



FD223a

*Dual Channel Differential Electrometer*

www.wpiinc.com

## **INSTRUCTION MANUAL**

Serial No. \_\_\_\_\_

### **About Your Warranty**

This instrument has a limited warranty. To ensure that you receive all notices regarding hardware changes, improvements or recalls as well as software updates if applicable, please complete the warranty registration for this product.

2009.03.09

***World Precision Instruments***



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## INTRODUCTION

The **FD223a** 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 FD223a will faithfully reproduce the measured signal.

### **Features**

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.

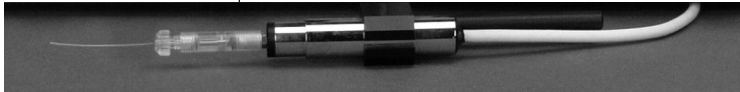
- WPI product numbers appear in **bold type**.
- References to instrument panel control blocks are specified using UNDERLINED SMALL CAPS (e.g., METER, CLAMP COMMANDS).
- References to specific controls within a block are specified using non-underlined small caps (e.g., MODE SWITCH, TIMER RANGE).
- References 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.



## CONTROL DESCRIPTION

### Probe



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

A microelectrode holder (**MEH3SF**, available for glass diameters of 1.0 mm, 1.2 mm, 1.5 mm, or 2.0 mm) 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 FD223a 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.)

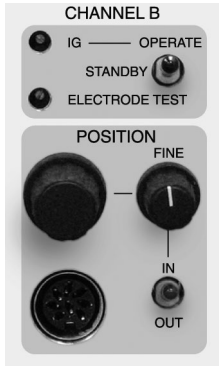
As a general rule, keep the mode select toggle (and hence the probe) in STANDBY until the probe is connected to the measurement site, then the mode select toggle may be changed to OPERATE.

#### 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  $10^{10} \Omega$  to  $10^{12} \Omega$  can be measured.



(100 G Ohm)

**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 BNC (A OUTPUT or B OUTPUT) and at the meter.

**Meter**

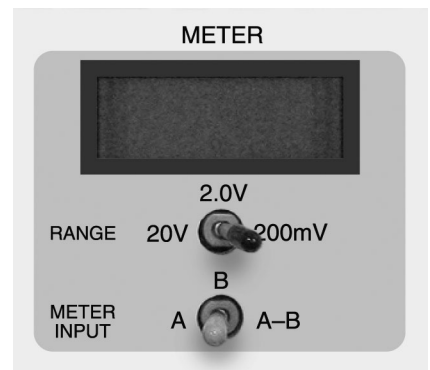
This section is comprised of the meter, the RANGE toggle, and the METER INPUT toggle.

**Range**

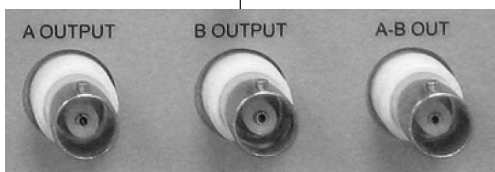
The RANGE toggle sets the meter display range. Full range voltages are selectable between  $\pm 20$  V,  $\pm 2.0$  V, or  $\pm 200$  mV.

**Meter Input**

The meter can be selected to display voltages for channel A, channel B, or the difference between the two (A-B).



**Output BNC's**



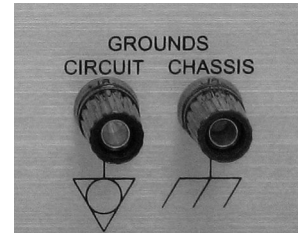
Output BNCs for CHANNEL A (A OUTPUT), CHANNEL B (B OUTPUT), and the difference between channels A and B (A-B OUT) are available for external viewing or recording. The output resistance is  $50 \Omega$  and the accuracy is  $\pm 0.1\%$  with a  $1 \text{ M}\Omega$  or greater load.



## 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 **FD223a** 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. 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 FD223a.
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 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 FD223a 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  $0 \pm 0.1$  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  $\mu$ V.

The meter reading may take several minutes to settle to its lowest point due to the very large RC time constants. See "Effect of Stray Capacitance", page 7.

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 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  $10^{11} \Omega$  (100 G Ohm) 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 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. (If the display does not show 100 mV, see “Electrode Test Calibration”, page 9.)

**9.** Input Offset

Leave the probe in the PROBE TEST port. Verify that the POSITION (IN/OUT) toggle is set to *in*. Rotate the coarse 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. WPI's **MicroFil™** fills micropipettes easily and reliably. 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 FD223a 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 mV/MΩ 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 FD223a probe is a standard-tip plug into which WPI microelectrode holders 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  $10^{10} \Omega$  to  $10^{12} \Omega$  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 mV/MΩ. 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 seconds. For resistances of  $10^{11} \Omega$ , one second 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 FD223a 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 two 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.

## **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.

*\* 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.*



## **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 an anti-static bag 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 FD223a is on the order of  $10^{15}$   $\Omega$  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:

Use an electrode holder. WPI electrode holders suitable for the FD223a 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.

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 (WPI #2547) 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 **MEH3SF** is a preferred electrode holder for the FD223a. It has a straight body and incorporates a Ag/AgCl pellet 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- containing medium. We strongly recommended using a second half cell, such as WPI's **RC3**, for connection from the bath to the FD223a circuit ground.

<b>Catalog Number</b>	<b>Description</b>
<b>RC3</b>	Reference Cell, 4.5 mm diam. x 50 mm
<b>MEH3SF-10</b>	Straight Holder with 2 mm Jack for 1.0 mm Capillary
<b>MEH3SF-12</b>	Straight Holder with 2 mm Jack for 1.2 mm Capillary
<b>MEH3SF-15</b>	Straight Holder with 2 mm Jack for 1.5 mm Capillary
<b>MEH3SF-20</b>	Straight Holder with 2 mm Jack for 2.0 mm Capillary

**Service Notes**

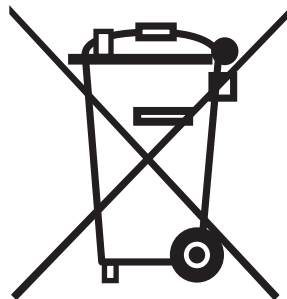
If the instrument power light fails to illuminate, check the fuse at the rear panel. If needed replace with a 3AG 1/2 Amp, normal blow. If the replacement also fails, please call for help.

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.

**Disposal**

Do not dispose of this device with municipal waste – special collection/disposal is required.

The instrument may be returned to WPI for proper recycling and disposal.





## SPECIFICATIONS

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



**WORLD PRECISION INSTRUMENTS, INC.**

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**DECLARATION OF CONFORMITY**

We: World Precision Instruments, Inc.  
175 Sarasota Center Boulevard  
Sarasota FL 34240-9258  
USA

as the distributor of the apparatus listed, declare that the product:

**Title: FD223A Dual Channel Differential Electrometer**

to which this declaration relates is in conformity with the following standards or other normative documents:

**Safety:** EN61010-1:1993

**EMC:** EN55022 Class A  
EN61000-3-2  
EN61000-3-3  
EN50082-1:1992  
EN61000-4-2  
EN61000-4-3  
ENV50204  
EN61000-4-4  
EN61000-4-8  
EN61000-4-11

and therefore conforms with the protection requirements of Council Directive 89/336/EEC relating to electromagnetic compatibility and Council Directive 73/23/EEC relating to safety requirements.

**Issued on: March 17, 2008**

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## WARRANTY

WPI (World Precision Instruments, Inc.) warrants to the original purchaser that this equipment, including its components and parts, shall be free from defects in material and workmanship for a period of one year\* from the date of receipt. WPI's obligation under this warranty shall be limited to repair or replacement, at WPI's option, of the equipment or defective components or parts upon receipt thereof f.o.b. WPI, Sarasota, Florida U.S.A. Return of a repaired instrument shall be f.o.b. Sarasota.

The above warranty is contingent upon normal usage and does not cover products which have been modified without WPI's approval or which have been subjected to unusual physical or electrical stress or on which the original identification marks have been removed or altered. The above warranty will not apply if adjustment, repair or parts replacement is required because of accident, neglect, misuse, failure of electric power, air conditioning, humidity control, or causes other than normal and ordinary usage.

To the extent that any of its equipment is furnished by a manufacturer other than WPI, the foregoing warranty shall be applicable only to the extent of the warranty furnished by such other manufacturer. This warranty will not apply to appearance terms, such as knobs, handles, dials or the like.

WPI makes no warranty of any kind, express or implied or statutory, including without limitation any warranties of merchantability and/or fitness for a particular purpose. WPI shall not be liable for any damages, whether direct, indirect, special or consequential arising from a failure of this product to operate in the manner desired by the user. WPI shall not be liable for any damage to data or property that may be caused directly or indirectly by use of this product.

## Claims and Returns

- Inspect all shipments upon receipt. Missing cartons or obvious damage to cartons should be noted on the delivery receipt before signing. Concealed loss or damage should be reported at once to the carrier and an inspection requested. All claims for shortage or damage must be made within 10 days after receipt of shipment. Claims for lost shipments must be made within 30 days of invoice or other notification of shipment. Please save damaged or pilfered cartons until claim settles. In some instances, photographic documentation may be required. Some items are time sensitive; WPI assumes no extended warranty or any liability for use beyond the date specified on the container.
- WPI cannot be held responsible for items damaged in shipment en route to us. Please enclose merchandise in its original shipping container to avoid damage from handling. We recommend that you insure merchandise when shipping. The customer is responsible for paying shipping expenses including adequate insurance on all items returned.
- Do not return any goods to WPI without obtaining prior approval and instructions (RMA#) from our returns department. Goods returned unauthorized or by collect freight may be refused. The RMA# must be clearly displayed on the outside of the box, or the package will not be accepted. Please contact the RMA department for a request form.
- Goods returned for repair must be reasonably clean and free of hazardous materials.
- A handling fee is charged for goods returned for exchange or credit. This fee may add up to 25% of the sale price depending on the condition of the item. Goods ordered in error are also subject to the handling fee.
- Equipment which was built as a special order cannot be returned.
- Always refer to the RMA# when contacting WPI to obtain a status of your returned item.
- For any other issues regarding a claim or return, please contact the RMA department

*\* Electrodes, batteries and other consumable parts are warranted for 30 days only from the date on which the customer receives these items.*

**Warning: This equipment is not designed or intended for use on humans.**

## **World Precision Instruments, Inc.**

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