GenRad

Type 1433
DECADE RESISTOR

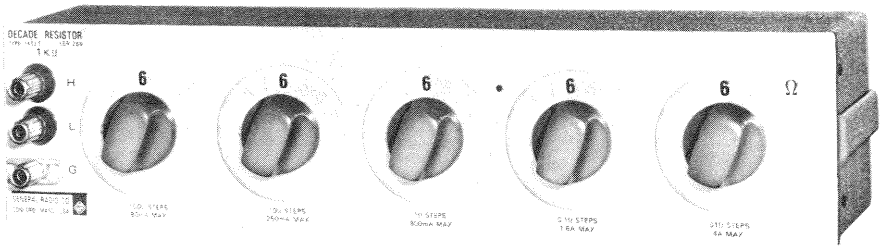


Figure 1-1. Type 1433-T Decade Resistor.

SPECIFICATIONS

Accuracy: The specified tolerances apply for low-current measurement at dc or low-frequency ac (see below).

Over-all Accuracy: The difference between the resistances at any setting and at the zero setting is equal to the indicated value ±(0.01% + 2 mΩ).

Incremental Accuracy: See table. This is the accuracy of the change in resistance between any two settings on the same dial.

Max Current: The max current for each decade is given in the table below and also appears on the panel of each decade box and on the dial plate of each decade resistance unit.

Frequency Characteristic: The accompanying plot shows the max percentage change in effective series resistance, as a function of frequency for the individual decade units. For low-resistance decades the error is due almost entirely to skin effect and is independent of switch setting. For the high-resistance units the error is due almost entirely to the shunt capacitance and its losses and is approx proportional to the square of the resistance setting.

The high-resistance decades (510-E, -F, -G, and -H) are very commonly used as parallel resistance elements in resonant circuits, in which the shunt capacitance of the decades becomes part of the tuning capacitance. The parallel resistance changes by only a fraction (between a tenth and a hundredth) of the series-resistance change, depending on frequency and the insulating material in the switch.

Characteristics of the 1433's are similar to those of the individual 510's modified by the increased series inductance, L_o, and shunt capacitance, C, due to the wiring and the presence of more than one decade in the assembly. At total resistance settings of approx 1000 ohms or less, the frequency characteristics of any of these decade resistors are substantially the same as those shown for the 510's. At higher settings, shunt capacitance becomes the controlling factor, and the effective value of this capacitance depends upon the settings of the individual decades.

Typical Values of R_o, L_o, and C for the Decade Resistors:

Zero Resistance (R_o): 0.001 Ω per dial at dc; 0.04 Ω per dial at 1 MHz; proportional to square root of frequency at all frequencies above 100 kHz.

Zero Inductance (L_o): 0.1 μH per dial + 0.2 μH.

Effective Shunt Capacitance (C): This value is determined largely by the highest decade in use. With the low terminal connected to the shield, a value of 15 to 10 pF per decade may be assumed, counting decades down from the highest. Thus, if the third decade from the top is the highest resistance decade in circuit (i.e., not set at zero), the shunting terminal capacitance is 45 to 30 pF. If the highest decade in the assembly is in use, the effective capacitance is 15 to 10 pF, regardless of the settings of the lower-resistance decades.

Temperature Coefficient of Resistance: Less than ±10 ppm per degree C for values above 100 Ω and ±20 ppm per degree C for 100 Ω and below, at room temperatures. For the 1433's the box wiring will increase the over-all temperature coefficient of the 0.1- and 0.01-Ω decades.

Switches: Quadruple-leaf brushes bear on lubricated contact studs of ⅜-in. diameter in such a manner as to avoid cutting but yet give a good wiping action. A ball-on-cam detent is provided. There are eleven contact points (0 to 10 inclusive). The switch resistance is less than 0.0005 Ω. The effective capacitance is of the order of 5 pF, with a dissipation factor of 0.06 at 1 kHz for the standard cellulose-filled molded phenolic switch form and 0.01 for the mica-filled phenolic form used in the 510-G and 510-H units.

Max Voltage to Case: 2000 V pk.

Terminals: Low-thermal-emf jack-top binding posts on standard ¾-in. spacing; also provisions for rear-panel connections. Shield terminal is provided.

Mounting: Lab-bench cabinet, rack models include mounting hardware.

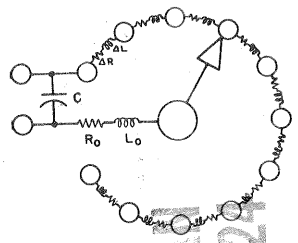
Dimensions and Weights: in. (mm), lb (kg):

	4-dial U, K, J, L, Q	5-dial T, N, M, P, Y	6-dial W, X, B, Z	7-dial F, G, H
Width*	12.3 (312)	14.8 (375)	17.3 (439)	
Height		3.5 (89)		5.3 (135)
Depth	5 in. over-all, 4 in. behind panel (127, 102)			
Net Wt**	4.8 (2.2)	5.8 (2.7)	7 (3.2)	8.8 (4.0)
Ship. Wt**	5.5 (2.5)	6.5 (3.0)	8.5 (3.9)	10.3 (4.7)

* Data given for bench models. All rack models same except 19 in. (483 mm) wide.

** Add approx 1 lb (0.5 kg) for rack-mount hardware.

Type	Total Ohms	Ohms per Step	No. of Dials	Type 510 Decades Used	Catalog Number Bench	Catalog Number Rack
1433-U	111.1	0.01	4	AA, A, B, C	**1433-9700**	**1433-9701**
1433-K	1111	0.1	4	A, B, C, D	**1433-9702**	**1433-9703**
1433-J	11,110	1	4	B, C, D, E	**1433-9704**	**1433-9705**
1433-L	111,100	10	4	C,, D, E, F	**1433-9706**	**1433-9707**
1433-Q	1,111,000	100	4	D, E, F, G	**1433-9708**	**1433-9709**
1433-T	1111.1	0.01	5	AA, A, B, C, D	**1433-9710**	**1433-9711**
1433-N	11,111	0.1	5	A, B, C, D, E	**1433-9712**	**1433-9713**
1433-M	111,110	1	5	B, C, D, E, F	**1433-9714**	**1433-9715**
1433-P	1,111,100	10	5	C, D, E, F, G	**1433-9716**	**1433-9717**
1433-Y	11,111,000	100	5	D, E, F, G, H	**1433-9718**	**1433-9719**
1433-W	11,111.1	0.01	6	AA, A, B, C, D, E	**1433-9720**	**1433-9721**
1433-X	111,111	0.1	6	A, B, C, D, E, F	**1433-9722**	**1433-9723**
1433-B	1,111,110	1	6	B, C, D, E, F, G	**1433-9724**	**1433-9725**
1433-Z	11,111,100	10	6	C, D, E, F, G, H	**1433-9726**	**1433-9728**
1433-F	111,111.1	0.01	7	AA, A, B, C, D, E, F	**1433-9729**	**1433-9730**
1433-G	1,111,111	0.1	7	A, B, C, D, E, F, G	**1433-9731**	**1433-9732**
1433-H	11,111,110	1	7	B, C, D, E, F, G, H	**1433-9733**	**1433-9734**



Equivalent circuit of a resistance decade, showing residual impedances.

DECADE-RESISTANCE UNITS

Type	Total Resistance Ohms	Resistance Per Step (ΔR) Ohms	Accuracy of Resistance Increments	Max Current 40° C Rise	Power Per Step Watts	ΔL μH	C** pF	L_o μH
510-AA	0.1	0.01	±2%	4 A	0.16	0.01	7.7–4.5	0.023
510-A	1	0.1	±0.4%	1.6 A	0.25	0.014	7.7–4.5	0.023
510-B	10	1	±0.1%	800 mA	0.6	0.056	7.7–4.5	0.023
510-C	100	10	±0.04%	250 mA	0.6	0.11	7.7–4.5	0.023
510-D	1000	100	±0.01%	80 mA	0.6	5	7.7–4.5	0.023
510-E	10,000	1000	±0.01%	23 mA	0.5	13	7.7–4.5	0.023
510-F	100,000	10,000	±0.01%	7 mA	0.5	70	7.7–4.5	0.023
510-G	1,000,000	100,000	±0.01%	2.3 mA	0.5	—	7.7–4.5	0.023
510-H	10,000,000	1,000,000	±0.01%	0.7* mA	0.5	—	7.5–4.5	0.023

* Or a max of 4000 V, pk.

** The larger capacitance occurs at the highest setting of the decade. The values given are for units without the shield cans in place. With the shield cans in place, the shunt capacitance is from 0 to 20 pF greater than indicated here, depending on whether the shield is tied to the switch or to the zero end of the decade.

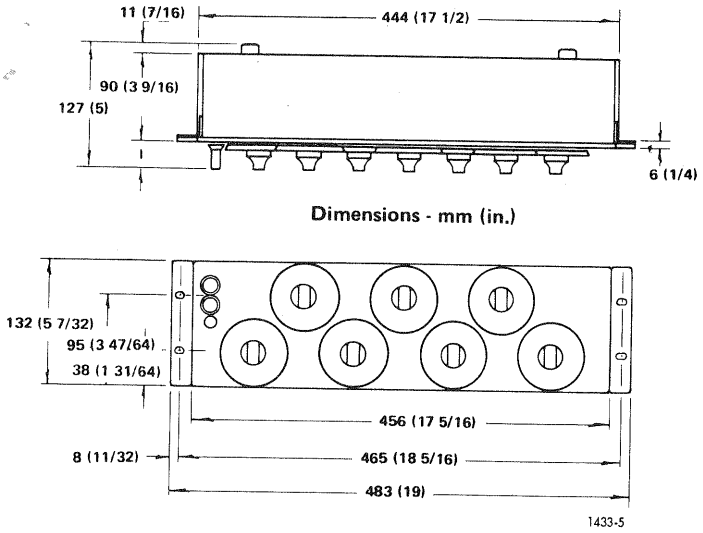


Figure 2-2. Approximate dimensions of 1433 Decade Resistors with 7 decades.

2.2 INSTALLATION.

To install a 1433 Decade Resistor in a standard 19-inch relay rack using the appropriate Panel-Adaptor Set, see Figure 2-3 and proceed as follows:

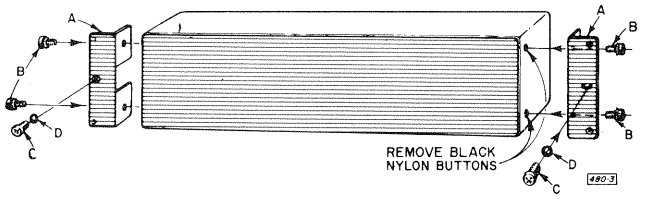


Figure 2-3. Relay-rack installation of a 1433 Decade Resistor.

a. Remove the black nylon buttons from the holes in the side panels of the instrument. These buttons are press fitted and are easily removed with a small screwdriver.

b. Install the adaptor panel (A) on each side of the instrument, using the 3/8-inch locking screws (B) supplied. The holes in the side panels are tapped to receive these screws.

c. Mount the assembly in a standard 19-inch relay-rack cabinet, using the 5/8-inch No. 10-32 screws (C) and nylon washers (D) supplied.

2.3 OPERATION.

2.3.1 CONNECTIONS – GENERAL.

The terminals on the 1433 are standard 3/4-inch-spaced binding posts that accept banana plugs, standard telephone tips, alligator clips, crocodile clips, spade terminals, and wire sizes up to No. 10. See Figure 2-4.

The banana-plug patch cords listed in Table 2-1 are GR catalog items that are readily available for use with the 1433 and associated instruments equipped with 3/4-inch-spaced binding posts.

2.3.2 FRONT-PANEL CONNECTIONS.

Standard 3/4-inch-spaced binding posts are available on the front panel for general use. The high (H) and low (L) binding posts are insulated from the panel and used for regular two-terminal applications. For grounded operation, connect the ground link between the ground (G) terminal and the low (L) terminal. Refer to section 3 (Frequency Characteristics) for a detailed comparison of two- and three-terminal connections.

Table 2-1
Patch-Cord Accessories

Type	Description	Catalog Number
274-NQ	Double-plug patch cord, in-line cord, 36" long	0274-9860
274-NP	Double-plug patch cord, right-angle cord, 36" long	0274-9880
274-NL	Shielded double-plug patch cord, 36" long	0274-9883
274-LLB	Single-plug patch cord, black, 36" long	0274-9468
274-LLR	Single-plug patch cord, red, 36" long	0274-9492

● Single 510 Decade. An equivalent circuit for a single, shielded 510 Decade Resistance Unit mounted in a 1433 decade box is shown in Figure 3-1 (the values are approximate because they depend on the value of the resistance steps used in the particular decade). The change in effective

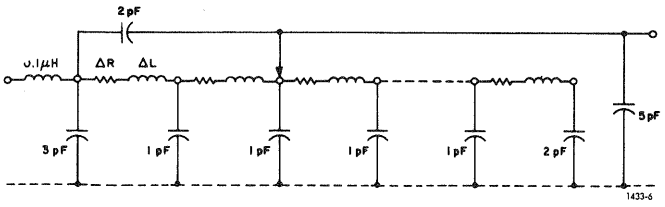


Figure 3-1. Equivalent circuit for a single decade in a decade box.

series* resistance of an individual decade is shown in Figure 3-2. The series resistance of the high-valued decades is reduced because of shunt capacitance at higher frequencies. The series resistance of the low-valued units is increased because of skin effect.

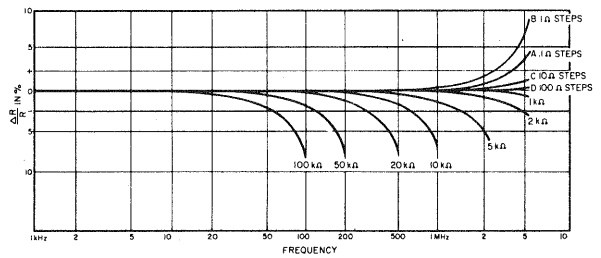


Figure 3-2. Maximum percentage change in series resistance as a function of frequency for Type 510 Decade-Resistance Units.

The parallel** resistance of the high-valued decades changes much less than the series resistance because it is not affected by the lumped shunt capacitance.

● Decade Boxes. When several decades are installed in a 1433 decade box, the complete equivalent circuit becomes too complicated to be useful. A much simpler circuit, such as the one shown in Figure 3-3, is desirable.

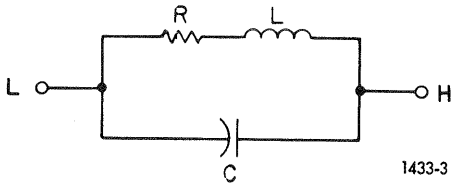


Figure 3-3. A simplified equivalent circuit for a decade box with the low (L) terminal tied to case.

*Series resistance = real part of impedance: $Z = R + jX$

**Parallel resistance = $\frac{1}{G}$ G= real part of admittance: $Y = G + jB$

In figure 3-3:

R =setting of the decade box.

$L = L_o + N_1 \Delta L_1 + N_2 \Delta L_2 + \ldots\ldots$

where $L_o \approx 0.1\ \mu H$ per decade x number of decades in unit $+ 0.2\ \mu H$.

$\Delta L_1, \Delta L_2, \ldots \approx$ values from table in specifications.

$N_1, N_2, \ldots \approx$ settings of corresponding decades.

$C = C_o + MC_1$

where $C_o \sim 15$ pF

$C_1 \approx 19$ pF

M =number of unused decades (set to zero) preceding first decade used.

The phase angle (Q) for this circuit is:

$$Q = \omega \left(\frac{L}{R} - RC\right).$$

At low values of R, the $\frac{L}{R}$ term is dominant; at high values of R, the RC term is more important.

The effective series resistance is:

$$R_s = \frac{R}{1 + \omega^2 R^2 C^2}$$

The effective parallel resistance is:

$$R_p = R\left(1 + \frac{\omega^2 L^2}{R^2}\right)$$

At low values, the series resistance remains constant to rather high frequencies because inductance has no effect on R_s. At very low values, skin effect increases R_s (see Figure 3-2).

At high values, the series resistance falls off rather rapidly with frequency, because of capacitance. The parallel resistance, however, is not affected by the lumped capacitance shown in the simple equivalent circuit (see Figure 3-3). The parallel value is affected by distributed capacitance and dielectric loss not shown. An approximate equation that considers these effects on R_p is:

$$R_p \approx R\left[1 + \frac{\omega^2 L^2}{R^2} - \omega R 10^{-13} - 4\omega^2 R^2 10^{-24} - 25\omega^2 R R_y 10^{-24}\right]$$

The $\omega R 10^{-13}$ term represents dielectric loss, the next term represents distributed capacitance in the first decade used (not zero), and the last term represents distributed capacitance in the first decade if it is not used (set at zero), where R_y is the total possible value of that decade. (The last term is not used if the first decade is not set to zero.)

When the case is not tied to either terminal, the decade resistor becomes a three-terminal circuit as shown in Figure 3-4.

In Figure 3-4:

R =setting of the decade box

$L = L_o + N_1 \Delta L_1, + N_2 \Delta L_2 + \ldots\ldots$

4.4.2 CABINET REMOVAL.

The cabinet is easily removed to gain access to the interior of the instrument: place the cabinet on a flat surface with the rear panel facing upward, remove the three 10-32 screws and lockwashers from the rear panel (c, Figure 2-4), and slide the cabinet up and directly away from the front panel.

To reassemble the unit, place the instrument on a flat surface with its front panel facing down, slide the cabinet into place, and reinstall the three 10-32 screws and lockwashers in the rear panel.

4.4.3 PARTS REPLACEMENT.

Refer to the parts list and Figures 4-1 and 4-2 for 510 ● Decade Resistance Units and other parts that may require replacement.

KNOB REMOVAL. To remove a knob and dial assembly:

a. Set the decade to the X position.

b. Grasp the knob firmly with the fingers and pull it straight away from the panel.

CAUTION

To avoid damage to the knob and dial assembly, do not pry the knob loose with a screwdriver or similar flat tool, and do not attempt to twist the knob from the shaft.

c. Release the No. 3-32 set screw in the dial-assembly hub and pull the assembly from the shaft.

● KNOB INSTALLATION. To install a knob and dial assembly:

a. Mount the dial assembly in the correct position on the shaft (see step a under KNOB REMOVAL).

b. Make certain the dial clears the panel and lock the No. 3-32 set screw.

NOTE

With the dial assembly properly installed, the end of the shaft should not protrude through the dial-assembly hub so that it interferes with proper seating of the knob.

c. Place the knob on the dial-assembly hub and push it in until it snaps into the groove.

PARTS LIST

REF. NO.	DESCRIPTION	PART NO.
J101	JACK, Binding post assembly	4060-0108
J102	JACK, Binding post assembly	4060-0108
J103	JACK, Binding post assembly	0938-2022
S101 thru S107*	DECADE ASSEMBLY, 510-AA, 0.01Ω/step	0510-4001
	DECADE ASSEMBLY, 510-A, 0.1Ω/step	0510-4002
	DECADE ASSEMBLY, 510-B, 1Ω/step	0510-4003
	DECADE ASSEMBLY, 510-C, 10Ω/step	0510-4004
	DECADE ASSEMBLY, 510-D, 100Ω/step	0510-4005
	DECADE ASSEMBLY, 510-E, 1 kΩ/step	0510-4006
	DECADE ASSEMBLY, 510-F, 10 kΩ/step	0510-4007
	DECADE ASSEMBLY, 510-G, 100 kΩ/step	0510-4008
	DECADE ASSEMBLY, 510-H, 1 MΩ/step	0510-4009
Mechanical Replacement Parts:		
	KNOB ASSEMBLY	5500-5420
	DIAL ASSEMBLY	5120-2033*
	DIAL ASSEMBLY	5120-2040*
	DIAL ASSEMBLY	5120-2041*
	CONNECTING WIRE LINK, Ground strap	5080-4802

*See Figures 4-1 and 4-2

Note: There are no Federal Stock Numbers for these parts.

Table 4-1
Resistance Per Decade — All 1433 Models
(Refer to Figures 4-1 and 4-2)

TYPE	S101	S102	S103	S104	S105	S106	S107
1433-U	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX	0.1Ω STEPS 1.6A MAX	.01Ω STEPS 4A MAX			
1433-K	100Ω STEPS 80mA MAX	10Ω STEPS 250 mA MAX	1Ω STEPS 80C nA MAX	0.1Ω STEPS 1.6A MAX			
1433-J	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX			
1433-L	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX			
1433-Q	100KΩ STEPS 2.3mA MAX	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	S105		
1433-T	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX	0.1Ω STEPS 1.6A MAX	.01Ω STEPS 4A MAX		
1433-N	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX	0.1Ω STEPS 1.6A MAX		
1433-M	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX		
1433-P	100KΩ STEPS 2.3mA MAX	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX		
1433-Y	1MΩ STEPS 0.7mA MAX	100KΩ STEPS 2.3mA MAX	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	S106	
1433-W	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX	0.1Ω STEPS 1.6A MAX	.01Ω STEPS 4A MAX	
1433-X	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX	0.1Ω STEPS 1.6A MAX	
1433-B	100KΩ STEPS 2.3mA MAX	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX	
1433-Z	1MΩ STEPS 0.7mA MAX	100KΩ STEPS 2.3mA MAX	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	S107
1433-F	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX	0.1Ω STEPS 1.6A MAX	.01Ω STEPS 4A MAX
1433-G	100KΩ STEPS 2.3mA MAX	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX	0.1Ω STEPS 1.6A MAX
1433-H	1MΩ STEPS 0.7mA MAX	100KΩ STEPS 2.3mA MAX	10KΩ STEPS 7mA MAX	1KΩ STEPS 23mA MAX	100Ω STEPS 80mA MAX	10Ω STEPS 250mA MAX	1Ω STEPS 800mA MAX