OPERATING INSTRUCTIONS

TYPES 1454-A, -AH

DECADE VOLTAGE DIVIDERS

GENERAL RADIO COMPANY

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GENERAL RADIO COMPANY

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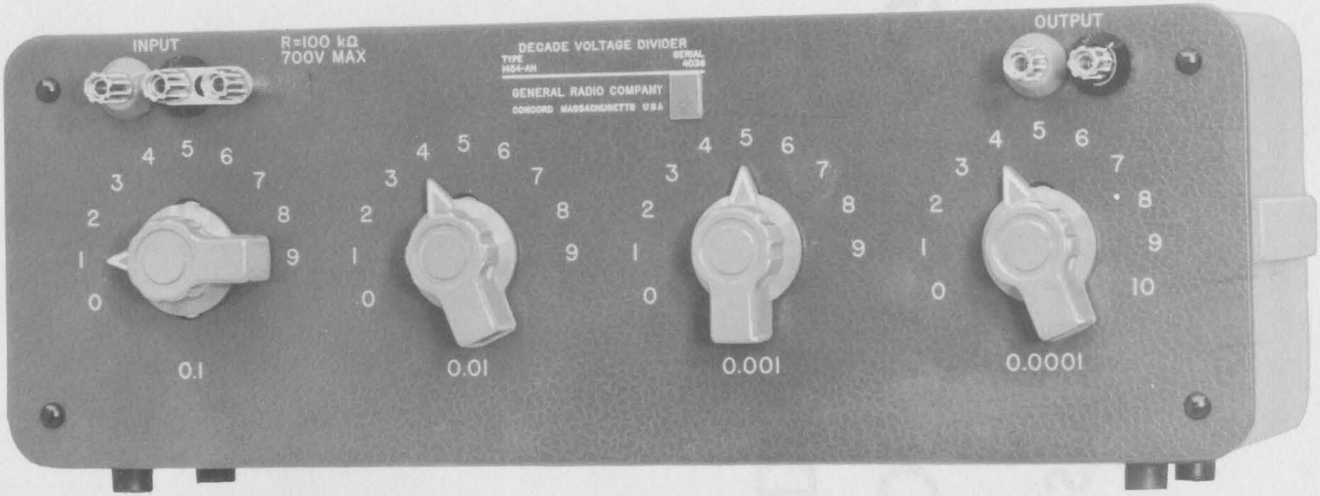


Figure 1. Type 1454 Decade Voltage Divider.

TYPES 1454-A AND 1454-AH

DECADE VOLTAGE DIVIDERS

1 INTRODUCTION.

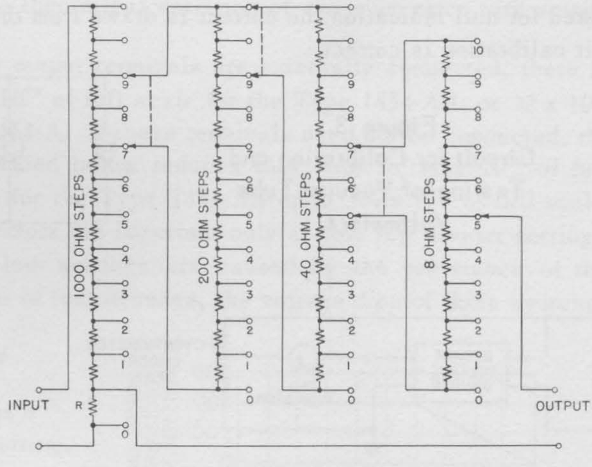
1.1 PURPOSE. The Type 1454-A Decade Voltage Divider (Figure 1) is a convenient means of obtaining accurately known voltage ratios. Among its many uses are the calibration of voltmeters, linearity measurements on continuously adjustable transformers and resistors, measurement of gain and attenuation, the precise measurement of frequency-response characteristics of audio-frequency networks, and the determination of turns ratios in transformers. At dc, its accuracy is adequate for many measurements for which the slide-wire potentiometer is commonly used, while its equally good ac performance extends its field of application to the entire audio-frequency range.

The Type 1454-AH Decade Voltage Divider is identical to the Type 1454-A except that all resistance values are increased by a factor of 10.

1.2 DESCRIPTION. The Decade Voltage Divider is housed in a 15¾ by 5¼ by 5-inch aluminum cabinet, with an aluminum front panel. Two pairs of insulated jack-top binding posts serve as input and output connectors. A separate grounded input-binding post with connecting link permits use of the divider in grounded as well as ungrounded circuits. Four selector switches are used to set the voltage ratio desired.

2 PRINCIPLES OF OPERATION. The Voltage Divider has a constant input resistance of 10,000 ohms (100,000 ohms for the AH model). The method of voltage division, which is attributed to Kelvin and Varley, is shown in the schematic diagram, Figure 2. Eleven equal resistors comprise the first (left)

Figure 2. Elementary Schematic Diagram.



decade. The next decade has resistors one-fifth the resistance of the first and bridges any pair of resistors in the first decade. Across the second decade is placed, therefore, one-tenth the potential of the input. Similarly, the third decade has units one-fifth the resistance of the second and is bridged across two resistors of the eleven in the second decade. The fourth decade is a conventional ten-step voltage divider.

On each decade, the position of the bridge contacts (and therefore of the voltage level, with respect to the negative terminal) can be varied. by a panel selector switch, between zero and full voltage.

3 OPERATING PROCEDURE.

3.1 GENERAL. Connect the voltage source to the two insulated INPUT terminals. If grounded operation is to be used, connect the ground link between the right-hand insulated INPUT terminal and the grounded terminal. Connect the device to be supplied from the divider to the OUTPUT terminals. Remember that the voltage divider, like any potentiometer, should be used only with very high resistance loads.

Set the four selector switches to indicate the desired voltage ratio. For instance, if the output voltage is to be 0.2373 times the input voltage, set the switches (from left to right) to 2, 3, 7, and 3, respectively.

3.2 TYPICAL USES.

3.2.1 CALIBRATION OF VACUUM-TUBE VOLTMETERS. The simple circuit of Figure 3 is useful for checking ac and dc vacuum-tube voltmeters. The standard meter shown is relied on only for a calibration value near its full-scale reading, where best accuracy is obtained.

3.2.2 LINEARITY CHECKS OF POTENTIOMETERS. A voltage comparison method is widely used for checking the linearity of wire-wound potentiometers. A simple diagram of the setup is shown in Figure 4. With the voltage divider adjusted for null indication, no current is drawn from the divider, and the open-circuit calibration is correct.

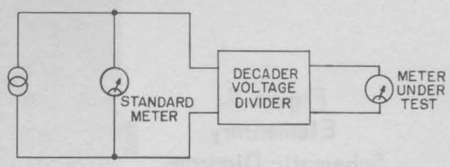


Figure 3.
Circuit for Calibration and Testing of Vacuum-Tube Voltmeters.

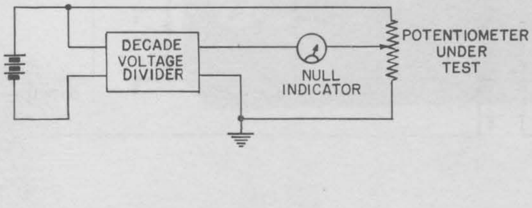


Figure 4.
Voltage Divider in Null Circuit for Linearity Tests.

The method of Figure 4 is equally useful at power and audio frequencies, although capacitive loading must be watched as a possible source of error. Even with the system balanced to a null, current is still drawn by the ground capacitance of the null detector. By the use of shielding (e.g., by a General Radio Type 578 Shielded Transformer), the location of the ground capacitance can be placed where it will be least harmful. In general, if the impedance of the device under test is greater than 2500 ohms (maximum output impedance of the voltage divider), the shielding should be arranged to place the ground capacitance across the divider output. On the other hand, if the impedance of the device under test is low compared with 2500 ohms, less error will be introduced if the capacitance is shunted across the output of the device.

3.3 UNGROUNDED MEASUREMENTS. Greatest immunity from the effects of stray capacitance, both external and within the divider, is obtained by ungrounded operation. This requires the use of shielded transformers at both input and null detector.

Generally speaking, at the important frequencies of 400 and 1000 cps, no difficulty should be encountered from stray capacitance if reasonable precautions are taken, and the accuracy of measurement can be taken as the dc accuracy.

4 ACCURACY.

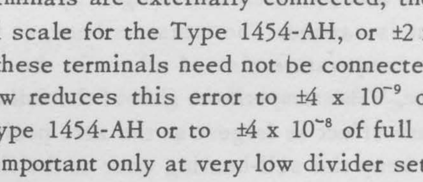
4.1 GENERAL. With the fixed precision resistors used in the voltage divider, extremely high accuracy of voltage division is obtained. Component resistors are selected to keep the maximum possible error to less than ±0.04%. Figure 5 shows the variation of this error vs decade setting.

In terms of full-scale setting, which is a common method of expressing instrument errors and voltage-divider errors, the linearity error is held to less than ±0.02% for any decade. The theoretical variation of maximum error with setting is shown in Figure 6.

If the low input and low output terminals are externally connected, there is an additional error of $\pm 2 \times 10^{-8}$ of full scale for the Type 1454-AH, or $\pm 2 \times 10^{-7}$ of full scale for the Type 1454-A. If these terminals need not be connected, the compensation scheme described below reduces this error to $\pm 4 \times 10^{-9}$ of full scale (which is negligible) for the Type 1454-AH or to $\pm 4 \times 10^{-8}$ of full scale for the Type 1454-A. These errors are important only at very low divider settings.

These small errors at low settings are caused by the resistance of the switches. In an arrangement of four decades, the voltage drop of three switches

Figure 5.
Maximum Error as a
Function of Scale Setting.



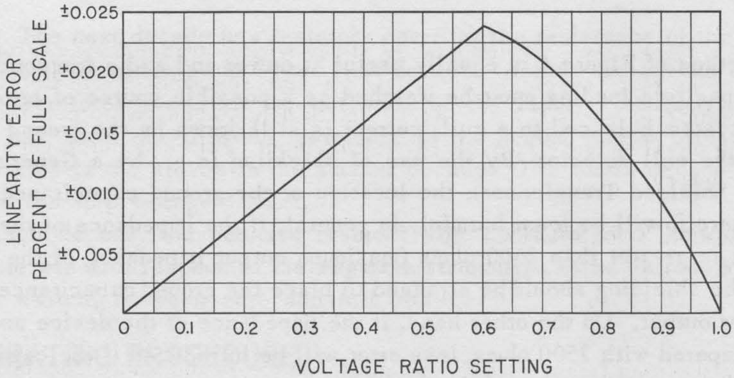


Figure 6. Maximum Linearity Error in Percent of Full-Scale Setting for any Decade.

in series would cause a residual output voltage at the zero setting. This switch-contact resistance is compensated for by the addition of a small resistor (R in Figure 2) at the low end of the first decade, between the low input and output terminals. The potential difference between these terminals is thus made equal to the switch contact drop. The balancing resistor, R, is very small (about 2 milliohms), and does not otherwise affect operation.

In order for the compensation resistor (R) to be effective, the switch contact resistance must be constant. For this reason, and to keep the resistance low, critical contact buttons use a silver overlay. In the unlikely event of surface contamination of these contact buttons, rotate the switches back and forth several times to wipe the contacts clean. (Rotate all the switches. The first switch contributes most to the error even when it is set to zero.)

4.2 EFFECTS OF TEMPERATURE. Since all resistors are of similar construction and have more or less equal temperature coefficients, the effects of changes in ambient temperature are very small. The effects from self-heating are not balanced out, however. In Figure 2, note that in the first decade between contacts 7 and 9, which are bridged by the second decade, only half of the input current is carried. The resistors between these points will have only one-quarter of the temperature rise of others in the decade, causing an error in the output voltage. The temperature rise of the following decades is negligible. The temperature effect is largest at the zero position of the first decade.

To keep the self-heating error at the first decade within specifications, limit the input voltage to the divider to 120 volts, instead of the normal 230 volts. With the Type 1454-AH Divider, limit the input voltage to 350 volts, instead of its normal 700 volts.

In dc measurements at very low levels, substantial error can result from thermal emf's at the junctions of dissimilar metals. The Type 1454 Voltage Dividers use low-thermal-emf binding posts to minimize these voltages when connections are made with copper wire.

At settings near zero, the inductance of the wiring introduces an error of the same nature as that previously described for zero resistance. The total output loop inductance is about 0.7 μh. At 10 kc, this produces an output voltage at zero setting equal to one microvolt per volt of input. This error increases directly with frequency.

4.3 FREQUENCY RESPONSE. The frequency response of the divider can be estimated from a knowledge of system parameters, checked by measurements at frequencies high enough to magnify any errors.

The resistors themselves have extremely low residual inductance and capacitance, and the significant factor in ac performance is the shunt capacitance of wiring and switch frames as it affects the first decade. The maximum error from this source occurs at half setting, where output resistance is 2500 ohms. If the external capacitance across the output terminal is less than 50 $\mu\mu$f, the frequency error is less than 0.1 percent up to 20 kc (2 kc for the Type 1454-AH) at any setting.

5 CALCULATION OF OUTPUT RESISTANCE.

The decimal voltage division is the ratio of the open-circuit output voltage to the voltage impressed on the INPUT terminals, and the voltage divider is intended primarily for use with high-impedance loads (e.g. in null circuits, where no current is drawn). For loads of finite impedance, it is necessary to know accurately the effective output impedance of the divider in order to calculate the actual voltage on the load, or at least to know the approximate output impedance in order to estimate the reduction in voltage.

To determine the output resistance of the voltage divider, let us first consider the output resistance of the simple divider system of Figure 7. The input is shown shorted because the input voltage is considered to be maintained and measured at the input of the voltage divider, a condition that connotes a zero-impedance generator. Here the output resistance is expressed thus:

$$R = a(1-a)R_o$$

where R = output resistance; a = incremental setting of divider; and R_o = input resistance.

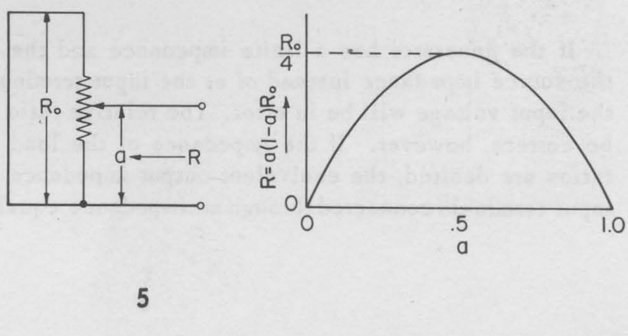


Figure 7. Output-Resistance Characteristic of a Simple Divider.

In the multiple-decade circuit of Figure 2, the output resistance is the sum of the output resistances of the individual decades. However, the voltage ratio of each decade (a) must be considered as the sum of its setting plus the settings of the succeeding decades. The input resistances (R_o) of the four decades are 10,000, 1000, 200, and 40 ohms, respectively (with the -AH Divider, these values are increased by a factor of 10). Thus, if the Type 1454-A Voltage Divider were set to 0.2373, the total output resistance, from the equation, would be:

$$\begin{aligned} & 0.2373\,(1-0.2373)\,10{,}000 \\ & +0.373\,(1-0.373)\,1000 \\ & +0.73\,(1-0.73)\,200 \\ & +0.3\,(1-0.3)\,40 \\ = {} & 1809.9 + 233.9 + 39.4 + 8.4 = 2091.6 \text{ ohms} \end{aligned}$$

If the degree of accuracy yielded by the above method of computation is not needed, Table 1 can be consulted for an approximate value of output resistance. Note that, because of the nature of the above calculation, interpolation is not possible. For Type 1454-AH Divider, multiply all values by a factor of 10.

TABLE I

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0	0	189	356	501	624	725	804	861	896	909
.1	900	1069	1216	1341	1444	1525	1584	1621	1636	1629
.2	1600	1749	1876	1981	2064	2125	2164	2181	2176	2149
.3	2100	2229	2336	2421	2484	2525	2544	2541	2516	2469
.4	2400	2509	2596	2661	2704	2725	2724	2701	2656	2589
.5	2500	2589	2656	2701	2724	2725	2704	2661	2596	2509
.6	2400	2469	2516	2541	2544	2525	2484	2421	2336	2229
.7	2100	2149	2176	2181	2164	2125	2064	1981	1876	1749
.8	1600	1629	1636	1621	1584	1525	1444	1341	1216	1069
.9	900	909	896	861	804	725	624	501	356	189

If the generator has a finite impedance and the voltage is measured behind the source impedance instead of at the input terminals, the ratio with respect to the input voltage will be in error. The relative ratio of two divider readings will be correct, however. If the impedance of the load is not infinite, and relative ratios are desired, the equivalent output impedance should be measured with the input terminals connected through an impedance equal to the generator impedance.

6 SERVICE AND MAINTENANCE.

6.1 GENERAL. The two-year warranty given with every General Radio instrument attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible.

In case of difficulties that cannot be eliminated by the use of these service instructions, please write or phone our Service Department, giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office (see back cover), requesting a Returned Material Tag. Use of this tag will insure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

SPECIFICATIONS

Voltage Ratio: 0.0001 to 1.0000 in steps of 0.0001.

Linearity: ±0.005% of full scale at dc and low audio frequencies for input voltages below one half of rating (see below).

Accuracy: ±0.04% of reading $\pm 4 \times 10^{-8}$ of full scale for input voltages below one half of rating (see below). With low terminals common, there is an additional $\pm 2 \times 10^{-7}$ of full scale error.

Frequency Characteristics: If the external capacitance placed across the output terminals of the Type 1454-A is less than 50 $\mu\mu f$, the frequency error is less than 0.1% to 20 kc for any setting. For the Type 1454-AH, the frequency limit is 2 kc for the same capacitance.

Input Resistance: Type 1454-A, 10,000 ohms. Type 1454-AH, 100,000 ohms.

Output Resistance: Varies with output setting, depending primarily on the setting of the highest decade in use. Refer to paragraph 5.

Maximum Input Voltage: 230 volts rms (or dc) for 40° C rise of resistors of the input decade. Input voltage should be limited to 120 for maximum accuracy. At maximum rated voltage the total error can approach ±0.1%. For Type 1454-AH, 700 volts rms, limited to 350 volts for maximum accuracy.

Resistance Units: Type 510 Decade Resistors.

Temperature Coefficient: Of each resistor, less than ±0.002% per degree C. Since the voltage ratios are determined by resistors of similar construction, ambient temperature effects are very small.

Terminals: Low-thermal-emf jack-top binding posts with standard ¾-inch spacing at input and output. A separate ground post is provided, so that the divider circuit can be used grounded or ungrounded, with the shield grounded.

Mounting: Aluminum panel and cabinet, finished in gray lacquer.

Dimension: Width 15¾ in., depth 5½ in., height 5 in. (400 by 135 by 130 mm) over-all.

Net Weight: 7¼ lb. (3.3 kg).

General Radio EXPERIMENTER reference: Volume 33 No. 7, July, 1959.

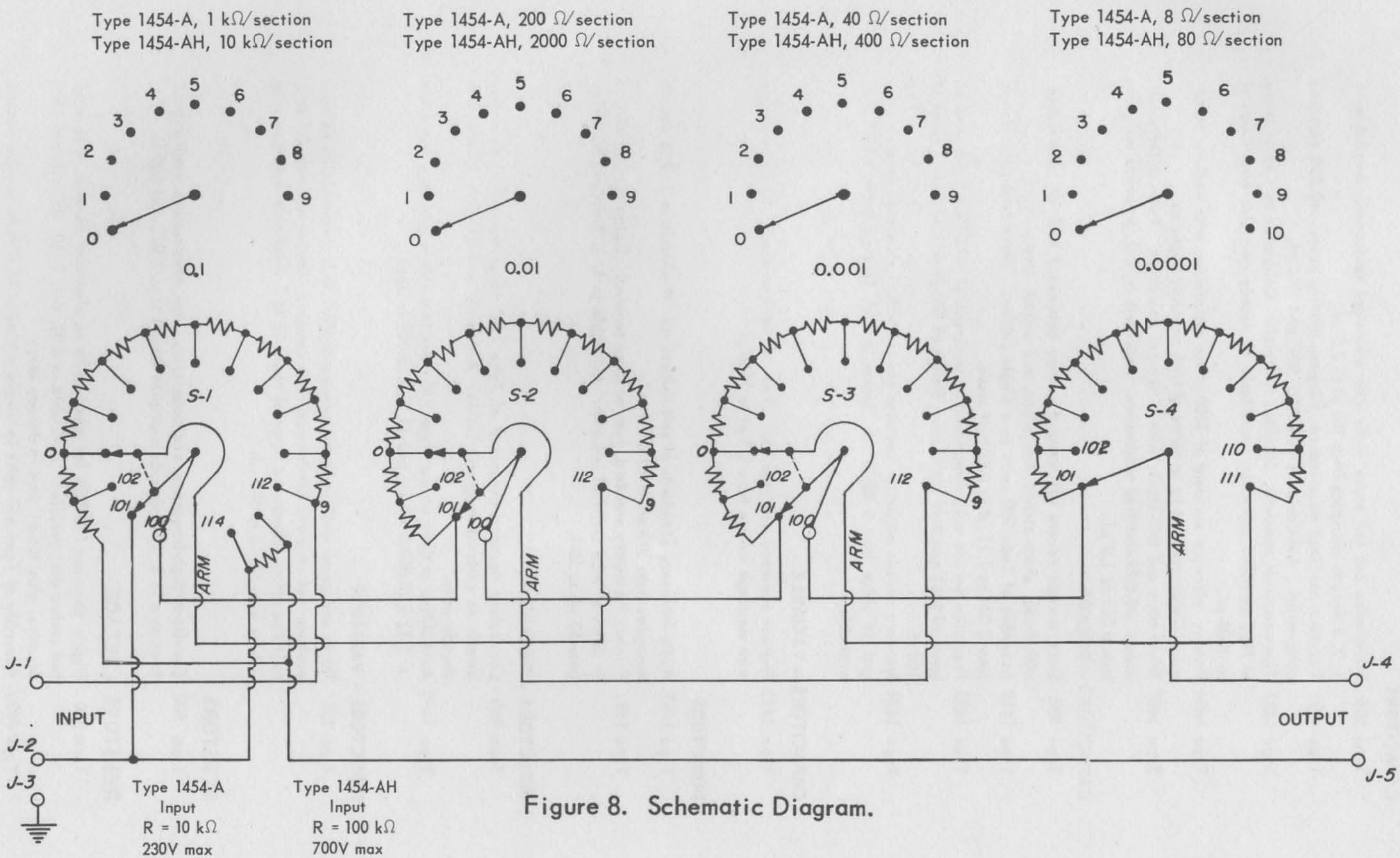


Figure 8. Schematic Diagram.

GENERAL RADIO STANDARDS

(Refer to latest General Radio Catalog for details.)

CAPACITORS

Type 505	Silver-mica and foil stack units with silica-gel desiccant. Available in 1, 2, 5 decade multiples from 100 pf to 0.5 μf.
Type 1401	Two-terminal fixed air standard. Plug-top binding posts. ±0.03% certified calibration. Available in 100, 200, 500, and 1000 pf.
Type 1403	Three-terminal standard. Shielded terminals. Calibrated at 1 kc in terms of NBS certified capacitor. Available in decade multiples from 0.001 pf to 1000 pf.
Type 1404	Primary reference standard of 1000 pf for comparison with working standards. Calibrated at 1 kc in terms of NBS certified capacitor.
Type 1409	Silver-mica and foil-stack, with silica-gel desiccant. Two- or three-terminal. ±0.03% certified calibration. Available in 1, 2, 5 decade multiples from 0.001 to 1.0 μf.

CAPACITORS – DECADE

Type 980	Each decade covers all integral values between 1 and 10. Furnished with knob, photo-etched dial plate, and switch stops.
Type 1419	Assembly of Type 980 units in a single cabinet. Three terminal. Range from 0.001 to 1.11 μf in 0.001-μf steps.
Type 1423	Precision decade with direct-reading accuracy of ±0.05%. Calibrated in terms of NBS certified standards. Range of 100 pf to 1.111 μf in steps of 100 pf.
Type 1424	Standard decade capacitor contains ten individual standards at each integral μf value from 0 to 10 μf. Lower priced, less accurate model also available.

CAPACITORS – VARIABLE

Type 1422	Highest accuracy and stability. Two- or three-terminal. Units available with maximum values from 1.1 pf to 1150 pf.

INDUCTORS

Type 1481	Audio-frequency standards of self-inductance. Available in 1, 2, 5 decade multiples from 100 mh to 10 h.
Type 1482	Primary laboratory standard, two- or three-terminal. Calibrated at 100 cps in terms of NBS certified inductor. Available in 1, 2, 5 decade multiples from 50 μh to 10 h.

INDUCTORS – DECADE

Type 940	Convenient decades comprised of Type 1481 Inductors. Toroids nearly astatic to external magnetic fields. Available in 0.01, 0.1, 1, and 10 h decade units.
Type 1490	Assemblies of three or four Type 940 units in a single cabinet. Available in 1.11 h (0.001-h steps) and 11.11 h (0.001-h steps).

INDUCTORS – VARIABLE

Type 107	Rotor and stator coils mounted concentrically. Inductance varied as rotor position and coupling between coils is changed. Series and parallel connections afford inductance range of about 25 to 1. Available with maximum values from 50 μh to 500 mh.

RESISTORS

Type 500	Excellent high-frequency characteristics, low temperature coefficient. Available in 1, 2, 5 decade multiples from 1 Ω to 1 MΩ, and 600 Ω.

RESISTORS – DECADE

Type 510	Highly accurate (±0.05% for most) units in aluminum shields, with knob and etched dial supplied. Available in 0.01, 0.1, 1, 10, 100 kΩ, and 1 MΩ decades, plus 100-kΩ unit in decade steps.
Type 1432	Assembly of Type 510 units in single cabinet. Available in many ranges from 111 Ω to 1.1111 MΩ total resistance and 0.1 to 1000 Ω steps.
Type 1450	Attenuation range 110 or 111 db in steps of 1 or 0.1 db respectively. 600-Ω terminal impedance, up to 1 watt input power.