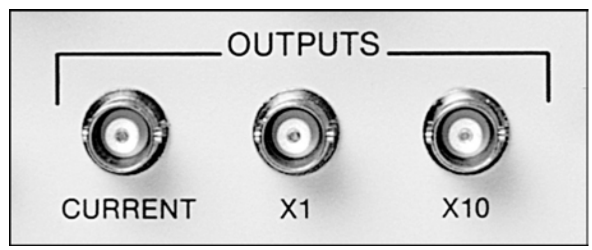
DC Offset

DC OFFSET KNOB: This knob sets the variable DC offset voltage, which is summed with the input voltage. This feature may be used to compensate for electrode potentials and to position the signal trace on an oscilloscope recording device. An offset range of 0.0 V to ±1.0 V is available at the **X1 OUTPUT** and 0.0 V to ±10 V at the **X10 OUTPUT**.

DC OFFSET SWITCH (+ OFF -): This switch sets the DC offset polarity or alternately turns the feature **OFF**.

ZERO: This control nulls any instrument offset potential when the **DC OFFSET SWITCH** is **OFF**, thereby providing a true zero offset.

Outputs



CURRENT: This BNC connector allows the value of current supplied to the electrode to be monitored on an external recording device. The signal is 10 mV/nA in low range (high range button out) and 1 mV/nA in high range (high range button in).

X1 OUTPUT: This BNC connector provides the measured signal (plus any DC offset) for recording on a chart recorder or oscilloscope.

X10 OUTPUT: This BNC connector provides 10 times the measured signal (plus any DC offset) for recording on a chart recorder or oscilloscope.

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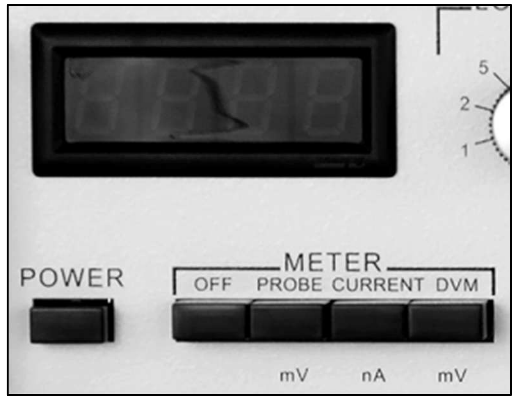
Digital Meter



OFF: This button disconnects the **METER** inputs and turns off all power to the **METER** module, thus increasing battery endurance by about 50 percent.

PROBE: This button displays the DC potential of the **X1 OUTPUT**. When the **ELECT TEST** button is also pressed, the electrode resistance is shown in MΩ.

CURRENT: This button displays the injection current in nA, as determined by the **CURRENT INJECTION: CURRENT** knob and the **INPUTS: CURRENT** connector. The current is displayed regardless of the **CURRENT INJECTION (CONT-OFF-MOMEN)** switch position or the signal level at the **INPUTS: CURRENT GATE** connector.

DVM: This button allows the **METER** to be used as a digital voltmeter without disrupting other instrument functions. When pressed, the **DVM INPUT** connector is connected directly to the **METER** which displays the potential in mV.

DVM INPUT: This BNC connector allows direct access to **METER** for use as a digital voltmeter. The available range is ±1999 mV.

Power Supply

POWER: This button is the main power switch, controlling the DC power input to the main circuit of the instrument. The switch face is lit when the instrument is **ON**. This button does not control the power input to the AC Power Supply or AC Battery Charger Adapter (optional). To power the instrument with the AC Power Supply, the AC power switch located on the back panel of the instrument must be **ON**. Please turn the AC Power Supply **OFF** after using the instrument.

Rear Panel

AC POWER SUPPLY SWITCH: This switch connects the AC power source to the Power Supply. This must be **ON** to provide power to the DC Power Switch located on the front panel. Please do not forget to turn this switch **OFF** after use.

Operating Instructions

Typical Set-Up Procedure

This is a generalized procedure for setting up the *Neuroprobe Amplifier Model 1600* for intracellular recording and stimulation. Portions of this procedure may need to be modified for your specific application.

1. Connect the Headstage Probe cable to the **PROBE** connector.
2. Set the instrument controls as follows:

LOW PASS	**OFF**
DC OFFSET knob	counterclockwise
DC OFFSET (+ OFF -)	**OFF**
BRIDGE BALANCE ON\OFF	**OFF**
TRANSIENT knob	counterclockwise
DC BALANCE	counterclockwise
CURRENT INJECTION (CONT-OFF-MOMEN)	**OFF**
CAPACITY COMP.	counterclockwise
ELECT TEST	**OFF**
NOTCH FILTER	**OFF**
10 MV CALIBRATE	**OFF**
1000 MV CALIBRATE	**OFF**
HIGH RANGE	**OFF**
METER	**PROBE**

3. Turn on power to the *Model 1600* and allow it to warm up for 5 minutes.
4. Mount a micropipette in a micropipette half-cell type holder, which in turn is connected to the Headstage. Clamp the Headstage in a micromanipulator.
5. Connect the reference electrode to the **GND** connector.
6. Dip the micropipette and the reference electrode into a beaker of physiological saline solution (or the solution in which the tissue will be bathed). The solution should have the same temperature and ionic strength as that in which measurements will be made. *Note: immerse the micropipette to approximately the same depth as will be used during the measurement.* 7. Observe the offset potential between the two electrodes displayed on the **METER**.
   Set the **DC OFFSET (+ OFF -)** switch to the appropriate polarity and adjust the **DC OFFSET** knob to zero the digital display and amplifier outputs.
8. Connect an oscilloscope to either the **X1** or **X10 OUTPUT**, with the horizontal sweep rate set to 2ms/division.

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9. Press the **ELECT. TEST** button to inject a 100 Hz square-wave current through the electrode. The digital display now indicates electrode resistance in MΩ. If this value is less than 100 MΩ, press the **HIGH RANGE** button to obtain greater accuracy.
10. Adjust the oscilloscope for a good display of the square-wave.
11. Increase the **CAPACITY COMP.** to "square-up" the corners of the waveform. Avoid overcompensation, which will cause ringing, excessive noise, and high frequency oscillation.
12. Press the **ELECT. TEST** button to stop the test signal.
13. If the electrode resistance is less than 50 MΩ, ensure that the **HIGH RANGE** button is pressed to operate in High Range Mode.
14. Press the **METER: CURRENT** button.
15. Set the **POLARITY** switch to the desired current polarity and adjust the **CURRENT** knob to the maximum current level which will be injected during the experiment.
16. Connect the current gating signal to the **CURRENT GATE** input and adjust the signal source for a repetitive waveform with a pulse duration similar to that which will be used in the experiment.
17. Connect a second oscilloscope channel to the **OUTPUTS: CURRENT** connector. Two signals, one proportional to the injection current, and the other representing the resultant voltage drop across the electrode, should now be available.
18. Switch the **BRIDGE BALANCE ON\OFF** knob slightly clockwise to activate the current balance circuitry.
19. Adjust the **DC BALANCE** knob to remove the electrode voltage drop from the output signal.
20. Adjust the **SCOPE** and **PEAK** controls of the **TRANSIENT** knob to minimize transients occurring when the current is gated on and off.
21. If the injection current magnitude is to be controlled by an external signal, connect this signal to the **INPUTS: CURRENT** connector. Remember this signal will be summed with the setting of the **CURRENT** knob, with the total current displayed when the **METER: CURRENT** button is pressed. The current is injected only when triggered by the **CURRENT INJECTION (CONT-OFF-MOMEN)** switch or by the signal applied to the **CURRENT GATE** input.
22. If the electrode test capability will be used, apply an appropriate control signal to the **ELECTRODE TEST** connector.
23. Connect the desired recording device to the output connector(s).
24. Apply the electrodes to the experimental preparations.
25. If needed, connect an electrode shield to the driven shield ring on the Headstage.
26. Apply the **LOW PASS** filter and **NOTCH FILTER** if necessary.

Power Requirements

Units are powered by a standard AC supply (115/230 VAC)

The *Model 1600* should be warmed up for 30 minutes before any critical adjustments are made.

Headstage and Microelectrode Operation

Headstage Cable Connections

The Headstage cable is connected to the **PROBE** connector on the front panel of the instrument or directly to the *Iontophoresis Adapter Model 6820* if used. ***Note: Always connect and disconnect the*** **PROBE** ***cable with the*** **POWER OFF*.***

Headstage Care

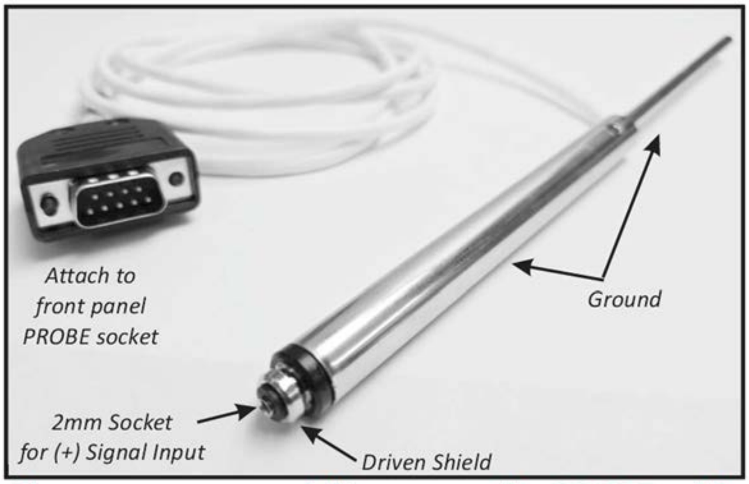
To preserve the high input impedance, the connector end of the headstage must be kept meticulously clean and dry. Contamination on the insulation between the input connector, driven shield and case (even from contact with fingers) can cause current leakage particularly in the humid environment surrounding most experimental preparations. Use tissue paper to wipe this area clean and ensure that all micropipette holders are clean and dry before attaching them to the Headstage. Also, observe the ±10 V limit at the Headstage input. The input FET is protected against static charge however there is no overvoltage protection since such circuitry would result in a loss of input impedance. Be particularly careful near high voltage stimulators.

Mounting Micropipettes

The easiest way to mount a micropipette is with a half-cell type holder. This holder should have a 2.0 mm diameter pin connector to fit the headstage. Fill the holder with the same solution as the micropipette, typically 3M KCl. Be sure there are no air gaps which could cause discontinuity in the electrical connection between the micropipette and holder.

If the micropipette must have freedom of movement or “float,” as when recording from moving muscle fibers, place the end of a thin chloride silver wire into the stem of a filled micropipette, securing the wire at the open end of the pipette with a fast drying cement. Solder the other end of the wire to a 2.0 mm diameter pin connector (Catalog # 521000). Coil the wire between the pipette and pin connector into spring. Insert the clean and dry pin connector in the Headstage.

Driven Shield and Ground Connections



Always connect and disconnect the PROBE cable with the POWER OFF.

The Headstage circuitry is enclosed by a driven shield maintained at the same potential as the input connectors, thus there is no electric field between the input connections and shield, and therefore, no capacitive shunting. This shield is brought out of the Headstage case through the gold ring surrounding the input connector. This connecting ring may be used to extend the driven shield to the micropipette holder and micropipette. Shielding the electrode and holder is recommended since this portion of the circuit is particularly sensitive to stray electric fields, due to the high impedance of the electrode tip and the Headstage input. Using a driven shield for this purpose has the advantage of not introducing any additional shunt capacitance nor a path for current leakage to ground.

A shield can be made from a coil of wire wrapped around the shield ring and extended along the length of the electrode holder and electrode. Foil or other conductive coatings on the electrode surface can also be used for shielding. *Note: Make certain that the driven shield does not contact either the Headstage case or the experimental preparation, as both are at ground or reference potential and such contact will prevent proper circuit operation.*

The Headstage case and **GND** connector are both connected to the circuit ground. This can be used for connecting the reference electrode in situations where it is inconvenient to run a separate reference cable to the experimental preparation. Such a connection can be made directly to the headstage case with a 6-32 x 1/4-inch machine screw inserted into the tapped hole in the case near the Headstage cable opening.

Mounting the Headstage in a Micromanipulator

The Headstage should be clamped in the micromanipulator by means of the mounting rod supplied. The mounting rod can be screwed into the cable end of the headstage for in-line mounting, or attached to the adjustable clamp for right angle mounting. The latter arrangement is generally preferable since it is less sensitive to vibration.

Electrode Calibration

To inject currents and measure membrane potentials accurately compensation must be made for the characteristics of each individual electrode. Electrodes have three key properties: offset potential, resistance, and capacitance.

Any conductive material placed in an ionic solution has a potential with respect to that solution known as the half-cell potential. This potential is a function of the material composition of the electrode, the ions in the solution, ionic activity, and temperature. The potential between two electrodes in a solution is equal to the difference between their half-cell potentials. Ideally, two identical electrodes should have zero potential between them, but small differences in surface properties usually are noticed as a small potential difference.

Most intracellular measurements are made with 3M KCl filled micropipettes which contain or contact Ag/AgCl to form an electrolyte to metal junction. A second Ag/AgCl electrode is generally used as a reference. If the micropipette and reference electrodes are placed in physiological saline, which duplicates the chloride concentration of most biological fluids, a potential difference will be observed. This potential occurs because the Ag/AgCl electrode in the micropipette "sees" the Cl concentration of the 3M KCl, which is much higher than that of the saline surrounding the reference electrode. There should be no significant potential due to concentration gradients at the electrode tip, since potassium and chloride ions have approximately the same ionic mobilities. Thus, to accurately measure the potential across a cell membrane, it is necessary to null the electrode potential using the **DC OFFSET** control. Alternately, one may use an Ag/AgCl electrode surrounded by 3M KCl as a reference electrode. To accomplish this, use an agar bridge or standard pH reference electrode with an Ag/AgCl internal wire (Catalog # 533000).

The micropipette resistance, which normally ranges from 10 to several hundred MΩ, is normally of little concern for measuring potentials, due to the high input impedance of the *Model 1600*. However, when injecting currents through a recording electrode, voltage drop will appear across the electrode resistance and be recorded along with the membrane response. Since the membrane response alone is desired, the

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electrode response must be subtracted from the signal. This is accomplished through the **DC BALANCE**.

The electrode also has capacitance, which is in parallel with the resistance. This capacitance acts as a shunt which attenuates the higher frequency components of the signal. The **CAPACITY COMP**ensation is adjusted to accentuate these higher frequencies, thus compensating for the loss.

For current injection, it is also necessary to adjust the balance circuitry to compensate for this capacitance. The waveform which is subtracted from the recorded signal must have precisely the same rise-time and shape as the electrode voltage drop, or a transient spike will be observed in the signal whenever injected current turns on or off. This waveform is adjusted with the **SLOPE** and **PEAK** portions of the **TRANSIENT** control. *Note: some types of micropipettes exhibit nonlinear impedance characteristics. When these are severe, the amplifier cannot fully compensate for them and the result is a transient signal upon current injection. The magnitude and shape of this transient should be recorded during initial setup, then later manually subtracted from the recorded signals to obtain the true membrane response.*

Current Injection

The *Model 1600* offers several options for controlling injection current to allow for a variety of experimental preparations.

The basic configuration requires no additional instrumentation. The injection current magnitude is established with the **CURRENT** knob, and injection takes place when the **CURRENT INJECTION (CONT-OFF-MOMEN)** switch is set to either **CONT** or **MOMEN**. In the **MOMEN**tary position, the current is injected only as long as the switch is held down. This mode of stimulation is generally useful for sub threshold membrane conductivity studies using continuous DC stimulation.

Most studies, however, require precise control of injection current pulse duration and repetition rate in addition to magnitude. The easiest configuration for this type of experiment includes a function generator or another signal source to control the pulse duration and repetition rate, and the **CURRENT** knob to set the injection current magnitude. The signal source is applied to the **CURRENT GATE** connector. This input requires a signal greater than +2.5 V to turn the injection current on and less than +0.6 V to turn the injection current off. The maximum voltage limit for this connector is +15 V.

When external control of current magnitude is also required, a control signal may be applied to the **INPUTS: CURRENT** connector. The injection current is proportional to the voltage of the control signal. The final injection current is obtained by adding the control signal current to any current set by the **CURRENT** knob. Current switching remains under the control of the **CURRENT INJECTION (CONT-OFF-MOMEN)** switch or the **CURRENT GATE** connector as discussed above. When complete control over current settings zero the internal current source and provide continuous injection of the current applied to the **INPUTS: CURRENT** connector. Thus, current magnitude, polarity, and duration are all controlled by the signal applied to the **INPUTS: CURRENT** connector, with current injection stopped when the input signal is zero.

The current control capabilities of the *Model 1600* may be combined in various ways to simplify otherwise complex control situations. For example, if it is necessary to modulate the amplitude of a train of current pulses, a pulse signal can be applied to the **CURRENT GATE** connector which will establish the duration and repetition rate, while the amplitude modulation signal (frequently a ramp or triangle waveform) is applied to the **INPUTS: CURRENT** connector. As another example, if a continuous injection current, interrupted by pulses of differing magnitudes and polarity is desired, the base injection current level can be established by the **CURRENT** knob and the **POLARITY** switch. A signal applied at the **INPUTS: CURRENT** connector can provide the pulses of differing magnitude and polarity which will be summed with the internal injection current source.

Iontophoresis Adapter

An *Iontophoresis Adapter Model 6820* (Catalog# 682000) is available for use with the *Model 1600* to apply high voltages to the micropipette for iontophoretic injection of drugs or dyes, or any other application where currents greater than those provided by the *Model 1600* are required.

The *Model 6820* is connected between the Headstage Probe and the *Model 1600*. Its selector switch determines the mode of operation. When the switch is in the **INT** position, routine recording and injecting operations can be performed with the *Model 1600* as if the *Model 6820* were not present. For iontophoretic techniques, switch to the **EXT** position. Up to ±200 V can be applied to the electrode to permit injection of dyes or drugs into the cell. The injection current equals the voltage applied to the + and - terminals on the *Model 6820* divided by the sum of the electrode resistance and the 9.0 MV protective resistance of the Headstage. The - terminal on the *Model 6820* is connected internally to the system **GND**. *Note: potential and injected currents cannot be monitored by the amplifier while the* Model 6820 *selector switch is set to the* ***EXT*** *position, due to Headstage isolation.*

Problem Solving

If the *Model 1600* does not function properly, consult the following list which suggests solutions to the most common problems. If you need further assistance, please contact customer service at A-M Systems, Inc. at the numbers listed on the title page of this manual.

Problem	Cause / Solution
Excessive offset potential	Instrument oscillates due to excessive capacitance compensation. Turn **CAPACITY COMP** counter-clockwise.
Incorrect potential reading	Ensure that **ELECT TEST** is **OFF**, **CURRENT INJECTION** is **OFF**, **DC OFFSET** and **DC BALANCE** are **OFF** or properly adjusted, and **CALIBRATE** buttons are **OFF**. Also, see above.
Incorrect response to injected current	Electrode impedance may be too great for desired current level. Also, see above.
Meter out of range (flashing zeros) (just a “1.”)	Excessive input potential or open electrode circuit. Check for good connections in micropipette and reference electrode circuit, and for bubbles in micropipette or holder.
Electrode impedance impedance incorrect or unstable	Excessive noise included in signal. Make measurement using **HIGH RANGE** whenever possible, and shield electrodes if necessary.
DC BALANCE cannot be set	Check electrode impedance and set **HIGH RANGE** to **ON** or **OFF** as needed. Also, see above.
Transients cannot be balanced out	Check setting of **CAPACITY COMP**. Also, some transients are due to non-linear electrode impedance characteristics and cannot be fully corrected. Most problems are due to improper control settings. See the section “Typical Set-Up Procedure” in this manual for further assistance.

Specifications

Current Input

Impedance	10^{11} Ω
Capacitance	Adjustable to zero
Working range	± 2.5 V
Maximum range	± 10 V
Iontophoresis adapter input	± 200 V

Current Injection

External Source

Input impedance	20 kΩ
Frequency range	DC to 250 kHz
Low range maximum current	10 nA/V
Low range maximum voltage	lesser of ±10 V and (± 2.5 x 10^8 VΩ)/(electrode resistance)
High range maximum current	100 nA/V
High range maximum voltage	lesser of ±10 V and (± 2.5 x 10^7 VΩ)/(electrode resistance)

Internal Source

Low range maximum current	lesser of ± 100nA and 2.5 V/(electrode resistance)
High current range	lesser of ± 1000 nA and 2.5 V/(electrode resistance)

Current Gate

ON signal	+ 2.5 V (step with rise time 10 μsec)
OFF signal	+ 0.6 V
Maximum input	± 15 V
Input impedance	20 kΩ

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Electrode Test

External Signal Source

Input impedance	10 kΩ
Input voltage range	± 10 V
Scale factor (**X1 OUTPUT**)	Low Range: 1 mV / MΩ / (input voltage) High Range: 10 mV / MΩ / (input voltage)

Internal Signal Source

Signal	100 Hz square wave
Low range scale factor (**X1 OUTPUT**)	1 nA peak-to-peak produces 1 mV/MΩ
High range scale factor (**X1 OUTPUT**)	10 nA peak-to-peak produces 10 mV/MΩ

Signal Processing

Input Bias Current

Optimal	Adjustable to zero	
Maximum without adjustment	Low Range:	3×10^{-12} Amp
	High Range:	3×10^{-11} Amp
Drift versus temperature	Low Range:	1×10^{-13} Amp/ºC
	High Range:	1×10^{-12} Amp/ºC
Drift versus time	Low Range:	3×10^{-13} Amp/12 hours
	High Range:	3×10^{-12} Amp/12 hours

Frequency Response

Frequency range	DC to 325 kHz

Rise Time

Square wave (500 mV)	50 Ω source: 0.8 µsec, 10% to 90% 20 MΩ source: 7.0 µsec, 10% to 90%

(Compensation set for 10% overshoot)

Zero Stability

Stability versus temperature	200 µV/ºC
Stability versus time	1 mV/12 hours

Low Pass Filter

Cut-off frequencies (-3dB)	1, 2, 5, 10, 20, 50, and 100 kHz
Slope	-12 dB/octave

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Notch Filter

Center frequency	50 Hz or 60 Hz (factory preset)
Q	10
Rejection	-50 dB

Capacitance Compensation

Range	-4 pF to +30 pF

Internal Calibration Voltage

10 mV	± 1%
1000 mV	± 1%

Noise

0 Ω source	13 µV RMS (10 Hz to 50 kHz)
1 MΩ source	79 µV RMS (10 Hz to 50 kHz)
20 MΩ source	310 µV RMS (10 Hz to 50 kHz)

(Compensation set for 1% overshoot)

DC Balance

Low range	up to 500 MΩ
High range	up to 50 MΩ

Outputs

x 1 output

Voltage gain	1.00 ± 0.1%
Maximum voltage	± 10 V
Impedance	220 Ω
DC Offset range	0.0 V to ± 1.0 V

x 10 output

Voltage gain	10.0 ± 1.0%
Maximum voltage	± 10 V
Impedance	220 Ω
DC Offset range	0.0 V to ± 10.0 V

Current Monitor

Low range scale factor	10 mV/nA
High range scale factor	1 mV/nA
Maximum output	± 1.0 V
Output impedance	1 kW

Digital Volt Meter (DVM)

Range	± 1.999 V
Accuracy	0.1% ± least significant digit
Input impedance	1 MΩ
Resolution	1 mV

Power Supply Requirements

AC Power

Power source	115/230 VAC input (factory preset)

Physical Dimensions

Amplifier

Width	17 inches (43.2 cm)
Height	4.75 inches (12.1 cm)
Depth	11.25 inches (28.6 cm)
Weight	AC Power: 22 lbs.

Headstage Probe

Input connector	0.08 inch (2.0 mm) female pin connector
Case diameter	0.44 inch (1.1 cm)
Case length	4.00 inches (10.2 cm)
Mounting rod diameter	0.187 inch (4.7 mm)

Warranty and Service

LIMITED WARRANTY

What does this warranty cover?

A-M Systems, LLC (hereinafter, "A-M Systems") warrants to the Purchaser that the Instruments manufactured by A-M Systems (hereinafter the "hardware"), and sold after June 1, 2025, is free from defects in workmanship or material under normal use and service for 5 years from date of purchase. Headstages manufactured by A-M Systems and sold after June 1, 2025, will be repaired under warranty only once per year. This warranty commences on the date of delivery of the hardware to the Purchaser.

For hardware sold prior to June 1, 2025, the warranty in effect at time of purchase applies.

What are the obligations of A-M Systems under this warranty?

During the warranty period, A-M Systems agrees to repair or replace, at its sole option, without charge to the Purchaser, any defective component part of the hardware provided that the defective part can be purchased from mainstream, common, electronic component distributors such as Digi-Key Electronics, Newark, or Mouser Electronics. To obtain warranty service, the Purchaser must return the hardware to A-M Systems or an authorized A-M Systems distributor in an adequate shipping container. Any postage, shipping and insurance charges incurred in shipping the hardware to A-M Systems must be prepaid by the Purchaser, and all risk for the hardware shall remain with Purchaser until A-M Systems takes receipt of the hardware. Upon receipt, A-M Systems will promptly repair or replace the defective unit and then return the hardware (or its replacement) to the Purchaser with postage, shipping, and insurance prepaid by the Purchaser. A-M Systems may use reconditioned or like-new parts or units at its sole option, when repairing any hardware. Repaired products shall carry the same amount of outstanding warranty as from original purchase. Any claim under the warranty must include a dated proof of purchase of the hardware covered by this warranty. In any event, A-M Systems liability for defective hardware is limited to repairing or replacing the hardware.

What is not covered by this warranty?

This warranty is contingent upon proper use and maintenance of the hardware by the Purchaser and does not cover batteries. Neglect, misuse whether intentional or otherwise, tampering with or altering the hardware, damage caused by accident, damage caused by unusual physical, electrical, chemical, or electromechanical stress, damage caused by failure of electrical power, or damage caused during transportation are not covered by this warranty. Further, no guarantee is made regarding software compatibility with future updated operating systems. Products may not be returned to A-M Systems for service, whether under warranty or otherwise, which are contaminated by infectious agents, radioactive compounds or other materials constituting a health hazard to employees of A-M Systems

What are the limits of liability for A-M Systems under this warranty?

A-M Systems shall not be liable for loss of data, lost profits or savings, or any special, incidental, consequential, indirect or other similar damages, whether arising from breach of contract, negligence, or other legal action, even if the company or its agent has been advised of the possibility of such damages, or for any claim brought against you by another party.

THIS EQUIPMENT IS NOT INTENDED FOR CLINICAL MEASUREMENTS USING HUMAN SUBJECTS. A-M SYSTEMS DOES NOT ASSUME RESPONSIBILITY FOR INJURY OR DAMAGE DUE TO MISUSE OF THIS EQUIPMENT.

Jurisdictions vary with regard to the enforceability of provisions excluding or limiting liability for incidental or consequential damages. Check the provision of your local jurisdiction to find out whether the above exclusion applies to you.

This warranty allocates risks of product failure between the Purchaser and A-M Systems. A-M Systems hardware pricing reflects this allocation of risk and the limitations of liability contained in this warranty. The agents, employees, distributors, and dealers of A-M Systems are not authorized to make modifications to this warranty, or additional warranties binding on the company. Accordingly, additional statements such as dealer advertising or presentations, whether oral or written, do not constitute warranties by A-M Systems and should not be relied upon. This warranty gives you specific legal rights. You may also have other rights which vary from one jurisdiction to another.

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A-M Systems. **manual 1600** **DRW-5026100 rev 11**

Approved:

Revision History

Rev	Date	Description
5	6/30/06	Initial Document Control release
6	4/28/10	DCR 201200. Revise warranty page and company name
7	7/8/16	DCR 202462. Remove customer calibration instructions.
9	1/18/19	DCR 202615. Review content, add rev control to content. Correct rev number
10	3/19/20	DCR 203316. Updated Warranty
11	4/29/25	DCR 204239.Updated Warranty