

1433 SERIES

High-Accuracy Decade Resistor

User and Service Manual



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1433 im/October 2018

Effective for serial numbers beginning with “E”



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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

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WARNING



OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

**Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qualified personnel**

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO
AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE
CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND
KEEP UNREQUIRED PERSONNEL SAFELY AWAY.



CAUTION



DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS
INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON
THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

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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 m Ω to over 111 M Ω . The **1433** Series employs stable, very-low-resistance switches with silver-alloy contacts. A special design keeps zero-resistance to less than 1 m Ω 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 m Ω and a maximum available resistance of over 111 M Ω , 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.

This series is part of a family of resistance substitutes suitable for filling many engineering and testing needs. Consult IET for:

- HPRS** High-power substitutes - up to >400 W
- HRRS** High-resistance substitutes - to 1 T Ω
- RTD** simulators
- HARS-LX** Laboratory-standard-grade substitutes - to 1 ppm accuracy
- PRS** Programmable substitutes - IEEE-488 or BCD; SCPI protocol.



Figure 1-1: 1433 Series High Accuracy Decade Resistor

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 (\pm ppm/yr) | Long-term stability (\pm ppm/3 yrs) | Temperature coefficient (\pm ppm/ $^{\circ}$ C) | Resistor type |
|---------------------|-------------------------|-------------|------------------------|----------------------|---------------------------|--|--|--------------------------|
| 1 m Ω | 10 m Ω | 8.0 A | 5 mV | 0.04 W | 50 | 75 | 50 | Resistance wire |
| 10 m Ω | 100 m Ω | 4.0 A | 40 mV | 0.16 W | 50 | 75 | 20 | |
| 100 m Ω | 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 k Ω | 80 mA | 8 V | 0.6 W | 20 | 25 | 5 | |
| 1 k Ω | 10 k Ω | 23 mA | 23 V | 0.5 W | 20 | 25 | 5 | |
| 10 k Ω | 100 k Ω | 7 mA | 70 V | 0.5 W | 20 | 25 | 5 | |
| 100 k Ω | 1 M Ω | 2.3 mA* | 230 V* | 0.5 W* | 20 | 25 | 5 | |
| 1 M Ω | 10 M Ω | 0.7 mA* | 700 V* | 0.5 W* | 20 | 25 | 5 | Metal oxide film |
| 10 M Ω | 100 M Ω | 0.1 mA* | 1000 V* | 0.1 W* | 50 | 100 | 10 | |

*Subject to maximum of 2000 V to case

Accuracy:

≤ 1 M Ω decades: $\pm(0.01\% + 2 \text{ m}\Omega)$

10 M Ω decades: $\pm 0.03\%$

after subtraction of zero resistance, at 23 $^{\circ}$ C;
traceable to SI

Zero resistance:

≤ 1 M Ω decades: $< 1 \text{ m}\Omega$ per decade at dc

10 M Ω decade: $\approx 3 \text{ m}\Omega$ at dc

Max voltage to case:

2000 V peak

Terminals:

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

-K Option: Kelvin connection to is available as an option with 5 binding posts

Typical Value of Zero Impedance:

$< 0.001 \Omega$ /decade at 1 Hz.

0.04Ω /decade at 1 MHz

Proportional to square root of frequency above 100 kHz

Switch capacitance:

$< 1 \text{ pF}$ between contacts

Zero Inductance (L_0):

$0.1 \mu\text{H}$ /decade + $0.2 \mu\text{H}$.

Switches:

Continuous rotation

11 positions marked "0"-10"

Multiple solid silver-alloy contacts

Environmental conditions:

Operating: 10 $^{\circ}$ C to 40 $^{\circ}$ C

Storage: -40 $^{\circ}$ C to 70 $^{\circ}$ C

Humidity: $< 80\%$ RH

Supplied with unit:

Instruction manual

Calibration Certificate

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 |

Ordering Information:

| 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 k Ω | 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 M Ω | 4 | 100 Ω | 1433-Q |
| 1433-09 | 11.11 M Ω | 4 | 1 k Ω | |
| 1433-09A | 111.1 M Ω | 4 | 10 k Ω | |
| 1433-10 | 1.1111 k Ω | 5 | 0.01 Ω | 1433-T |
| 1433-12 | 11.111 k Ω | 5 | 0.1 Ω | 1433-N |
| 1433-14 | 111.11 k Ω | 5 | 1 Ω | 1433-M |
| 1433-16 | 1.1111 M Ω | 5 | 10 Ω | 1433-P |
| 1433-18 | 11.111 M Ω | 5 | 100 Ω | 1433-Y |
| 1433-18A | 111.11 M Ω | 5 | 1 k Ω | |
| 1433-19 | 1.111 11 k Ω | 6 | 0.001 Ω | |
| 1433-20 | 11.1111 k Ω | 6 | 0.01 Ω | 1433-W |
| 1433-22 | 111.111 k Ω | 6 | 0.1 Ω | 1433-X |
| 1433-24 | 1.111 11 M Ω | 6 | 1 Ω | 1433-B |
| 1433-26 | 11.1111 M Ω | 6 | 10 Ω | 1433-Z |
| 1433-27 | 111.111 M Ω | 6 | 100 Ω | |
| 1433-28 | 11.111 11 k Ω | 7 | 0.001 Ω | |
| 1433-29 | 111.1111 k Ω | 7 | 0.01 Ω | 1433-F |
| 1433-31 | 1.111 111 M Ω | 7 | 0.1 Ω | 1433-G |
| 1433-33 | 11.111 11 M Ω | 7 | 1 Ω | 1433-H |

| Model | Total resistance | Number of decades | Resolution | Historic GR model numbers |
|-----------------|---------------------------|-------------------|----------------|---------------------------|
| 1433-34 | 111.1111 M Ω | 7 | 10 Ω | |
| 1433-35 | 111.111 11 k Ω | 8 | 0.001 Ω | |
| 1433-36 | 1.111 111 1 M Ω | 8 | 0.01 Ω | |
| 1433-37 | 11.111 111 M Ω | 8 | 0.1 Ω | |
| 1433-38 | 111.111 11 M Ω | 8 | 1 Ω | |
| 1433-39 | 1.111 111 11 M Ω | 9 | 0.001 Ω | |
| 1433-39A | 11.111 111 1 M Ω | 9 | 0.01 Ω | |
| 1433-39B | 111.111 111 M Ω | 9 | 0.1 Ω | |
| 1433-40A | 11.111 111 11 M Ω | 10 | 0.001 Ω | |
| 1433-40 | 111.111 111 1 M Ω | 10 | 0.01 Ω | |
| 1433-41 | 111.111 111 11 M Ω | 11 | 0.001 Ω | |

OPTIONS:

- 1433-50:** Rack Mount Kit (4-dial)
- 1433-51:** Rack Mount Kit (5-dial)
- 1433-52:** Rack Mount Kit (6 and 7-dial)
- 1433-XX-RO:** Rear output binding posts
- 1433-XX-K:** Kelvin-type 4-terminal posts

1433 SERIES PRECISION DECADE RESISTORS

| Resistance per step | Total decade resistance | Max current | Max voltage | Power per/step | Stability | Long-term stability | Temp. coefficient | 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 | Wirewound, non-inductive |
| 1 Ω | 10 Ω | 0.8 A | 0.8 V | 0.6 W | ±20 ppm/yr | ±25 ppm/3 yrs | ±20 ppm/°C | |
| 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 | |

*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.

MODEL: 1433-26 **SN: E1-13013757**

 **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

1433 IBI/1433 genl/p4/48%/02-07-2013

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 Figure 3-2.

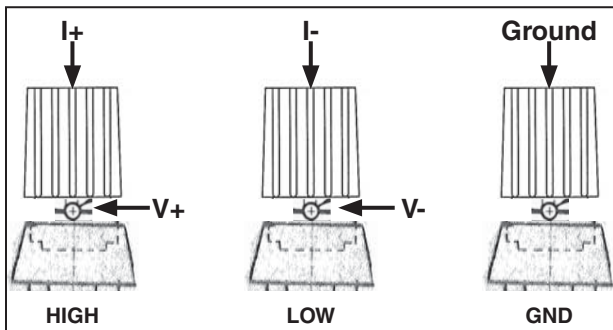


Figure 3-1: 4-Wire connection to a 3-terminal unit

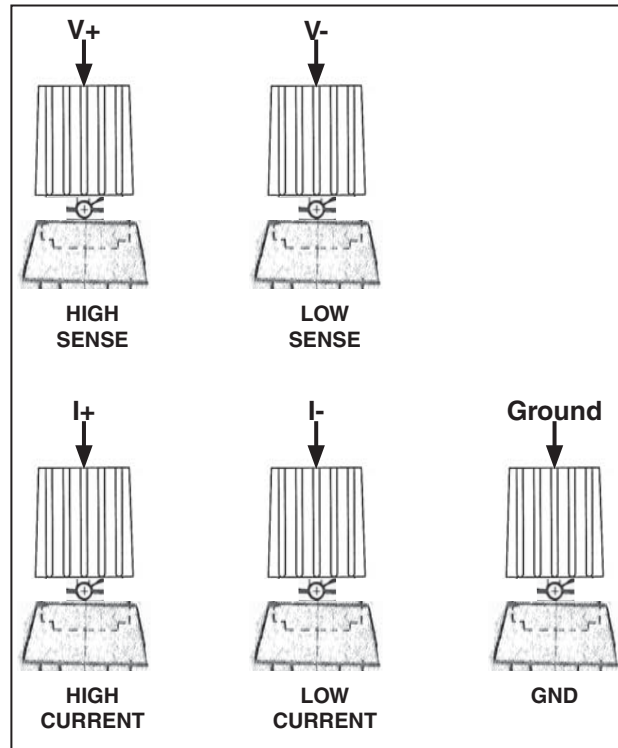


Figure 3-2: 4-Wire connection to a 5-terminal unit

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 | 0 |
| 10 | 1 | 0 | 0 | 0 | 0 |
| 0 | | | 0 | 0 | |
| 10 | | | 1 | 0 | |
| | | | | | |
| TOT | 3 | 7 | 0 | 1 | 0 |

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

| | | | | | | |
|------------|----------|----------|----------|----------|----------|------------|
| 10 | 1 | 0 | 0 | 0 | 0 | 0.0 |
| 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 |
| | | | | | | |
| TOT | 1 | 1 | 1 | 1 | 1 | 1.0 |

Chapter 4

MAINTENANCE

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 by 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, by IET Labs, 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 $\pm(100 \text{ ppm} + 2 \text{ m}\Omega)$ 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; consult IET Labs.

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 <80% RH. 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 $[R \pm (0.0001 R + 2 \text{ m}\Omega)]$.
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.

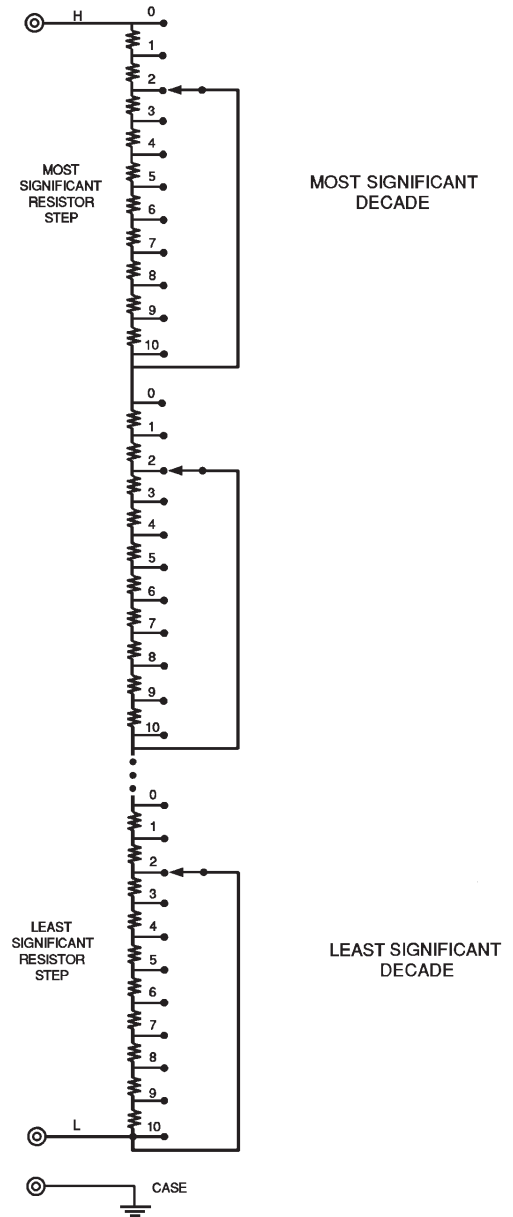


Figure 4-1: 1433 Series Schematic Diagram

4.6 Replaceable Parts List

| Model Ref | IET Pt No | Description |
|-----------|------------------|------------------------------------|
| 1 | BP-1000-RD | Binding Post, Red |
| 2 | BP-1000-BK | Binding Post, Black |
| 3 | BP-1000-GN | Binding Post, Green |
| 4 | 1433-4300-KNB | Knob Assembly |
| Not Shown | 1433-3100 | Foot |
| Not Shown | 1433-4000-X-.001 | 1 mΩ/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-0.01 | 10 mΩ/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-0.1 | 100 mΩ/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-1 | 1 Ω/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-10 | 10 Ω/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-100 | 100 Ω/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-1k | 1 kΩ/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-10k | 10 kΩ/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-100k | 100 kΩ/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-1M | 1 MΩ/step Decade Switch Assembly |
| Not Shown | 1433-4000-X-10M | 10 MΩ/step Decade Switch Assembly |

Table 4-1: Replacement List



Figure 4-2: 1433 Replaceable Parts