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INSTRUCTION MANUAL

FD223a

Dual Channel Differential Electrometer

Serial No._____

www.wpiinc.com

CONTENTS

ABOUT THIS MANUAL

The following symbols are used in this guide:

This symbol indicates a CAUTION. Cautions warn against actions that can cause damage to equipment. Please read these carefully.

This symbol indicates a WARNING. Warnings alert you to actions that can cause personal injury or pose a physical threat. Please read these carefully.

NOTES and TIPS contain helpful information.

Fig. 1 The FD223a dual channel electrometer comes with both probes.

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} Ω)
- Differential (A-B) output
- Low noise and wide bandwidth
- Electrode resistance test circuitry
- Probe test circuitry
- Driven guard shield

Notes and Warnings

CAUTION:

Parts List

After unpacking, verify that there is no visible damage to the sensor. Verify that all items are included:
(1) **FD223a** Amplifier
(2) **FD223AP** Probes in anti-static bags
(2) **2547** Driven guard shields
(2) **MEH1SF10** Micro electrode holder, 1.0mm
(2) **MEH1SF12** Micro electrode holder, 1.2mm
(2) **MEH1SF12** Micro electrode holder, 1.5mm
(2) **MEH1SF12** Micro electrode holder, 2.0mm
(1) Instruction Manual

Unpacking

Upon receipt of this instrument, make a thorough inspection of the contents and check for possible damage. Missing cartons or obvious damage to cartons should be noted on the delivery receipt before signing. Concealed damage should be reported at once to the carrier and an inspection requested. Please read the section entitled "Claims and Returns" on page 15 of this manual. Please contact WPI Customer Service if any parts are missing at 941.371.1003 or customerservice@wpiinc.com.

Returns: Do not return any goods to WPI without obtaining prior approval (RMA # required) and instructions from WPI's Returns Department. Goods returned (unauthorized) by collect freight may be refused. If a return shipment is necessary, use the original container, if possible. If the original container is not available, use a suitable substitute that is rigid and of adequate size. Wrap the instrument in paper or plastic surrounded with at least 100mm (four inches) of shock absorbing material. For further details, please read the section entitled "Claims and Returns" on page 15 of this manual.

INSTRUMENT DESCRIPTION

Probe

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

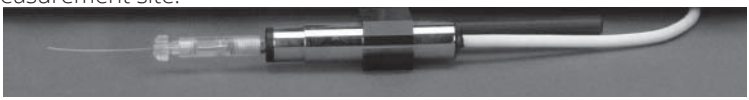

Fig. 2 The probe is an active headstage.

A microelectrode holder (**MEH3SF**, available for glass diameters of 1.0mm, 1.2mm, 1.5mm or 2.0mm) connects directly to the 2mm 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

Fig. 3 The front panel of the FD223a has the 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 (for example, 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 below.

Postion Adjust–The **Position** adjust circuit allows you to correct for bias currents or to view the input potential with no modification.

- Out–When the associated position (**In/Out**) toggle is set to **Out**, only the raw (uncorrected) input potential is measured.
- In–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 ±600 mV and the **Fine** adjust is ±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 (1pA) DC current through the probe test resistor to ground. This current yields a voltage of *1mV/G*Ω 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 ±20 V, ±2.0 V, or ±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 50Ω and the accuracy is ±0.1% with a 1MΩ or greater load.

Rear Panel Controls

Fig. 4 The rear panel of the FD223a has the power ports and the grounding pins.

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 A for 100 or 130 VAC, and 1/4 A for 220 or 240 VAC. Replacement should only be made with the proper ampere rating.

Setup

1. Position the unit in the desired location. Make sure the power switch is off. Then, plug the instrument in.

CAUTION: Connection to the wrong line voltage could result in damage to the **FD223a**.

2. To setup the **CHANNEL** section:
   a. Plug the probe into its connector.
   b. Set the **Position (In/Out)** toggle to **In**.
   c. Switch the mode select toggle to **Standby**.
   d. Insert the probe tip into the **Probe Test** port.

3. To setup the **Meter** section:
   - Set the **Range** toggle to 200mV.
   - Set the **Meter Input** toggle to the appropriate channel (**A** or **B**).
4. Turn the instrument on.

Verifying Zero Setting

1. Connect an oscilloscope to the associated channel output BNC.
2. Verify that the mode select toggle is set to **Standby**.
3. Verify that the **Position** (**In/Out**) toggle is set to **Out**.
4. 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.
5. Set the mode select toggle to **Operate**.
6. Verify that the oscilloscope and meter reads *0 ± 0.1mV*.
7. Return the mode select toggle to **Standby**.

Checking the Probe Input Leakage Adjustment

1. Select a high-gain sensitivity on the oscilloscope.
2. Place the probe into the **Probe Test** port.
3. Set the mode select toggle to **Operate**. The baseline signal should not shift from the previous reading (step 1 above) and should have a peak-to-peak noise amplitude no greater than *500 µV*.

   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" on page 9.

   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 1–2 hours.

Adjusting the Probe Input Leakage Current

If a voltage shift of greater than 0.1mV occurs between the zero setting and the input leakage tests 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.

1. To adjust the probe leakage current (**IG**), place the channel into STANDBY mode and insert the probe into the **Probe Test** port.
2. Set the **Meter Input** toggle to the channel being adjusted.

3. Set the **Range** toggle to *200mV*.
4. Switch the **Position** (**In/Out**) toggle to OUT.
5. Switch from **Standby** to **Operate**.
6. With a small screwdriver, adjust the **IG** trimpot so as to reduce the meter reading to less than 0.1mV (10^{-15} A).

NOTE: The adjustment lags 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 $10^{11}\Omega$ (100GΩ) 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 you get 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 1.0mV, then the input leakage current is approximately 10^{-14}A.

Conducting the Electrode Test

1. Leave the probe in the **Probe Test** port.
2. Verify that the mode select toggle is in **Operate**.
3. Verify that the **Range** toggle is set to *200 mV*.
4. 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 *100mV*.
5. Switch back to STANDBY. (If the display does not show 100mV, "Electrode Test Calibration" on page 10.)

Adjusting the Input Offset

1. Leave the probe in the **Probe Test** port.
2. Verify that the **Position** (**In/Out**) toggle is set to **In**.
3. Rotate the coarse position control *fully clockwise*. The associated channel output will shift approximately +600mV.
4. Return the **Position** control to the center of its rotation (*0mV* on the meter).
5. Place the instrument into **Standby**.

OPERATING INSTRUCTIONS

Electrode Assembly

1. Electrodes are pulled using a standard puller and filled (usually with 3M KCl), taking care to avoid bubbles or air spaces, following commonly published procedures. WPI"s **MicroFil™** fills micropipettes easily and reliably.
2. Then, carefully and firmly push the electrode shank into the holder through the bored hole and gasket.
3. Remove any excess fluid from the outside of the holder with a tissue.
4. 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.

1. Connect the channel output to an oscilloscope (A OUTPUT or B OUTPUT, depending on which channel is under test).
2. Place the electrode into the bath.
3. 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 presents a positive DC shift of 1mV/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 60Hz 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 1pA constant current through the probe input circuit. This yields a meter reading of 1mV/MΩ. The output is read on the meter.

Because of the input circuit time constant, allow sufficient time for the measurement to stabilize. The time required for stabilization depends 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 can be considered accurate.

Effect of Stray Capacitance

Consider a hypothetical voltage source (Es) with its associated source resistance (Rs). If Rs=$10^{12}\Omega$, and the stray capacitance is 1pF, then the input time constant is 1s. Therefore, the response time (to within 1%) for an applied DC potential is more than 5s. Clearly, minimal stray capacitance must be insured for rapid instrument response. Input capacity of each of the **FD223a** probes is approximately 1pF.

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

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 60Hz 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. If it is electrostatic, careful shielding can minimize this effect. On the other hand, electromagnetic induction by induced currents in multiple grounded recording lines can be an annoying problem. Careful attention and good "grounding practice" can reduce this problem to a negligible level. That means, you should 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.

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. The probe acts as a capacitative transducer. Any steps taken to minimize these motions aids 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 it into standby mode.

MAINTENANCE

Electrode Test Calibration

1. Place the channel into **Standby**.
2. Insert the probe into the **Probe Test** port.
3. Wait approximately 10s for the output to settle.
4. Switch the mode select toggle to **Electrode Test**.
5. Adjust the **Electrode Test** trimpot potentiometer until the meter reads 100 mV**.**

The 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 the probe in an anti-static bag in a dry environment when it is 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 avoid kinks abrasions and strain on either the connector or probe ends.

Electrode Holders

Correct storage of the electrode holders prolongs 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 it in a dry place. Do not use alcohol or solvents on the electrode holders, because this will seriously degrade the polycarbonate body.

Electrode Connection

Fluid filled glass microelectrodes have very high resistances, typically 20MΩ 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 2mm 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 5mm, 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. **RC1** and **RC1T** are also options.

Part Number	Description
RC3	Reference Cell, 4.5mm diam. x 50mm
RC1	Reference Cell with 1.5m lead
RC1T	Reference Cell with 1.5m lead, terminated with 2mm pin
MEH3SF-10	Straight Holder with 2mm Jack for 1.0mm Capillary
MEH3SF-12	Straight Holder with 2mm Jack for 1.2mm Capillary
MEH3SF-15	Straight Holder with 2mm Jack for 1.5mm Capillary
MEH3SF-20	Straight Holder with 2mm Jack for 2.0mm Capillary

Service Notes

If the instrument power light fails to illuminate, check the fuse at the rear panel. If needed, replace it with a 3AG 1/2 A, normal blow. If the replacement also fails, call WPI technical support or email technicalsupport@wpiinc.com.

Occasionally, a knob on the front panel can come loose. 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

This unit conforms to the following specifications:

Input Impedance	> $10^{15}\Omega$, shunted by 0.5pF
Input Capacitance	1 pF, nominal
Leakage Current	75 fA max
Gain	1.000 ± 0.1%
Output Resistance	50Ω
Input Swing Voltage	±10V
Rise Time (10 to 90%)	5μs, small signal
Noise (0.1 Hz to 10 kHz)	<100μV p-p, input shorted
Baseline Stability	±0.1mV/day
Position Controls Range	±600mV
Physical Dimensions	Case: 8.8 x 21.0 x 17.5cm (H x W x D) Probe: 12.7 x 65mm (D x L) with 1.8 m cable
Power	90-265VAC, 50/60Hz, 10VA
Probe Handle	6.5 x 65mm (D x L)
Shipping Weight	2.5kg
Operating Conditions	Equipment is intended to be operated in a controlled laboratory environment. Temperature: 0-40°C; altitude: sea level to 2000m; relative humidity: 0-95%.

DECLARATION OF CONFORMITY

WORLD PRECISION INSTRUMENTS, INC.
175 Sarasota Center Boulevard
Sarasota, FL 34240-9258 USA
Telephone: (941) 371-1003 Fax: (941) 377-5428
e-mail wpi@wpiinc.com

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

Mr. Cliff Bredenberg
General Manager
World Precision Instruments, Inc.
175 Sarasota Center Boulevard
Sarasota, FL 34240-9258 USA

Mr. Glen Carlquist
Vice President of Manufacturing
World Precision Instruments, Inc.
175 Sarasota Center Boulevard
Sarasota, FL 34240-9258 USA

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 30 days* 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 ten (10) days after receipt of shipment. Claims for lost shipments must be made within thirty (30) days of receipt of invoice or other notification of shipment. Please save damaged or pilfered cartons until claim is settled. 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

Do not return any goods to us without obtaining prior approval and instructions from our Returns Department. Goods returned (unauthorized) by collect freight may be refused. Goods accepted for restocking will be exchanged or credited to your WPI account. Goods returned which were ordered by customers in error are subject to a 25% restocking charge. Equipment which was built as a special order cannot be returned.

Repairs

Contact our Customer Service Department for assistance in the repair of apparatus. Do not return goods until instructions have been received. Returned items must be securely packed to prevent further damage in transit. The Customer is responsible for paying shipping expenses, including adequate insurance on all items returned for repairs. Identification of the item(s) by model number, name, as well as complete description of the difficulties experienced should be written on the repair purchase order and on a tag attached to the item.

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

USA
International Trade Center, 175 Sarasota Center Blvd., Sarasota FL 34240-9258
Tel: 941-371-1003 • Fax: 941-377-5428 • E-mail: sales@wpiinc.com

UK
1 Hunting Gate, Hitchin, Hertfordshire SG4 0TJ
Tel: 44 (0)1462 424700 • Fax: 44 (0)1462 424701 • E-mail: wpiuk@wpi-europe.com

Germany
Zossener Str. 55, 10961 Berlin
Tel: 030-6188845 • Fax: 030-6188670 • E-mail: wpide@wpi-europe.com

China & Hong Kong
WPI Shanghai Trading Co., Ltd.
Rm 29a, No8 Dongfang Rd., Pudong District, Shanghai, 200120 PR China
Tel: +86 21 6888 5517 • E-mail:chinasales@china.wpiinc.com

Brazil
Av. Conselheiro Nébias, 756 sala 2611, Santos-CEP: 11045-002, São Paulo Brazil •
Tel: (013) 406-29703 • E-mail: info@brazil.wpiinc.com

Internet
www.wpiinc.com • www.wpi-europe.com • www.wpiinc.cn