1433 SERIES

High-Accuracy
Decade Resistor
User and Service Manual

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Chapter 1
INTRODUCTION

1.1 Product Overview

The **1433** Decade Resistors are a family of instruments providing a very broad choice of high-performance resistance sources. Any number of decades from one to eleven is available.

The **1433** is a precision resistance source with excellent characteristics of stability, temperature coefficient, power coefficient, and frequency response.

There are over 30 models available covering a wide resistance range from 1 mΩ to over 111 MΩ. The **1433** Series employs stable, very-low-resistance switches with silver-alloy contacts. A special design keeps zero-resistance to less than 1 mΩ per decade. Self-cleaning keeps the silver contacts from becoming tarnished when unused, or when only low currents are passed through them. This is most often the case when only minute test currents are drawn by digital multimeters or other test instruments. Contact resistance is stable and remains low and repeatable.

The dials, marked **"0"** to **"10"**, offer smooth rotation from position to position with no stops. Each dial has an overlap **"10"** position for maximum convenience and flexibility in setting and adjusting resistance values. The resistance per step and maximum current of each dial are clearly shown on the front panel. Electrical shielding is provided by an attractive aluminum cabinet and front panel. The resistance elements have no electrical connection to the cabinet and panel; a separate shield terminal is provided.

High-quality gold-plated, tellurium-copper binding posts serve to minimize the thermal emf effects which can introduce errors into dc resistance measurements. All other conductors within the instrument, as well as the solder employed, contain no metals or junctions that contribute to thermal emf problems.

With a minimum resistance as low as 1 mΩ and a maximum available resistance of over 111 MΩ, the **1433** series may be used for exacting precision measurement applications requiring high accuracy, good stability, and low zero-resistance. They can be used as components of dc and ac bridges, for calibration, as transfer standards, and as RTD simulators.

The **1433** Series may be rack-mounted to serve as components in measurement and control systems.

Chapter 2
SPECIFICATIONS

For the convenience of the user, the pertinent specifications are given in an **OPERATING GUIDE** affixed to the case of the instrument.

Decade Specifications

Resistance per step	Total decade resistance	Max current	Max voltage (per step)	Max power (per step)	Stability (±ppm/yr)	Long-term stability (±ppm/3 yrs)	Temperature coefficient (±ppm/°C)	Resistor type
1 mΩ	10 mΩ	8.0 A	5 mV	0.04 W	50	75	50	Resistance wire
10 mΩ	100 mΩ	4.0 A	40 mV	0.16 W	50	75	20	
100 mΩ	1 Ω	1.6 A	0.16 V	0.25 W	50	75	20	
1 Ω	10 Ω	0.8 A	0.8 V	0.6 W	20	25	20	Wirewound, non-inductive
10 Ω	100 Ω	0.25 A	2.5 V	0.6 W	20	25	15	
100 Ω	1 kΩ	80 mA	8 V	0.6 W	20	25	5	
1 kΩ	10 kΩ	23 mA	23 V	0.5 W	20	25	5	
10 kΩ	100 kΩ	7 mA	70 V	0.5 W	20	25	5	
100 kΩ	1 MΩ	2.3 mA*	230 V*	0.5 W*	20	25	5	
1 MΩ	10 MΩ	0.7 mA*	700 V*	0.5 W*	20	25	5	
10 MΩ	100 MΩ	0.1 mA*	1000 V*	0.1 W*	50	100	10	Metal oxide film

*Subject to maximum of 2000 V to case

Accuracy:

≤1 MΩ decades: ±(0.01% + 2 mΩ)
10 MΩ decades: ±0.03%
after subtraction of zero resistance, at 23°C; traceable to SI

Zero resistance:

≤1 MΩ decades: <1 mΩ per decade at dc
10 MΩ decade: ≈3 mΩ at dc

Max voltage to case:

2000 V peak

Terminals:

Gold-plated, 5-way, tellurium-copper binding posts with low thermal emf and low resistance. Rear outputs are available as an option.

Typical Value of Zero Impedance:

Zero Resistance (Ro):

<0.001 Ω/decade at dc
0.04 Ω/decade at 1 MHz
Proportional to square root of frequency above 100 kHz

Switch capacitance:

< 1 pF between contacts

Zero Inductance (Lo):

0. 1 μH/decade + 0.2 μH.

Switches:

Continuous rotation
11 positions marked “0”-”10”
Multiple solid silver-alloy contacts

Mechanical:

Model	Dimensions	Weight
3 decade	31 cm W x 8.9 cm H x 10.2 cm D (12.2" x 3.5" x 4")	1.7 kg 3.8 lb
4-5 decade	37.6 cm W x 8.9 cm H x 10.2 cm D (14.8" x 3.5" x 4")	2.0 kg 4.3 lb
6-7 decades	43.9 cm W x 8.9 cm H x 10.2 cm D (17.3" x 3.5" x 4")	2.4 kg 5.3 lb
8-9 decades	48.3 cm W x 17.8 cm H x 17.8 cm D (19" x 7" x 7")	3.5 kg 7.7 lb
10-11 decades		3.7 kg 8.1 lb

Environmental conditions:

Operating: 10°C to 40°C; <50% RH

Storage: -40°C to 70°C

Supplied with unit:

Instruction manual

Calibration Certificate

Model	Total resistance	Number of decades	Resolution	Historic GR model numbers
1433-01	1.11 Ω	3	0.001 Ω	
1433-00	111.1 Ω	4	0.01 Ω	1433-U
1433-02	1.111 kΩ	4	0.1 Ω	1433-K
1433-04	11.11 k Ω	4	1 Ω	1433-J
1433-06	111.1 k Ω	4	10 Ω	1433-L
1433-08	1.111 MΩ	4	100 Ω	1433-Q
1433-09	11.11 MΩ	4	1 kΩ	
1433-09A	111.1 MΩ	4	10 kΩ	
1433-10	1.1111 kΩ	5	0.01 Ω	1433-T
1433-12	11.111 kΩ	5	0.1 Ω	1433-N
1433-14	111.11 kΩ	5	1 Ω	1433-M
1433-16	1.1111 M Ω	5	10 Ω	1433-P
1433-18	11.111 MΩ	5	100 Ω	1433-Y
1433-18A	111.11 MΩ	5	1 kΩ	
1433-19	1.111 11 kΩ	6	0.001 Ω	
1433-20	11.1111 kΩ	6	0.01 Ω	1433-W
1433-22	111.111 kΩ	6	0.1 Ω	1433-X
1433-24	1.111 11 MΩ	6	1 Ω	1433-B
1433-26	11.1111 MΩ	6	10 Ω	1433-Z
1433-27	111.111 MΩ	6	100 Ω	

Model	Total resistance	Number of decades	Resolution	Historic GR model numbers
1433-28	11.111 11 kΩ	7	0.001 Ω	
1433-29	111.1111 k Ω	7	0.01 Ω	1433-F
1433-31	1.111 111 MΩ	7	0.1 Ω	1433-G
1433-33	11.111 11 MΩ	7	1 Ω	1433-H
1433-34	111.1111 MΩ	7	10 Ω	
1433-35	111.111 11 kΩ	8	0.001 Ω	
1433-36	1.111 111 1 MΩ	8	0.01 Ω	
1433-37	11.111 111 MΩ	8	0.1 Ω	
1433-38	111.111 11 MΩ	8	1 Ω	
1433-39	1.111 111 11 MΩ	9	0.001 Ω	
1433-39A	11.111 111 1 MΩ	9	0.01 Ω	
1433-39B	111.111 111 MΩ	9	0.1 Ω	
1433-40A	11.111 111 11 MΩ	10	0.001 Ω	
1433-40	111.111 111 1 MΩ	10	0.01 Ω	
1433-41	111.111 111 11 MΩ	11	0.001 Ω	

1433 SERIES PRECISION DECADE RESISTORS

Resistance per step	Total deacde resistance	Max current	Max voltage	Power per/step	Stability	Long-term stability	Temp. coeffieient	Resistor type
1 mΩ	10 mΩ	8.0 A	5 mV	0.04 W	±50 ppm/yr	±75 ppm/3 yrs	± 50 ppm/°C	Resistance Wire
10 mΩ	100 mΩ	4.0 A	40 mV	0.16 W	±50 ppm/yr	±75 ppm/3 yrs	± 20 ppm/°C	
100 mΩ	1 Ω	1.6 A	0.16 V	0.25 W	±50 ppm/yr	±75 ppm/3 yrs	± 20 ppm/°C	
1 Ω	10 Ω	0.8 A	0.8 V	0.6 W	±20 ppm/yr	±25 ppm/3 yrs	± 20 ppm/°C	Wirewound, non-inductive
10 Ω	100 Ω	0.25 A	2.5 V	0.6 W	±20 ppm/yr	±25 ppm/3 yrs	± 15 ppm/°C	
100 Ω	1 kΩ	80 mA	8 V	0.6 W	±20 ppm/yr	±25 ppm/3 yrs	± 5 ppm/°C	
1 kΩ	10 kΩ	23 mA	23 V	0.5 W	±20 ppm/yr	±25 ppm/3 yrs	± 5 ppm/°C	
10 kΩ	100 kΩ	7 mA	70 V	0.5 W	±20 ppm/yr	±25 ppm/3 yrs	± 5 ppm/°C	
100 kΩ	1 MΩ	2.3 mA*	230 V*	0.5 W*	±20 ppm/yr	±25 ppm/3 yrs	± 5 ppm/°C	
1 MΩ	10 MΩ	0.7 mA*	700 V*	0.5 W*	±20 ppm/yr	±25 ppm/3 yrs	± 5 ppm/°C	
10 MΩ	100 MΩ	0.1 mA*	1000 V*	0.1 W*	±50 ppm/yr	±100 ppm/3 yrs	± 10 ppm/°C	Metal oxide film

***Subject to maximum of 2000 V to case**

Accuracy: **≤1 MΩ steps**: ±(0.01% + 2 mΩ)
10 MΩ steps: ±0.03%
At 23°C, after subtraction of zero resistance
Traceable to SI

Zero Resistance: **≤1 MΩ steps:** ≤1 mΩ per decade
10 MΩ steps: approx. 3 mΩ

Max Voltage to Case: 2000 V peak

Switch Type: Multiple solid silver alloy contacts; continuous-rotation; 11 positions marked "0" to "10".

Operation: If switches have not been operated for an extended period, they should be rotated a few times in both directions to restore contact resistance to specifications.

Operating Conditions: +10 to + 40°C, <50% RH.

WARNING

Observe all safety rules when working with high voltages or line voltages. Connect the (G) terminal to earth ground in order to maintain the case at a safe voltage. Whenever hazardous voltages (>45 V) are used, take all measures to avoid accidental contact with any live components: a) Use maximum insulation and minimize the use of bare conductors. b) Remove power when adjusting switches. c) Post warning signs and keep personnel safely away.

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Figure 2-1: Sample operating guide affixed to unit

Chapter 3
OPERATION

3.1 Initial Inspection and Setup

This instrument was carefully inspected before shipment. It should be in proper electrical and mechanical order upon receipt.

An **OPERATING GUIDE** is attached to the case of the instrument to provide ready reference to specifications.

3.2 Connection

3.2.1 General Considerations

The **1433** Series Decade unit provides three terminals labeled **H** (high), **L** (low), and **G** (ground). The **H** and **L** terminals are connected to the set resistance; the **G** terminal is connected to the case. The **G** terminal may be used as a guard or shield terminal. It may also be connected (using a shorting link) to the **L** terminal to allow two-terminal as opposed to three-terminal measurements.

In order to make the most stable measurements, determine which is the more sensitive of the two user leads, i.e. the one going into a higher impedance. This lead should be connected to the more *protected* of the two terminals: **H** (high) or **L** (low). That would either be the terminal that is shorted to the case, or the **L** terminal if neither is connected to the **G** (case).

If switches have not been operated for an extended period, they should be rotated a few times to assure that contact resistance is within specifications.

3.2.2 Electrical Considerations

In order to make proper use of the full performance capabilities of the **1433** unit, especially if low resistance or low-resistance increments are important, take care when connecting to the terminals. In particular, in order to keep contact resistance to a minimum, make the most substantial and secure connection to the binding posts. They accept banana plugs, telephone tips, spade lugs, alligator clips, and bare wire. The largest or heaviest mating connection should be made, and, where applicable, the binding posts should be securely tightened.

These considerations may be relaxed whenever single milliohms are considered insignificant for the task being performed.

3.2.3 Four-Wire Kelvin-Lead Connections

Whenever possible, 4-wire Kelvin leads (the best connection) should be employed. Such a connection minimizes the effects of contact resistance and approaches ideal performance.

If the four terminals are available as clamps similar to alligator clips, they may be connected to the necks of the binding posts on a 3-terminal unit. If the four-wire connections are available separately, the optimal connections are shown in Figure 3-1 and Figure3-2.

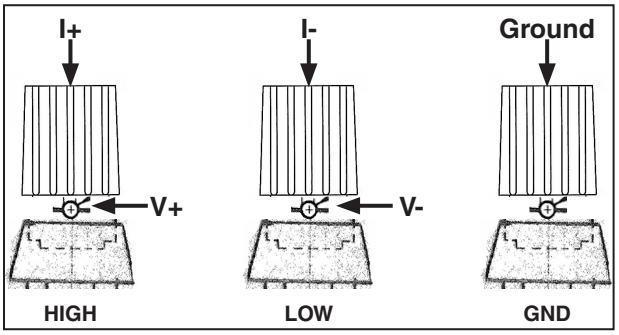

Figure 3-1: 4-Wire connection to a 3-terminal unit

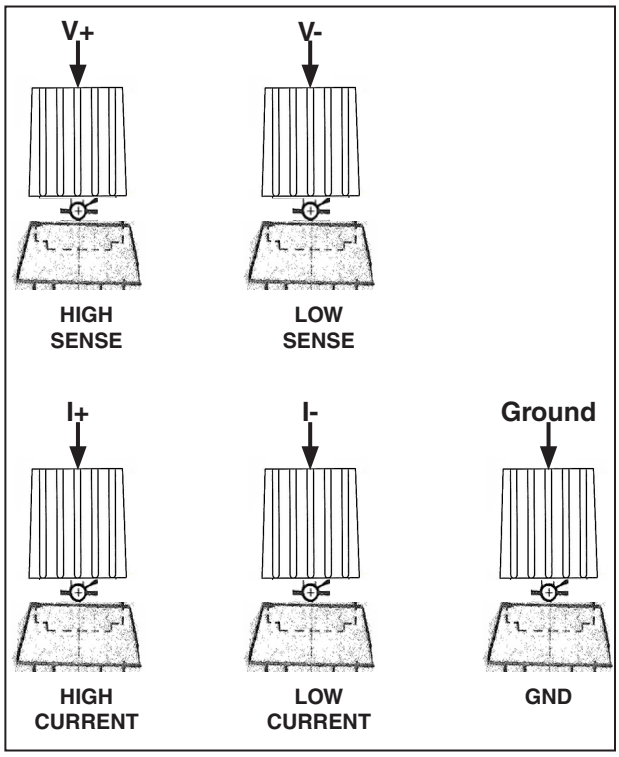

Figure 3-2: 4-Wire connection to a 5-terminal unit

3.2.4 Thermal emf Considerations

The highest-quality low-emf components are used in the **1433** Series. There nevertheless may be some minute thermal emf generated at the test leads where they contact the gold-plated binding posts.

This emf will not manifest itself if an ac measurement instrument is employed. It will also be eliminated if a meter with a "True Ohm" capability is used. Otherwise it may appear as a false component of the dc resistance measurement. It is possible to eliminate this component of the reading error by taking a second measurement with the leads reversed and averaging the readings.

3.3 Dial Setting

Whenever the dials are used in positions 0-9, the resulting resistance is read directly. The decimal point and the steps are clearly marked on the panel. For additional flexibility and range, each decade provides a "10" position setting. This "10" position on any one decade equals the "1" position on the next higher decade. It adds about 11% to the nominal total decade resistance.

To determine the resistance obtained when one or more "10" settings are used, simply add "1" to the next higher decade. For example, a setting of 3-6-10-0-10 Ω becomes:

3	3	0	0	0	0
6		6	0	0	0
10		1	0	0	0
0				0	0
10				1	0
TOT	**3**	**7**	**0**	**1**	**0**

and a setting of 10-10-10-l0-10.10 Ω becomes:

10	1	0	0	0	0	0.0
10		1	0	0	0	0.0
10			1	0	0	0.0
10				1	0	0.0
10					1	0.0
.10						1.0
TOT	**1**	**1**	**1**	**1**	**1**	**1.0**

Chapter 4
MAINTANENCE

4.1 Preventative Maintenance

Keep the unit in a clean environment. This will help prevent possible contamination.

The 1433 is packaged in a closed case, which limits the entry of contaminants and dust to the inside of the instrument. If it is maintained in a clean or air-conditioned environment, cleaning will seldom be required. In a contaminated atmosphere, cleaning may be required.

Should cleaning be needed, do the following:

1. Remove the 4 screws from the sides of the housing, and remove the housing.
2. Remove any dust or debris using optical grade dry compressed air or a clean brush.
3. Should switch contact cleaning or lubrication be required, as may be indicated by an increase in the zero resistance, this may be done be spraying the switch contacts with a conditioning compound such as WD-40 or Deoxit from Caig Laboratories, or Super Lube with PTFE from Synco Chemical Corp.
4. Replace the housing and reinstall the 4 housing screws.

The front panel should be periodically cleaned to eliminate any leakage paths around the binding posts. To do this wipe the front panel clean using alcohol and a lint-free cloth.

4.2 Calibration Interval

The recommended calibration interval for **1433** Series decade substituters is twelve (12) months. The calibration procedure may be carried out by the user if a calibration capability is available or by a certified calibration laboratory. If the user should choose to perform this procedure, then the considerations below should be observed.

4.3 General Considerations

It is important, whenever testing the **1433** Series Decade Units, to be very aware of the capabilities and limitations of the test instruments used. A resistance bridge may be employed, and there are direct-reading resistance meters or digital multimeters available that can verify the accuracy of these units, especially when used in conjunction with standards that can serve to confirm or improve the accuracy of the testing instrument

Such test instruments must be significantly more accurate than ±(l00 ppm+2 mΩ) for all applicable ranges, allowing for a band of uncertainty of the instrument itself. A number of commercial bridges and meters exist that can perform this task.

It is important to allow both the testing instrument and the **1433** to stabilize for a number of hours at the nominal operating temperature of 23˚C, and at nominal laboratory conditions of humidity. There should be no temperature gradients across the unit under test.

Substantial Kelvin-type 4-wire test terminals should be used to obtain accurate low-resistance readings. It is convenient, once the zero resistance has been determined, to subtract it from the remaining measurements. This can be automatically done in many instruments which have an offset subtraction capability.

4.4 Calibration Procedure

1. Employ proper metrological practices.
   Allow a confidence band for the uncertainty of the measuring instrument and setup.
2. Confirm the zero resistance of the unit.
3. Determine the allowable upper and lower limits for each resistance setting of each decade based on the specified accuracy.
   For the 1433 series, these limits for any resistance "R" are [R±(0.0001 R + 2 mΩ)].
4. Confirm that the resistances fall within these limits after subtraction of the zero resistance.
5. If any resistances fall outside these limits, the associated switch assembly may require trimming or replacement.

4.5 Schematic

Figure 4-1 gives the schematic of the **1433** decade unit.

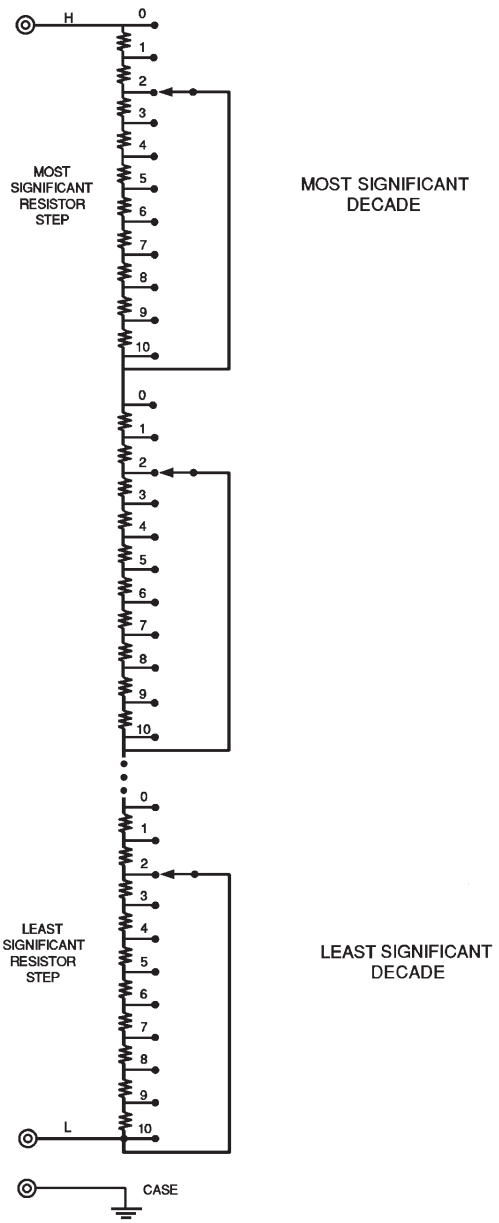

Figure 4-1: 1433 Series Schematic Diagram