FD223

Dual Differential Electrometer

INSTRUCTION MANUAL

Serial No._____

8/97

World Precision Instruments, Inc.

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1.0 DESCRIPTION

The model FD223 is a dual differential electrometer with very high input impedance. Its main feature is a matched pair of gold plated probes with specially designed integrated circuit electronic amplifiers. The instrument is particularly suited for electrochemical measurements which use macro or micro-ion specific (K^+, Na^+, Cl^-, etc.) and pH electrodes.

When using ion-selective electrodes, the “pX” meter range may prove convenient. This range allows the user to vary the meter sensitivity (slope) and to correct for the effect of temperature. The control varies sensitivity from 10 to 110 millivolts per decade of the “X” ion concentration.

A meter selector switch allows for digital LCD readout of either channel or the difference between them. In addition to the digital meter on the instrument panel, the output may be singly and/or differentially recorded by using one or more channels of an external recorder.

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

The probes can be brought directly to the measurement site. This overcomes one of the bothersome aspects of electrometer use — long, noisy and lossy cables which were required to bring the potential measurement to the instrument. Signal driven guarding of the probe input is used to maintain the specified high resistance and to reduce the stray capacity. Reducing the stray capacity, as will be explained later, allows measurements to be made more rapidly. The input connector itself is a standard 2 mm tip plug which will accept standard tip jacks or WPI microelectrode holders.

1.1 THE PROBE

FD223 probes are small and easily manipulated. High impedance potential difference measurements are made directly at the site or origin, without the necessity of lossy and noisy cables.

Probes are gold plated and sealed with epoxy for resistance to moisture and dirt. A signal driven guard collar encircles the front of the probe capsule. This guard sustains the high input resistance and low shunt capacity of the probe input connector.

> IT IS VERY IMPORTANT TO AVOID AN OPEN-CIRCUIT CONDITION AT THE PROBE INPUT. For this reason we provide the STAND-BY MODE switch. (Refer to 4.2 for description.) If the input were accidentally allowed to become open circuited, it is possible that probe leakage current will exceed specified levels for 10 or more minutes before recovering. KEEP THE PROBE CLEAN AT ALL TIMES. IF SALT OR OTHER SOILS APPEAR, WIPE THE PROBE TIP AREA CLEAN WITH A TISSUE AND ANY APPROPRIATE SOLVENT. LEAVE NO RESIDUE ON THE INPUT INSULATION.

2.0 SPECIFICATIONS

PROBES

Input Resistance .....10^{15} Ohms, typical

Input Capacitance .....1 pF, nominal

Voltage Gain .....Unity +/- 0.1%

Dual Channel Match .....less than +/- .01% difference in probe gains.

Input Voltage Swing .....+/- 10 volts

Maximum Allowable Input Volts .....+/- 50 volts

Input Leakage Current .....10^{-14} Amps maximum, 10^{-15} Amps typical, adjustable.

Output Resistance .....1K Ohms per channel

Noise Output (input shorted) .....100µV peak to peak, DC-30 KHz

Output Position Adjust .....+/- 600 mV, nominal

Baseline Stability .....+/- 0.1 mV per day @ 20°C (each channel)

DIGITAL METER INTERNAL MODE

Ranges .....0 to +/- 199.9 mV
0 to +/- 1.999 V
0 to +/- 5.00 V
pX, sensitivity adjustable from 10 mV to 110 mV per decade.

Input Select .....GND, channel A, channel B, channel A-B

Absolute Accuracy of Digital Readout .....+/- 0.1% or 1 digit

Resolution of Digital Meter .....+/- 0.1 mV, range 3-1/2 digits

DIGITAL METER EXTERNAL MODE

Input Impedance .....1 Meg Ohm

Ranges .....0-199.9 mV
0-1.999 V
0-19.99 V

PHYSICAL DIMENSIONS

Probe

- Body .....19 mm diam (0.75 in.) x 3.68 cm long (l.45 in.)
- Tip .....2 mm diam (0.080 in.) x 9.1 mm long (0.36 in.)
- Cable .....152 cm long (5 ft)
- Handle .....4.8 mm diam (0.19 in.) x 10.2 cm long (4.0 in.)
- Weight .....85.4 g; 3.0 oz.

Cabinet .....W 43.2 x H 13.1 x D 24.1 cm (17 x 5.18 x 9.5 in.)

- Weight .....3.4 kg (7.5 lb)
- Shipping Weight .....4.8 kg (10.5 lb)

Power Requirements .....110/220 Volts, 50 - 60 Hz

*NOTE: External input “LOW” black binding post is connected internally to the instrument circuit ground and may be separated from the green (chassis and mains) ground when separate circuit grounding is deemed advisable.

3.0 THEORY OF OPERATION

Two probes, A and B, are the non-inverting (+) and inverting (-) channels respectively. Input resistance is greater than 10^{15} Ohms for each probe, and leakage current from the probe inputs has been adjusted to 10^{-15} Amperes or less.

Electromotive forces associated with high source resistance such as glass and other ion-selective electrodes, piezoelectric crystals and capacitors may be accurately measured with WPI Model FD223 Dual/Differential Electrometer. The use of two active, very high impedance probes brings the instrument to the source of potential; and, therefore, cable capacity and noise effects associated with cables are significantly reduced. Thus, higher speed and lower input noise are realized. In electrochemical measurements each of a pair of electrodes may have a common voltage superimposed which may preferably be eliminated. True differential voltage measurement may be used to separate junction or galvanic effects from chemical activity measurement. Alternatively, one may also use the FD223 as two separate, single-channel voltmeters.

4.0 FRONT PANEL CONTROLS (CH. A AND CH. B)

4.1 PROBE CONNECTORS

The probe input connectors are keyed to insure against improper insertion. Each probe is marked for a specific channel, either A or B, and should be connected accordingly.

NOTE

Reversal of the probes will not cause any damage but is not recommended since each probe and channel are electrically matched.

4.2 OPERATE/STANDBY

It is very important to avoid an open-circuit condition at the probe input. If the input is accidentally allowed to become open circuited it is possible that the probe leakage current can exceed specified levels for 10 or more minutes before recovering. Placing the probe amplifier in STANDBY electronically forces the probe input terminal to remain approximately near zero volts. This is equivalent to shorting the probe input (a practice always followed with very high impedance electrometers.) *As a general rule, always keep the probe in STANDBY when a*

resistive path from the probe tip to ground is absent. Once the probe is connected to the site of measurement, the STANDBY switch may be changed to the OPERATE mode.

4.3 IG ADJUST

This control is provided so as to allow the user to minimize the probe input leakage current (typically less than 10^{-15} A.)

4.4 ELECTRODE TEST (ERT)

ERT provides a convenient way to check microelectrode resistance without removing the microelectrode from the experiment. Resistances from 10^{10} to 10^{12} Ohms can be measured by depressing the ERT pushbutton.

NOTE

Refer to section 5.3 for detailed explanation of ERT operation.

4.5 PROBE TEST

A test port containing a 10^{11} Ohm resistor is located between Ch. A and Ch. B and is useful for checking and adjusting probe leakage current, and calibrating the Electrode Test (ERT) function of the instrument.

4.6 POSITION CONTROLS

Each probe output may be positioned with its coarse and fine controls when their respective IN/OUT switches are IN. The coarse adjust range is +/- 600 mV and fine adjust is +/- 1 mV. When the position switch is OUT only the raw input potential of the particular channel is measured. Thus it is possible to offset or buck out existing input voltage levels or view the input directly, unmodified by the position controls.

4.7 OUTPUT CONNECTOR

Channel A and B outputs are available for viewing or recording. The output resistance is lK Ohm and the accuracy is +/- 0.1% with a 1 MegOhm load or greater.

4.8 METER SECTION

A. Input Selector

The meter input can be selected to display either Channel A, Channel B, A-B or GND. (GND is useful to check for any offset due to the meter itself.)

B. Monitor Connector

The Monitor connector located beneath the Input Selector is provided for use with an external recorder. The Monitor connector will display the signal determined by the Input Selector.

C. INT/EXT

The digital voltmeter is available for use as an independent voltmeter. This is accomplished by applying the voltage source to the external input binding posts below the meter, and placing the INT/EXT switch in the EXT position.

> **NOTE**
>
> AN EXTERNAL INPUT “LOW” BLACK BINDING POST IS CONNECTED INTERNALLY TO THE INSTRUMENT CIRCUIT GROUND AND MAY BE SEPARATED FROM CHASSIS (MAINS) GROUND BY REMOVAL OF SHORTING LINK WHEN SEPARATE CIRCUIT GROUNDING IS DEEMED ADVISABLE.

The external meter mode is capable of measuring potentials to a maximum of 19.99V determined by the Meter Range switch.

D. RANGE

The sensitivity of the DPM is determined by the Range switch. Internal operation allows three ranges of sensitivity to a maximum of +/- 5.00 volts. External operation allows three ranges of sensitivity to a maximum of +/- 19.99 volts. The internal voltage maximum is limited by the instrument’s differential amplifier circuit.

E. pX RANGE AND pX SENSITIVITY

When using ion-selective electrodes, the “pX” capability of the instrument may prove convenient. This range allows the sensitivity to be varied and the effect of the temperature to be corrected. With the Range Switch in the “pX” mode, the sensitivity of the DPM is X millivolts per decade of concentration. The ten-turn sensitivity control determines the appropriate scale factor. Thus, pH or other ion activities may be measured on a direct reading basis.

4.9 POWER ON/OFF

The Power ON/OFF connects the main AC power to the instrument and indicates the prescence of voltage by illuminating the front panel light.

4.10 GROUNDS

The instrument ground (circuit) is the black binding post located below the PROBE TEST connector separating Channels A and B. Mains ground (CHASSIS) is the green binding post. Normally, the instrument and mains ground are strapped together. However, they may be separated if isolation of instrument ground from the power ground is desired.

5.0 OPERATING HINTS

5.1 LEAKAGE CURRENT ADJUSTMENT

It is advisable but not always necessary to minimize input leakage current (IG) before recording. Before checking or adjusting probe input leakage current, determine the offset potential of the electrometer with grounded input. If the offset exceeds 0.1 millivolts it may be internally adjusted to zero. See section 6 for the zero-adjustment procedure. It is not absolutely necessary to make this adjustment since the electrometer zero has excellent stability. In practice the zero is usually adjusted with manual position controls for all offsets, both external and internal to the instrument.

To adjust the probe leakage current (IG), insert the probe *(while in standby mode)* into the *probe test* 10^{11} Ohm. Allow the instrument to warm up for at least 15 minutes. Set the digital voltmeter CHANNEL SELECT switch for the probe to be adjusted. Set RANGE switch to the most sensitive range, 0-199.9 mV. Switch *position* switch to OUT. Switch from STANDBY to OPERATE.

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

Leakage current is directly computed by dividing the voltage deflection by

10^{11}Ohms. For example, if the deflection were 1.0 mV, input leakage current is approximately 10^{-14} A.

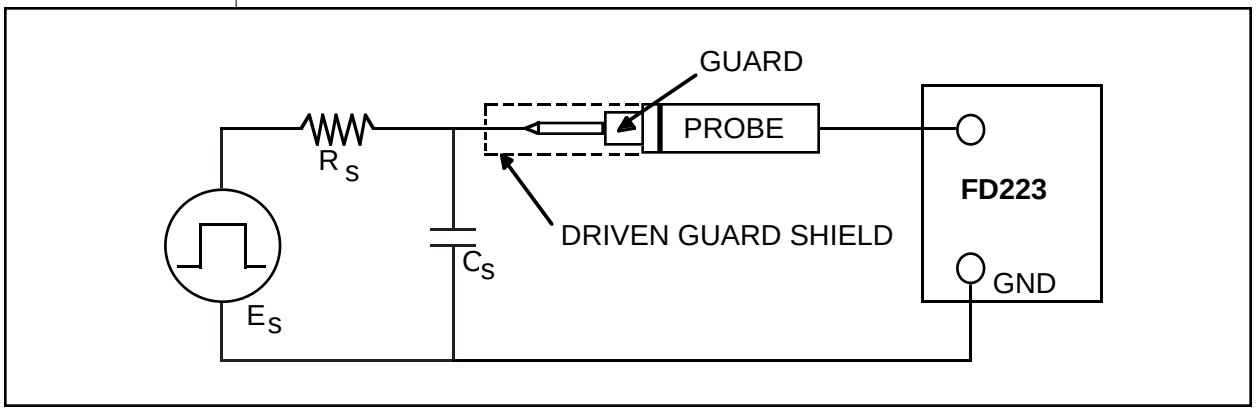
5.2 MEASURING POTENTIAL

Each probe output may be positioned with its COARSE and FINE position controls when the respective IN/OUT switches are IN. When the position switch is OUT, only the raw input potential of the particular channel is measured. Thus, it is possible to offset or buck out existing input voltage levels or view the input directly, unmodified by the position controls. Maximum positioning range is +/- 600 millivolts (nominal).

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 Ohms shielding is almost mandatory in order to obtain quiet, non-fluctuating meter readings or oscillograph recordings.

The input of each of the FD223 probes is a standard tip plug into which may be inserted standard tip-jacks or, alternatively, WPI microelectrode holders for electrolyte measurements. In Figure 1 a hypothetical voltage source Es with its associated source resistance R_S is shown. If, for example, $R_S = 10^{12}$ Ohms and the stray capacity to ground is 1 pF, the input time constant is 1 second. Thus, the response time to within 1 percent of final value for an applied D.C. potential is more than 5 seconds. Clearly, minimal stray capacity for rapid response must be insured. Input capacity of each of the FD223 probes is about 1 pF. If the measurement geometry allows, the stray capacity to earth can be reduced by extending the guard (a signal driven shield) which surrounds the input tip over the source. WPI provides a Driven Guard Shield for use with microelectrodes. See Figure 1.

Figure 1



5.3 ELECTRODE TEST (ERT)

ERT provides a convenient way to check the microelectrode's nominal resistance without removing the microelectrode from the experiment. Resistances from 10^{10} to 10^{12} can be checked by depressing the electrode test switch.

Electrode test is accomplished by passing 1 pA constant current through the probe input circuit. This yields a Voltage Reading of 1 mV per 1000 MegOhms. The output is read on the Digital Voltmeter. Because of the input circuit time constant, sufficient time must be allowed for the input circuit to stabilize. The time required for stabilization will depend on the microelectrode resistance and capacitance. Resistances on the order of 10^{12} Ohms will require a minimum of 10 seconds. For 10^{11} Ohms, 1 second should be sufficient. This is strictly an estimate and will also depend on the input circuit capacitance. Once the digital panel meter reading settles, the reading may be considered accurate.

NOTE:

Pushing the ERT button causes probe input potential to assume a positive polarity. Also note that because the test current is only approximately 1pA, the resistance test is approximate as well.

5.4 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 (R.F.I.) 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 (a) electrostatic or (b) electromagnetic. In the former case careful shielding can minimize this effect. Electromagnetic induction by induced currents in multiple grounded recording lines can be an annoying problem, but careful attention and good grounding* practice can reduce this problem to a negligible level.

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

R.F.I. and switching transients show through sudden or periodic jumps in the recording base line. 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 A.C. signals. In effect, the probe acts as a capacitative transducer. This effect will normally be negligible, but in some extreme cases it may be bothersome. Any steps taken to minimize this motion will aid in reducing this effect.

5.5 pH MEASUREMENT

If standard pH electrodes are to be used, the sensitivity control should be set to approximately 592 (59.2 mV/decade). Temperature correction would be approximately 0.2 mV per degree C. If the slope factor is non-ideal, the experimentally determined slope may be selected. NOTE THAT THE B PROBE SHOULD BE THE GLASS OR CATION SENSOR BECAUSE THE pH ELECTRODE BECOMES MORE NEGATIVE WITH INCREASING pH. Thus, the sensitivity may be set at a slope value appropriate to the type of electrodes used and direct decade readings of ion concentration may be obtained. In order to set up this scale, it is necessary to first try a known buffer and, using the B probe positioning control (switch out the A probe positioning), bring the DPM reading to the correct pH reading. If the sensitivity had been set correctly, the pH scale would be ready for use. It is best to check a second buffer value to confirm the accuracy of the sensitivity setting.

5.6 STABILITY

We recommend continuous operation of the instrument for optimum stability and accuracy. When the instrument is not in use, it is advisable to either ground the inputs to each probe or switch to Standby Mode.

6.0 MAINTENANCE

6.1 ERT CALIBRATION CHANNEL A

Set “Meter Select” to Channel A, “Meter Range” to 199.9 mV and “Int/Ext” to Int. With Channel A probe in Standby Mode insert probe into test port (10^{11} Ohms) and wait approximately 10 seconds for the output to settle. Verify that meter reads zero; if not, adjust IG adjustment. Then set Channel A in Operate Mode and depress ERT pushbutton. While ERT button is depressed, adjust ERT “ADJ” potentiometer located under IG potentiometer for a reading of approximately 100 mV. ERT is now calibrated. Note that the ERT test is not absolutely accurate, but rather is a coarse resistance measurement.

6.2 ERT CALIBRATION CHANNEL B

Set “Meter Select” to Channel B, “Meter Range” to 199.9 mV and “Int/Ext” to Int. With channel B probe in Standby Mode insert probe into test port (10^{11} Ohms) and wait approximately 10 seconds for the output to settle. Verify that meter reads zero; if not, adjust IG adjustment. Then set channel B in Operate Mode and depress ERT pushbutton. While ERT button is depressed, adjust ERT “ADJ” potentiometer located under IG potentiometer for a reading of 100 mV. ERT is now calibrated. Note again that this is an approximate setting which is not absolutely accurate and may vary with ambient temperature.

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

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

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

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DECLARATION OF CONFORMITY

We: World Precision Instruments, Inc.
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USA

as the manufacturers of the apparatus listed, declare under sole responsibility that the product(s):

Title: FD223

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

Safety: EN 61010-1:1993 (IEC 1010-1:1990)

EMC: EN 50081-1:1992
EN 50082-1:1992

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

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