



DISCOVER <sup>THE</sup>  
**“BLUE BOX”**  
 DIFFERENCE

## HIGH RESISTANCE METROLOGY PRODUCTS GUIDE



**Measurements International**  
*Metrology is Our Science, Accuracy is Our Business™*



## Metrology is our Science, Accuracy is Our Business™

Measurements International (MI) is the world's premier metrology company. MI provides innovative Standards Technology for both the Metrology and AC Power Industries. For the Metrology industry MI designs, develops, and manufactures electrical and temperature metrology instruments using AccuBridge™ technology. For the AC power industry MI designs, develops and manufactures high-voltage transformer test instruments, capacitance/Inductance Bridges, voltage dividers, wattmeters and current transformers using the AccuLoss™ and two-stage-compensated current transformers. All instruments are manufactured with the highest quality in support of our customer's organization.

### Model 6600A Dual Source High Resistance Bridge

- Based on proven NMI Design
- Range: 100kΩ to 10PΩ (100PΩ Optional)
- Voltages: 1 to 1000 Volts (5,000V Optional)
- Automatic and Manual Operation
- Not affected by Temperature change
- 10 and 20 Channel Coaxial Matrix Scanners (Optional)
- Environmental & Pressure Monitoring (Optional)
- Ratio 1:1, 10:1, 100:1, 1000:1
- Multiple Modes of Operation



Widest Range Commercially Available 100kΩ to 100PΩ  
Not only does Measurements International offer you the Technology of Choice of Major NMI's for the measurement of World Class Accuracy and Uncertainty levels, but we also offer the complete measurement solution for High Resistance Measurement!

The 6600A is the most modular High Resistance Measurement System based on the Preferred Technology by Major National Laboratories for High Resistance Measurement available! It was designed and built to provide National Laboratories (NMI's) an Automated System based on the chosen technology "Dual Source Bridge" which has become the technology of choice for most Major NMI's.

With the 6600A, you have the option to cover the resistance range from 100kΩ's to 100PΩ's, reaching voltages of up to 5,000 Volts! With the additional scanner and either a 4310HR temperature stabilized resistance standard, or the more standard option of Major NMI's, a 9300A air bath and 9331G High Value Resistance Standards, customers are now able to achieve the same level and accuracies of Major NMI's! Take a look at all the standard features available on 6600A!

The model 6650A is a low cost Dual Source High Resistance Meter using the preferred "Dual Source" method for measuring High resistances in the range of 100k $\Omega$  to 10P $\Omega$ .

The simplified construction and operation of the 6650A offers much improved operation and performance over the typical teraohmmeter/electrometer, with a more user friendly approach to high resistance measurements. The 6650A has numerous advantages over single input devices like the typical Teraohmmeter/electrometer such as reliability, traceability and the fact that measurements are not dependant on short term stability or repeatability of the measurement circuit.

## Model 6650A Dual Source High Resistance Meter

- Replaces Teraohmmeter/Electrometer Technology
- Range 100k $\Omega$  to 10P $\Omega$
- Automatic Scanner Control
- Any Ratio up to 100:1
- Live Ratio or Direct Measurement Mode
- Voltage and Current Measurements
- Surface and Volume Resistivity Measurements
- 1V to 1000V Variable Voltage Output



Measurements International is the only manufacturer of High resistance measurement systems whose measurement capabilities support its product specifications.

### Technology

Since the mid 1990's the modified Wheatstone bridge or Dual Source resistance bridge has set the standard for high precision measurement of resistances from  $10^9$  to  $10^{14}$ . Over the years, this technology has been further developed to the point that it has replaced all other technologies by utilizing a true "Bridge" measurement circuit, the Unit Under Test (UUT) is compared to a working or primary standard to produce a "Live Ratio". **The 6600A and 6650A are the only "bridges" commercially available for high resistance measurements.** Any value resistor up to and including the  $10^{16}\Omega$  level can be measured at ratios up to 100:1. Menu driven functions are selectable using the menu displayed for calibration, ratio measurements and absolute measurements. For the absolute measurements the value and related uncertainty of the reference resistor are entered. Measurement functions such as

voltage across the unknown resistor and settle time, number of measurements and number of statistics are all also entered. The user has the option to display data (several measurements at a time), a combination of data and a graph of the measurements or just the graph. All uncertainty calculations are 2 sigma calculations.

### Versatility

The 6600A and 6650A are enabled with numerous measurement functions that allow users to tailor their measurements for their own particular needs.

- **Live Ratio Mode** - The most accurate mode of use is the live ratio mode where the Bridge architecture is formed by substituting two of the resistive arms of a Wheatstone bridge circuit with low-impedance digitally-programmable voltage sources. In this mode a UUT is compared to a standard reference



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resistor providing a live ratio to the reference resistor. Measurements in this mode can further be improved by utilizing a resistor substitution method and thus removing the uncertainty contributor of the bridge.

- **Direct Measurement Mode** – In this mode, the UUT is measured directly. This mode offers the same functionality that is utilized on a less accurate single input device such as the teraohmmeter. The 6600A and 6650A offers users the ability to quickly establish nominal values, measure Insulation Resistance, Volume and Surface resistivity. This mode is also useful for determining resistor time constants, as well as voltage and temperature coefficients.
- **Voltage and Current Measurements** – Service mode features the ability to measure voltages from 1V to 1100V DC and currents from  $10^{-5}$  to  $10^{-15}$  Amps.

### Voltage Range

The 1000V DC sources offer voltage ratios of 1, 10, 100, and 1000 or any ratio in between. The voltage settings can be observed on the front panel display. **The model 6600A and 6650A are the only commercially available High Resistance Bridges which offers any selectable voltage between 1V to 1000V. Other manufacturers are limited to specific voltages within the set range of 1V to 1000V.** The Voltage output on the 6600A can be further increased to 5kV and higher for calibration of special use resistors used in ceramics manufacturing, Aerospace applications, and Insulation testing.

### Front Panel Operation

The front panel offers users simple and intuitive measurement options. Features include resistor protection, settle time to verify time constants of resistors, number of measurements, statistics, voltage and temperature coefficients and graphing. Users can create and combine several program tasks such as inter-comparing standards to standards, standards to measurands, and measurands to measurands. Selectable parameters include measurement time delays (wait times), settle time, number of measurement, applied voltage, number of runs, standards used, reversal rate, current threshold, and standard resistor uncertainty. All measurement parameters including statistical data are displayed during measurement.

### Software

Making a measurement on the 6600A or 6650A is simple. Software allows the user to define the

measurement and test parameters utilizing the same proven software used on the MI 6010 and 6000 series of DC Bridges that our customers have become accustomed to. Features include resistor protection, settle time to verify time constants of resistors, number of measurements, statistics, voltage and temperature coefficients and graphing. Programs Menu allows users to create and combine several program tasks such as inter-comparing standards to standards, standards to measurands and measurands to measurands. Selectable parameters include measurement time delays (wait times), settle time, number of measurement, applied voltage, number of runs, standards used, reversal rate, current threshold, and standard resistor uncertainty. All measurement parameters including statistical data is displayed during measurement.

### Accuracy/Uncertainty

The 6600A provides the Best Accuracy and Uncertainty Commercially available today! Other manufacturers can claim various levels of accuracy and uncertainty, but we ask you to verify these claims through your National Laboratory, or if you are the National Laboratory, please verify through any Major NMI as to what they are using to measure High Resistance! Measurements International is the only manufacturer of High resistance measurement systems whose measurement capabilities support its product specifications.

### Expandable Range

Measurements International is the only company to offer the widest range of measurement 100kΩ's to 100PΩ's! as well as the Widest Range of Voltage 1V up to 5kV!!! The Voltage output can be increased to over 5kV for calibration of special use resistors used in ceramics manufacturing, Aerospace applications, and Insulation testing. Other manufacturers can currently only reach a range of 1000 Volts, thus limiting the measurement capability of the units.

### Complete Automation

Metrologists currently are met with an increased workload which can be greatly reduced with the automation features of the 6600A and 6650A High Resistance Systems. With the incorporation of the new 4610A and 4620A High Resistance scanners, Metrologists now have the ability to fully automate the full measurement range! Simply setup your program, start your measurement, and only come back when the run is completed to gather your data.



### Cost of ownership

Calibration of the model 6600A and 6650A requires only the use of an 8.5 Digit DVM for traceability. Optionally, the bridge may be characterized at any time by employing a resistor interchange as described in the operator manual.

Customers are no longer left with having to use substitution method provided by Teraohmeter type devices for simulated results. Actual ratio bridge measurements are now achievable with the all new 6600A and 6650A from Measurements International.

## SUPPORTING PRODUCTS

### Model 4610A & 4620A

#### High Resistance Coaxial Matrix Scanner

At Measurements International we understand the need for automation as being the first Company in the World to release the first Fully Automated DC Resistance Bridge (6010A) over 25 years ago. Since then, we have continued providing customers with leading edge Automated Solutions and have supplied all Major National Laboratories with the best solutions available in Resistance Metrology.

With the release of the first commercial Dual Source High Resistance Bridge we have again automated the Primary Choice for Technology. The next step in the automation process was the need for allowing customers the ability to automate the measurement of multiple resistors in a combined program without human intervention. With the addition of the new 4610A and 4620A automated High Resistance Scanners, customers are now able to completely scale up or down with the push of a button.

The 6600A and 6650A can be optioned with 10 to 20 scanner channels allowing proper connection to a wide range of standards. The 4610A (10 ch.) and 4620A(20 ch.) Coaxial Matrix Scanners designed specifically for the use in High Resistance measurements with total emphasis on the sample path. Using a proprietary (completely) Coaxial design, leakage paths are minimized allowing measurements up to 1T Ohms with no noticeable uncertainty contribution. N-Type connections are utilized for their superior isolation properties and labeled High and Low on the rear panel. Additional cables are available for connection to various other types of High Resistance terminals such as BPO and Triax.

- 10 or 20 Two Terminal Channels
- N-Type Connections
- Front Panel or Remote Operation
- Maximum 1000V DC
- Resistance Measurements to 10P
- Insulation Resistance >  $10^{16}\Omega$



### 9331G (PRIMARY)

#### High Value Resistor

Various measurement solutions are designed to fit your specific needs. Based on the NMI Design, the MI 9331G is the highest performing Series of High Resistance Standards commercially available. Years of research and testing were done in an effort to offer customers the very best in High Resistance Standards. With the addition of the 9331G series a few years ago, Measurements International has accomplished this.

- Based on NMI design
- High stability
- 100M $\Omega$  to 100T $\Omega$
- Split guard circuit
- Internal temperature sensor
- Custom values available



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## 4310HR

### Temperature Stabilized High Resistance Standard - 4 to 6 Elements

Another option Measurements International has been providing customers for the past few years is the Model 4310HR. The model 4310HR is a Temperature Controlled Resistance Chamber which contains 4 to 6 high resistance standards. It offers an economical solution to customers to better fit their needs or requirements at the High Resistance Level.

- 100M $\Omega$  to 10T $\Omega$  or 1G $\Omega$  to 100T $\Omega$  in single decade elements
- Other Values Available
- N type Connectors
- Other connectors available
- Temperature Coefficient  $\pm 0.2$  ppm/ $^{\circ}\text{C}$
- Eliminates Oil Bath Requirements
- Ambient Temperature Range:  $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$
- Low Thermal EMF's - Shielded Chamber
- Temperature Regulation:  $\pm 0.01^{\circ}\text{C}$  over a 1 year period
- Guarded Resistance Element Chamber



## Model 9300A & 9300

To fully achieve the best possible results in accuracy and specification, Measurements International recommends customers the 9300A series air bath. Initial specifications of the 9300A air bath show a stability of less than 15mK is achievable. Various National Laboratories and high level customers are reporting much better typical results. This again offers customers the very best in environmental control for your standards.

### Model 9300A

- Stability <15 mK
- Large working area (4 SR104's)
- Temperature band protection
- Peltier cooled
- Stainless steel construction
- Temperature range  $15^{\circ}\text{C}$  to  $40^{\circ}\text{C}$
- IEEE488
- Interfaces to 6650A for automatic measurements of temperature coefficients using MI software



### 9300

- Stability < 50mK
- Large working area
- Temperature band protection
- Peltier cooled
- Light weight and portable
- Temperature range  $15^{\circ}\text{C}$  to  $40^{\circ}\text{C}$



MI Products are used in nearly every NMI around the world as well as the US AirForce, US Army, US Navy Primary and Lockheed's Laboratories for their superior speed and low uncertainties.

## 6600A Measurement Specifications

Measurement Range (Ohms)	Applied Voltage	Live Ratio Mode Uncertainty		Direct Measurement
		1:1 and 10:1 Ratio	100:1 Ratio	
100k to 1M	1 to 100V	< 7	< 20	< 80
1M to 10M	1 to 100V	< 7	< 20	< 80
10M to 100M	10 to 1000V	< 7	< 20	< 80
100M to 1G	10 to 1000V	< 7	< 20	< 80
1G to 10G	10 to 1000V	< 8	< 30	< 100
10G to 100G	10 to 1000V	< 10	< 30	< 200
100G to 1T	10 to 1000V	< 15	< 50	< 400
1T to 10T	100 to 1000V	< 20	< 80	< 600
10T to 100T	100 to 1000V	< 30	< 100	< 2000
100T to 1P	100 to 1000V	< 100	< 400	< 0.5%
1P to 10P	100 to 1000V	< 100	< 600	< 3%

## 6650A Measurement Specifications

Measurement Range (Ohms)	Applied Voltage	Live Ratio Mode Uncertainty		Direct Measurement
		1:1 and 10:1 Ratio	100:1 Ratio	
100K to 1M	1 to 100V	15	30	100
1M to 10M	1 to 100V	15	30	100
10M to 100 M	10V to 1000V	15	30	100
100M to 1G	10V to 1000V	15	30	100
1G to 10G	10V to 1000V	20	50	300
10G to 100G	10V to 1000V	20	50	500
100G to 1T	10V to 1000V	70	200	800
1T to 10T	100V to 1000V	200	400	2000
10T to 100T	100V to 1000V	500	900	3500
100T to 1P	100V to 1000V	1500	N/A	1%
1P to 10P	100V to 1000V	-	-	2%

1. Uncertainty Confidence Level: 99%
2. Uncertainties relative to calibration standards used and are independent of reference resistor or UUT uncertainty contributors.
3. Does not include settle time, dielectric or voltage coefficient etc. for the resistor being measured.

## Optional Accessories

4610A	10-Channel High Resistance Coaxial Matrix Scanner	6601	Voltage Range Extender
4620A	20-Channel High Resistance Coaxial Matrix Scanner	9331G-XXX	100MΩ, 1GΩ, 10GΩ, 100GΩ, 1TΩ, 10TΩ, 100TΩ
9300A	Ultra High Stability Programmable Air Bath		Standard Resistors
9300	High Stability Air Bath	9331G-01	Lead Set, N to GR
6600A-Cal	Accredited Calibration	9331G-02	Lead Set, N to N
6600A-SW	Control and Data Acquisition Software (Included)	9331G-03	Lead Set, N to BNC
6600A-Env	Environmental Monitoring	9331G-XX	Lead Set N to Special



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**1987**

Measurements International (MI) is founded. Developed Four Terminal Automated Resistance Scanner Model 4220A

**1990**

Developed first commercial Automated Potentiometer based on the Binary Voltage Divider Technology (BVD), Model 8000A Range 1mV to 10V Accuracy  $< 5 \times 10^{-8}$

**1992**

Develops first commercial automated Direct Current Comparator Resistance Bridge (DCC) Model 6010A, Range 1  $\Omega$  to 10k $\Omega$ , Accuracy  $10^{-7}$

**1993**

Developed first commercial automated High Resistance Bridge for the measurement of resistors. Range 10k $\Omega$  to 100M $\Omega$ , Accuracy  $10^{-6}$

**1993**

MI USA was founded

**1997**

Re-develops DCC Technology which resulted in the world famous 6010B Resistance Bridge from 0.001 $\Omega$  to 10k $\Omega$ , Accuracy  $10^{-7}$

**1998**

Develops 20,000 A Direct Current Comparator for the LHC at CERN

**2002**

Develops the world's first and only portable cryogenic QUANT $\Omega$  (QHR) System Model 6800A Accuracy  $1 \times 10^{-8}$

**25th Anniversary**

**2003**

Developed the world's first room temperature Direct Current Comparator DCC Bridge (6010Q) for cryogenic applications Accuracy  $2 \times 10^{-8}$

**2005**

Develops first commercial automated High Resistance Bridge based on the binary voltage divider technology to 100V, Model 6000B Accuracy  $2 \times 10^{-8}$   
MI Europe was founded

**2006**

Develops first self calibrating Direct Current Comparator Ratio Bridge. Model 6242B with touch screen display. Range 1 $\Omega$  to 100M $\Omega$  Accuracy  $5 \times 10^{-8}$

**2008**

Develops world's first AccuBridge™ Technology DCC Resistance Bridge with complete self calibration. Range 0.1 $\Omega$  to 100k $\Omega$  Accuracy  $2 \times 10^{-8}$

**2009**

Develops first commercial Dual Source Bridge Technology for the measurement of high value resistors Range 10k $\Omega$  to 100T $\Omega$  Voltage 1V to 1000V

**2010**

MI China was founded  
Develops first automated Direct Current Comparator Resistance Bridge Model 6010D with touch screen display Range 0.01 $\Omega$  to 100k $\Omega$ , Accuracy  $4 \times 10^{-8}$

**2011**

Develops first automated high current 3000A Direct Current Comparator DCC Shunt Measurement System Ratio 1,000,000:1

**2013**

Developed first Benchtop High Resistance Bridge



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