

Warner Instruments  
Dual Channel Differential Electrometer  
Model HiZ-223



Warner Instruments  
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The **HiZ-223** is a dual differential, high impedance amplifier/electrometer designed specifically for electrochemical measurements using ion specific ( $K^+$ ,  $Na^+$ ,  $Cl^-$ , etc.) or pH electrodes.

The instrument is very stable, drift free, and features a built in provision for measuring and adjusting input leakage current. DC levels may be independently adjusted for each probe channel.

The ability to locate the sensing probes directly at the measurement site overcomes the noise introduced by the long cables usually needed to bring the measured potential to the instrument. Signal-driven guards at the probe input maintains the specified high resistance and reduces the stray capacitance of the probes.

Careful design, coupled with quality component selection, particularly in the headstage, results in an excellent amplifier with low noise and wide bandwidth. The **HiZ-223** will faithfully reproduce the measured signal.

Featuring:

- ✓ High input impedance ( $10^{15} \Omega$ )
- ✓ Differential (A-B) output
- ✓ Low noise and wide bandwidth
- ✓ Electrode resistance test circuitry
- ✓ Probe test circuitry
- ✓ Driven guard shield

## NOMENCLATURE

### Text conventions

This manual refers to amplifier controls at three functional levels; control blocks, specific controls within a block, and settings of specific controls. To minimize the potential for confusion, we have employed several text conventions which are specified below. Since our goal is to provide clarity rather than complexity, we welcome any feedback you may wish to provide.

- Warner Instrument product numbers are presented using **bold type**.
- References to instrument panel control blocks are specified using UNDERLINED SMALL CAPS. (e.g. METER, CLAMP COMMANDS)
- References to specific controls within a block are specified using NON-UNDERLINED SMALL CAPS. (e.g. MODE SWITCH, TIMER RANGE)
- References to individual control settings are specified in *italic type*. (e.g. *Amplify, 100 mV*)
- Special comments and warnings are presented in **highlighted text**.

Any other formatting should be apparent from context.

**THIS EQUIPMENT IS NOT DESIGNED NOR INTENDED  
FOR USE ON HUMAN SUBJECTS**

## CONTROL DESCRIPTION

### Probe

The PROBE is a small, lightweight, active headstage designed for placement at the measurement site.



An available E Series electrode holder connects directly to the 2 mm input male pin. The exposed inner shield is driven at the input potential and can be extended over the electrode holder to reduce the input capacitance.

Mounting of the PROBE into a micropositioner is easily managed with the PROBE MOUNTING HANDLE which can connect to the probe axially or at a 90° angle.

### Front panel controls

The HiZ-223 front panel is comprised of inputs and controls for CHANNEL A, CHANNEL B, the PROBE TEST circuit, the METER block, and the OUTPUT BNC block.



### Channel A, Channel B

#### Mode Select toggle

The MODE SELECT (STANDBY/OPERATE) control is a three position toggle providing selection between *operate*, *standby*, and *electrode test* modes.

#### *Standby*

Standby places the instrument into *standby* mode and should be used when attaching microelectrodes or electrode holders to the PROBE input.

If the PROBE input is allowed to become open circuited (e.g., lacking a resistive path from the probe tip to ground) for any length of time, the resulting PROBE leakage current can exceed specified levels for 10 or more minutes before recovering. Placing the probe amplifier into *standby* electronically forces the PROBE input terminal to remain approximately near 0 V. This is equivalent to shorting the PROBE input (a practice always followed with very high impedance electrometers.)

As a general rule, keep the MODE SELECT toggle (and hence the PROBE) in *standby* until the PROBE is connected to the measurement site, then the MODE SELECT toggle may be changed to *operate*.

#### *Operate*

Places the instrument into *operate* mode.



### *Electrode Test*

The electrode test circuit allows the resistance of the electrode to be quickly checked prior to the beginning of an experiment, or at any time during the course of an experiment. Resistances from  $10^{10}$  to  $10^{12} \Omega$  can be measured.

### IG and Electrode Test trimpots

Two trimpots are provided for adjustment of the PROBE bias current and the ELECTRODE TEST circuit. Trimpot adjustments are made using a small screwdriver and adjustment procedures are detailed in the appropriate sections below.

### Position Adjust

The POSITION ADJUST circuit allows the user to correct for bias currents or to view the input potential with no modification. When the associated POSITION (IN/OUT) toggle is set to *out*, only the raw (uncorrected) input potential is measured.

When the POSITION (IN/OUT) toggle is set to *in*, the probe output may be positioned (corrected) using the coarse and fine controls. The coarse adjust range is  $\pm 600$  mV and the fine adjust is  $\pm 1$  mV.



### **Probe Test**

The input gate leakage current for the PROBE, as well as a convenient check of the amplifier zero setting, can be determined using the PROBE TEST jack.

Inserting the PROBE into the probe TEST JACK and selecting *electrode test* in the associated CHANNEL block injects a calibrated (1 pA) DC current through the PROBE test resistor to ground. This current yields a voltage of  $1 \text{ mV}/G\Omega$  at the associated (A OUTPUT or B OUTPUT) BNC and at the METER.



### **Meter**

This section is comprised of the METER, the RANGE toggle, and the METER INPUT toggle.

### Range

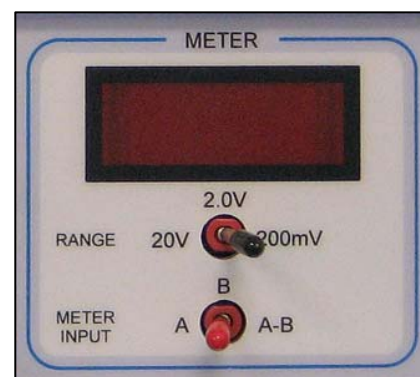
The RANGE toggle sets the meter display range. Full range voltages are selectable between  $\pm 20$  V,  $\pm 2.0$  V, or  $\pm 200$  mV.

### Meter input

The meter can be selected to display voltages for CHANNEL A, CHANNEL B, or the difference between CHANNELS A and B.

### **Output BNC's**

Output BNC's for CHANNEL A (A OUTPUT), CHANNEL B (B OUTPUT), and the difference between CHANNELS A and B

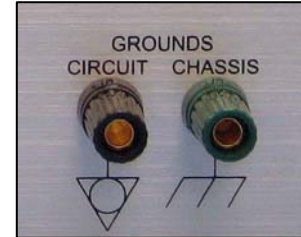


(A-B OUT) are available for external viewing or recording. The output resistance is 50  $\Omega$  and the accuracy is  $\pm 0.1\%$  with a 1 M $\Omega$  or greater load.

## Rear Panel Controls

### **Grounds: Chassis and Circuit**

Rear panel connectors are available for CHASSIS and CIRCUIT grounds. The preparation bath ground should be connected to the CIRCUIT ground via an appropriate electrode.



### **Power entry**

The power entry module contains the POWER SWITCH, a FUSE, and the attachment point for the power cord.

The FUSE (3AG type, regular blow) used in the **HiZ-223** will depend on the line voltage; 1/2 amp for 100 or 130 VAC, and 1/4 amp for 220 or 240 VAC. Replacement should only be made with the proper ampere rating.



## SETUP AND CHECKOUT

### Initial settings

1. (Placement) Position the unit in the desired location, make sure the POWER SWITCH is *off*, and plug the instrument in.

**NOTE:** Connection to the wrong line voltage could result in damage to the HiZ-223.

2. (CHANNEL section) Plug the PROBE into its connector. Set the POSITION (IN/OUT) toggle to *in*. Switch the MODE SELECT toggle to *standby*. Insert the PROBE tip into the PROBE TEST port.
3. (METER section) Set the METER RANGE toggle to *200 mV*. Set the METER INPUT toggle to the appropriate CHANNEL (A or B).
4. Turn the instrument *on*.

### Instrument checkout

5. Verify the HiZ-223 zero setting

Connect an oscilloscope to the associated CHANNEL OUTPUT BNC. Verify that the MODE SELECT toggle is set to *standby*. Verify that the POSITION (IN/OUT) toggle is set to *out*.

Using an alligator clip, connect the PROBE tip to the shield ground on the associated CHANNEL OUTPUT BNC. For example, if you are testing the zero setting for CHANNEL A use the shield for the A OUTPUT BNC.

Set the MODE SELECT toggle to *operate*. Verify that the oscilloscope and METER reads  $0 \pm 0.1 \text{ mV}$ . Return the MODE SELECT toggle to *standby*.

6. Check the PROBE input leakage adjustment

Select a *high-gain sensitivity* on the oscilloscope. Place the PROBE into the PROBE TEST port. Set the MODE SELECT toggle to *operate*. The baseline signal should not shift from the previous reading (step 5 above) and should have a peak-to-peak noise amplitude no greater than  $500 \mu\text{V}$ .

**NOTE:** Leakage current is affected by changes in temperature. This test is best performed once the instrument has thermally stabilized, usually after a warm-up period of 1 to 2 hours.

7. Adjusting the PROBE input leakage current

If a voltage shift of greater than 0.1 mV occurs between steps 5 and 6 above, then an adjustment of the input leakage current is necessary. This is achieved by use of the associated IG TRIMPOT in the CHANNEL sections.

To adjust the PROBE leakage current (IG), place the channel into *standby* mode and insert the PROBE into the PROBE TEST port. Set the METER INPUT toggle to the channel being adjusted. Set the RANGE toggle to *200 mV*. Switch the POSITION (IN/OUT) toggle to *out*. Switch from *standby* to *operate*.

With a small screwdriver, adjust the IG TRIMPOT (labeled IG) so as to reduce the METER reading to less than 0.1 mV ( $10^{-15}$  A). The adjustment will lag noticeably, and a transient error occurs as the trimpot is adjusted. (This error is a result of the time constant of the probe and the  $10^{11}$   $\Omega$  resistor.) For this reason it is better to use an oscilloscope or recorder to monitor this adjustment, but the METER alone can be used once the user gets the “feel” for this adjustment.

The corresponding leakage current is directly computed by dividing the measured voltage by  $10^{11}$   $\Omega$ . For example, if the voltage is shown to be 1.0 mV, then the input leakage current is approximately  $10^{-14}$  A.

#### 8. ELECTRODE TEST

Leave the PROBE in the PROBE TEST port. Verify that the MODE SELECT toggle is in *operate*. Verify that the METER RANGE toggle is set to *200 mV*.

Move the STANDBY/OPERATE toggle to *electrode test*. A 100 mV DC upward shift on the oscilloscope indicates proper amplifier function. The METER will also indicate *100 mV*. Switch back to *standby*.

#### 9. INPUT OFFSET

Leave the PROBE in the PROBE TEST port. Verify that the POSITION (IN/OUT) toggle is set to *in*. Rotate the course POSITION control *fully clockwise*. The associated CHANNEL output will shift approximately *+600 mV*. Return the POSITION control to the center of its rotation (*0 mV* on the METER). Place the instrument into *standby*.

## OPERATION

### Electrode Assembly

Electrodes are pulled using a standard puller and filled (usually with the 3 M KCl), taking care to avoid bubbles or air spaces, following commonly published procedures. The electrode shank is then carefully and firmly pushed into the holder through the bored hole and gasket. Finger tighten the threaded end-piece of the holder to obtain a secure seal. Remove any excess fluid from the outside of the holder with a tissue. Connect the electrode holder assembly to the **HiZ-223 PROBE**. The unit is ready for use.

### Electrode Test

With the PROBE mounted in the micropositioner, the quality and resistance of the electrode can be quickly checked. Connect the CHANNEL OUTPUT to an oscilloscope (A OUTPUT or B OUTPUT, depending on which CHANNEL is under test). Place the electrode into the bath and switch the MODE SELECT toggle to *electrode test*.

The presence of a faulty or blocked electrode will cause a large voltage (several V) to appear at the CHANNEL OUTPUT and on the METER. Alternatively, a working electrode will present a positive DC shift of  $1 \text{ mV}/M\Omega$  at the CHANNEL OUTPUT.

### Measuring Potential

Each PROBE output may be positioned with its coarse and fine POSITION controls when the respective POSITION (IN/OUT) switches are *in*. When the POSITION (IN/OUT) switch is *out*, only the raw input potential of the particular channel is measured.

Measurements of potentials where the source resistance is high are extremely susceptible to electrostatically induced noise spikes, pulses, and 60 Hz fields, as well as nearby motion of charged bodies. When the source exceeds  $10^9 \Omega$ , shielding is mandatory in order to obtain quiet, non-fluctuating meter readings or oscilloscope recordings.

The input of each **HiZ-223 PROBE** is a standard-tip plug into which Warner E Series microelectrode holders or, alternatively, standard tip-jacks may be inserted.

### Measuring Electrode Resistance

The electrode test circuit provides a convenient way to check the microelectrode's nominal resistance without removing it from the experiment. Resistances from  $10^{10}$  to  $10^{12}$  can be checked by selecting *electrode test* mode. Electrode test is accomplished by passing a 1 pA constant current through the PROBE input circuit. This yields a METER reading of  $1 \text{ mV}/G\Omega$ . The output is read on the METER.

Because of the input circuit time constant, sufficient time must be allowed for the measurement to stabilize. The time required for stabilization will depend on the microelectrode resistance and its capacitance. Resistances on the order of  $10^{12} \Omega$  require a minimum of 10 s. For resistances of  $10^{11} \Omega$ , 1 s should be sufficient. These values are strictly an estimate. Once the METER reading settles, the reading may be considered accurate.

## Effect of Stray Capacitance

Consider a hypothetical voltage source  $E_s$  with its associated source resistance  $R_s$ . If  $R_s=10^{12} \Omega$ , and the stray capacitance is 1 pF, then the input time constant will be 1 s. Therefore, the response time (to within 1%) for an applied DC potential is more than 5 s. Clearly, minimal stray capacitance must be insured for rapid instrument response. Input capacity of each of the **HiZ-223** PROBE is approximately 1 pF.

If the measurement geometry allows, the stray capacitance of the PROBE can be reduced by extending the guard (a signal driven shield which surrounds the input tip) over the source.

## Noise

The bane of the art of measurement is noise. For the purpose of this discussion, noise is any fluctuation of the instrument's output level that degrades the accuracy or resolution of the desired measurements. Noise can be arbitrarily divided into 2 categories, environmental and physical. Environmental noise includes 60 Hz power line induction, radio frequency interference (RFI), sparking transients caused by switching of electrical apparatus, and vibration. Physical noise is the result of the thermal properties of the conducting media and the statistical fluctuation of the numbers of charge carriers.

Power line induction may be of electrostatic or electromagnetic origin. In the former case, careful shielding can minimize this effect. On the other hand, electromagnetic induction by induced currents in multiply grounded recording lines can be an annoying problem, but careful attention and good 'grounding practice'\* can reduce this problem to a negligible level. RFI and switching transients are revealed as sudden or periodic jumps in the recording base line. Under these circumstances, electrostatic shielding of the probe and source may be helpful.

When the source resistance is large, motion of the probe, or of surrounding metallic structures, can generate small AC signals. In effect, the probe acts as a capacitive transducer. Any steps taken to minimize these motions will aid in reducing capacitive currents.

\* Bring the ground return lead from the measurement site directly to the instrument circuit ground (black terminal) or to the PROBE outer case. Do not return the ground lead through ground paths containing AC or DC currents.

## Stability

We recommend continuous operation of the instrument for optimum stability and accuracy. When the instrument is not in use or in storage, switch into *standby* mode.

**APPENDIX****Specifications**

Input Impedance	$> 10^{15} \Omega$ , shunted by 0.5 pF
Input Capacitance	1 pF, nominal
Leakage Current	75 fA max
Gain	$1.000 \pm 0.1\%$
Output Resistance	$50 \Omega$
Input Swing Voltage	$\pm 10 \text{ V}$
Rise Time (10 to 90%)	5 $\mu\text{s}$ , small signal
Noise (0.1 Hz to 10 kHz)	$< 100 \mu\text{V}$ p-p, input shorted
Baseline Stability	$\pm 0.1 \text{ mV/day}$
Position Controls Range	$\pm 600 \text{ mV}$

<b>Physical Dimensions</b>	Case: 8.8 x 21.0 x 17.5 cm (H x W x D) Probe: 12.7 x 65 mm (D x L) with 1.8 m cable
<b>Power</b>	90-265 VAC, 50/60 Hz, 10 VA
<b>Probe Handle</b>	6.5 x 65 mm (D x L)
<b>Shipping Weight</b>	2.5 kg
<b>Warranty</b>	Two years, parts and labor
<b>Operating Conditions</b>	Equipment is intended to be operated in a controlled laboratory environment. Temperature: 0-40 °C, Altitude: sea level to 2000 m, Relative humidity: 0-95%

## Maintenance

### ***Electrode Test Calibration***

Place the CHANNEL into *standby* and insert the PROBE into the PROBE TEST port. Wait approximately 10 s for the output to settle. Switch the MODE SELECT toggle to *electrode test*.

Adjust the ELECTRODE TEST TRIMPOT potentiometer until the METER reads 100 mV. Electrode test is now calibrated. Note that the electrode test adjustment is not absolute, but is rather a coarse adjustment.

### ***Probe***

The PROBE is nickel plated and epoxy sealed to prevent corrosion from saline solutions and mild chemicals. However, it is good practice to keep the surfaces dry, both when in use and during storage. Use only water or alcohol to clean the PROBE. Avoid solvents which can attack the epoxy. Store in a dry environment when not in use.

### ***Probe Cable***

The PROBE cable is of small diameter and very flexible. To avoid damage to the cable jacket and internal wires, take care to route the cable in a way to avoid kinks, abrasions and strain on either the connector or probe ends.

### ***Electrode Holders***

Correct storage of electrode holders will prolong their useful life. After each use, the holder should be rinsed by injecting it with distilled water. Dry the inside by injecting air with a clean syringe. Wipe the external surface dry and store in a dry place. Do not use alcohol or solvents on the electrode holders as this will seriously degrade the polycarbonate body.

## Theoretical considerations

### ***Electrode Connection***

Fluid filled glass microelectrodes have very high resistances, typically 20 M $\Omega$  or more. The input resistance of the recording amplifier must be greater than this by 100 times or more to faithfully record the measured potentials. The input resistance of the **HiZ-223** is on the order of 10<sup>15</sup>  $\Omega$  which more than satisfies this requirement.

### ***Input Capacitance***

Almost of equal importance in electrode connections is that of minimizing input capacitance. Increased input capacitance has the effect of reducing the amplifier bandwidth, yielding a slower rise-time. Therefore, when designing an experiment, efforts to minimize input capacitance can be rewarding.

The following considerations will aid in reducing input capacitance:

1. Use an electrode holder. Warner electrode holders suitable for the **HiZ-223** have a 2 mm diameter female jack which plugs directly onto the PROBE male pin. This direct connection eliminates the need for cabling which often increases input capacitance.

2. The PROBE is constructed of two concentric tubes with the outer shell connected to circuit ground. The inner shield (approximately 5 mm, exposed at the input end) is driven at the input potential and is exposed for the purpose of extending the driven guard over the electrode holder. Use of a compression spring with an ID slightly smaller than the inner shield diameter works well.

**CAUTION:** Care must be exercised to insure that the extension does not contact either the probe outer shield or the bath.

### ***Electrode Holders***

The ESP/W-FxxN is a preferred electrode holder for the **HiZ-223**. It has a straight body and incorporates a Ag/AgCl pellet or optional Ag<sup>2+</sup> wire at the interface between the fluid filled glass micropipette and the probe input.

Ag/AgCl half cells typically measure only a fraction of a mV potential difference between pairs in a Cl<sup>-</sup> containing medium. We strongly recommended using a second half cell, such as Warner's **REF-11**, for connection from the bath to the **HiZ-223** circuit ground.

<b>Electrode part numbers</b>		
<b>Catalog Number</b>	<b>Model Number</b>	<b>Description</b>
64-1301	REF-11	Reference cell
64-0964	ESP/W-F10N	Straight Holder with 2 mm Jack for 1.0 mm Capillary
640965	ESP/W-F12N	Straight Holder with 2 mm Jack for 1.2 mm Capillary
64-0966	ESP/W-F15N	Straight Holder with 2 mm Jack for 1.5 mm Capillary
64-0967	ESP/W-F20N	Straight Holder with 2 mm Jack for 2.0 mm Capillary

## Service and Warranty

We recommend all questions on service be referred to our Technical Support department. Normal business hours are 9:00 A.M. to 5:00 P.M.. Monday to Friday. Telephone (203) 776-0664 or fax (203) 776-1278

### Service Notes

1. If the instrument POWER light fails to illuminate, check the fuse at the rear panel. If needed replace with a 3AG 1/2 A normal blow. If the replacement also fails, please call for help.
2. Occasionally, a knob on the front panel can loosen. These are 'collet' style knobs and are tightened with a screw located under the knob cap. To gain access to the screw, pry the cap off using a thin bladed screwdriver or similar tool.

### Warranty

The **HiZ-223** is covered by our warranty to be free from defects in materials and workmanship for a period of two years from the date of shipment.

If a failure occurs within this period, Warner Instruments will either repair or replace the faulty component(s). This warranty does not cover failure or damage caused by physical abuse or by electrical stress (e.g., inputs exceeding specified limits).

Shipping charges to the factory are the customer's responsibility. Return charges will be paid by Warner Instruments. This warranty does not extend to electrode holders.

**NOTE:** Contact Warner Instruments for Return Merchandise Authorization (RMA) prior to returning equipment to the factory.

**Certifications**

***Declaration of Conformity***  
*CE MARKING (EMC)*

**Application of Council Directive: 89/336/EEC**

Standards To Which Conformity Is Declared:	EN55022 Class A EN61000-3-2 EN61000-3-3 EN50082-1:1992 EN61000-4-2 EN61000-4-3 ENV50204 EN610000-4-4 EN610000-4-8 EN610000-4-11
Manufacturer's Name:	Warner Instruments, LLC
Manufacturer's Address:	1125 Dixwell Avenue Hamden, CT 06514 Tel: (203) 776-0664
Equipment Description:	Instrument Amplifier
Equipment Class:	ITE-Class A
Model Numbers:	HiZ-223

***I the undersigned, hereby declare that the equipment specified above, conforms to the above Directive(s) and Standard(s).***

Place: Hamden, Connecticut USA

Signature:



Full Name: Ralph Abate

Position: General Manager

***Declaration of Conformity***  
*CE MARKING (LVD)*

**Application of Council Directive: 73/23/EEC**

Standards To Which Conformity Is Declared:	EN61010-1:1993
Manufacturer's Name:	Warner Instruments, LLC
Manufacturer's Address:	1125 Dixwell Avenue Hamden, CT 06514 Tel: (203) 776-0664
Equipment Description:	Instrument Amplifier Safety requirements for electrical equipment for measurement and laboratory use
Equipment Class:	Class I
Model Numbers:	HiZ-223

***I the undersigned, hereby declare that the equipment specified above, conforms to the above Directive(s) and Standard(s).***

Place: Hamden, Connecticut USA

Signature:



Full Name: Ralph Abate

Position: General Manager

## WEEE/RoHS Compliance Statement

### EU Directives WEEE and RoHS

#### To Our Valued Customers:

Harvard Apparatus is committed to being a good corporate citizen. As part of that commitment, we strive to maintain an environmentally conscious manufacturing operation. The European Union (EU) has enacted two Directives, the first on product recycling (Waste Electrical and Electronic Equipment, WEEE) and the second limiting the use of certain substances (Restriction on the use of Hazardous Substances, RoHS). Over time, these Directives will be implemented in the national laws of each EU Member State.

Once the final national regulations have been put into place, recycling will be offered for those Harvard Apparatus products which are within the scope of the WEEE Directive. Products falling under the scope of the WEEE Directive available for sale after August 13, 2005 will be identified with a "wheelie bin" symbol.

Two Categories of products covered by the WEEE Directive are currently exempt from the RoHS Directive - Category 8, medical devices (with the exception of implanted or infected products) and Category 9, monitoring and control instruments. Most of Harvard Apparatus' products fall into either Category 8 or 9 and are currently exempt from the RoHS Directive. Harvard Apparatus will continue to monitor the application of the RoHS Directive to its products and will comply with any changes as they apply.



- Do Not Dispose Product with Municipal Waste.
- Special Collection/Disposal Required.