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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

THE NEW TYPE 1432 DECADE RESISTORS

Also IN THIS ISSUE

● **THE PRECISION DECADE RESISTOR** is as useful and as necessary in the electrical measurement laboratory of today as is the wrench or the screwdriver on the mechanic's bench. Such everyday items reach, over the years, a certain stability of design not enjoyed by their more glamorous cousins in new and rapidly moving fields. But even monkey wrenches are redesigned and improved as new materials and processes become available.

This spring the old familiar Type 602 Decade Resistor appears in new packaging and under a new type number. Although the new cabinet is the most visible feature, far more important are the increased accuracy and stability. The basic accuracy of the resistance units is now ±.05%, better by a factor of two than that of their predecessors. Such a change is not accomplished overnight — in anticipation of this move, about 90% of GR precision resistors have been within the new tolerances for the past several years, and a large percentage of the last production runs of the Type 602 met the accuracy specifications of the Type 1432.

A Type 1432 Decade Resistor consists of a combination of Type 510

Figure 1. View of a Type 1432-A Decade Resistor. Inset at lower left shows Type 510-D Decade-Resistance Unit.

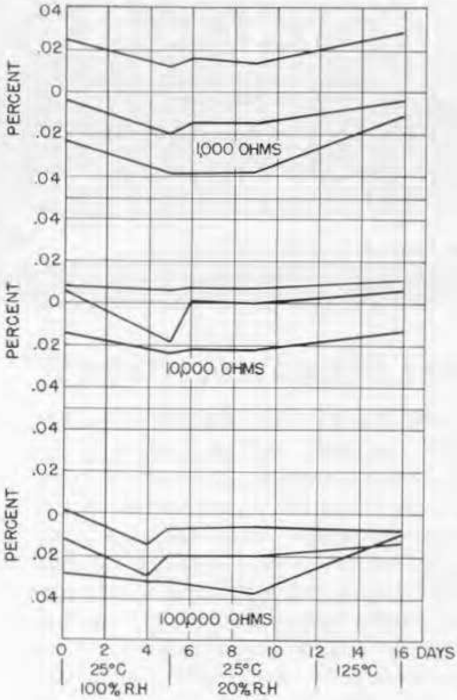


Figure 2. Measured deviations of typical resistance cards when subjected to extreme conditions of temperature and humidity. Long-term tests show a similar degree of stability.

Decade Resistance Units mounted on an aluminum panel and encased in a welded aluminum cabinet. Ample mechanical strength is assured by the use of 3/16-inch panel and 1/8-inch walls. A considerable reduction in volume is realized — 1/8-inch aluminum replacing 5/8-inch hardwood reduces both width and length by a full inch. Excellent electrostatic shielding and good thermal characteristics are also assured by this construction. A separate binding post for connection to the case is provided, thus permitting shielding of the resistors whether used grounded or ungrounded. Other time-proved features, such as engraving the current carrying capacity of each decade on the panel, are included.

Whether sold separately or assembled into "resistance boxes," the Type 510 Decade Units carry the new accuracy specifications, which, in the following table, are compared to the old.

Type	*Resistance per Step*	*Percent Tolerance New*	*Percent Tolerance Old*
510-A	.1 Ω	±0.5	±1.0
510-B	1. Ω	±0.15	±0.25
510-C	10. Ω	±0.05	±0.10
510-D	100. Ω	±0.05	±0.10
510-E	1000. Ω	±0.05	±0.10
510-F	10. kΩ	±0.05	±0.10
510-G	100. kΩ	±0.05	±0.10

Mere accuracy of adjustment, however, is not sufficient in a laboratory resistor. The stability of resistance value is equally important, if not more so. The resistor units used in General Radio Decades have a stability considerably better than the accuracy of adjustment and can be expected to stay within their specified tolerances well beyond the one-year warranty period.

Both the improved accuracy and greater stability result largely from the use of new resistance alloys made available during the past decade. These improved alloys have a low temperature coefficient that is substantially constant over a wide range of operating temperature, a high specific resistivity low thermal emf to copper, and a remarkable insensitivity to changes in resistance induced by mechanical strain. Furthermore, fine wire drawn of these alloys is much less susceptible to deterioration under conditions of high humidity than are the older alloys.

The new alloys are used in the 100 Ω, 1 kΩ, 10 kΩ, and 100 kΩ units. Manganin is still used in the lower-resistance units, where wire diameter is larger and atmospheric conditions are not so significant in determining long-time stability.

Figure 2 shows the performance of groups of 1 kΩ, 10 kΩ, and 100 kΩ cards

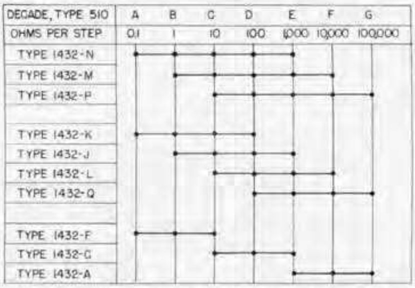


Figure 3. Chart showing the ranges of Type 1432 Decade Resistors currently available.

recently taken at random from production stock and subjected to temperature and humidity cycling. The excellent performance on these accelerated short-term tests has been duplicated by long-term tests over a period of years. Groups of these resistance units, used as working standards in our shops and laboratories, have shown a stability of better than 0.01% under constant usage over a period of years.

The 100,000-ohm unit is a new design, replacing the spool-wound resistors formerly employed for this resistance value. The winding form is a thin mica card of the type employed successfully for over twenty years in 1000-ohm and 10,000-ohm units. The high-resistivity alloy, in a wire having a diameter of one-thousandth of an inch, allows the desired resistance to be wound on a form of substantially the same size as used for lower-resistance units. These new 100,000 ohm cards result not only in improved performance but also in a reduction in the price of the Type 510-G Decade Resistance Unit, which uses ten of these cards.

The Type 1432 Decade Resistor is offered in three-, four-, and five-decade boxes in a total of ten different combinations. Included in these are four boxes containing the one-megohm decade, Type 510-G. With seven decades having increments per step ranging from 0.1 ohm to 100 kΩ, there are three possible 5-dial combinations, four possible 4-dial combinations, and five possible 3-dial combinations. Figure 3 indicates, by type number, the combinations available. The suffix letter formerly used is retained—thus Type 602-J is replaced by Type 1432-J.

—Ivan G. Easton

SPECIFICATIONS

Frequency Characteristics: Identical with those of the previous design, Type 602. A discussion of the frequency characteristics of these resistors will be found in the *Experimenter* for December, 1940, under the title "Radio Frequency Characteristics of Decade Resistors."

Residual Impedances:

Zero Resistance (R_0): 0.002 to 0.003 ohm per dial at dc; 0.04 ohm per dial at 1 Mc; proportional to square root of frequency at all frequencies above 100 kc.

Zero Inductance (L_0): 0.10 μh per dial.

Effective Shunt Capacitance (C): This value is determined largely by the highest decade in use. With the low terminal connected to shield, a value of 15 to 10 μμf 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 μμf. If the highest decade in the assembly is in use, the effective capacitance is 15 to 10 μμf, regardless of the settings of the lower-resistance decades.

Temperature Coefficient of Resistance: Less than ±0.002% per degree Centigrade at room temperatures, except for the 0.1 Ω decade, where the box wiring will increase the over-all temperature coefficient.

Accuracy of Adjustment: All cards are adjusted within ±0.05% of the stated value between card terminals, except the 1-ohm cards which are adjusted within ±0.15% and the 0.1-ohm units which are adjusted within ±0.5%.

Maximum Current: Same as for previous models, Type 602. Values for 40° Centigrade rise are engraved on panels directly above switch knobs.

Terminals: Jack-top binding posts set on General Radio standard ¾-inch spacing. Shield terminal is provided.

Mounting: Aluminum panel and cabinet.

Dimensions: Width, 4$\frac{5}{16}$ inches; height, 4$\frac{11}{16}$ inches; length, 10$\frac{5}{16}$ inches for 3-dial, 13 inches for 4-dial, and 15$\frac{3}{4}$ inches for 5-dial box.

Net Weight: TYPE 1432-A, C, F, 4 pounds, 2 ounces; TYPE 1432-J, K, L, Q, 5 pounds, 2 ounces; TYPE 1432-M, N, P, 6 pounds, 5 ounces.

Type	*Resistance*	*No. of Dials*	*Type 510 Decades Used*	*Code Word*	*Price*
1432-F	111 ohms total, in steps of 0.1 ohm	3	A, B, C	DELTA	$ 56.00
1432-K	1,111 ohms total, in steps of 0.1 ohm	4	A, B, C, D	DEFER	75.00
1432-C	11,100 ohms total, in steps of 10 ohms	3	C, D, E	DEBAR	65.00
1432-J	11,110 ohms total, in steps of 1 ohm	4	B, C, D, E	DEBIT	83.00
1432-N	11,111 ohms total, in steps of 0.1 ohm	5	A, B, C, D, E	DEMON	99.00
1432-L	111,100 ohms total, in steps of 10 ohms	4	C, D, E, F	DECAY	87.00
1432-M	111,110 ohms total, in steps of 1 ohm	5	B, C, D, E, F	DEMIT	107.00
1432-A	1,110,000 ohms total, in steps of 1000 ohms	3	E, F, G	DEMUR	96.00
1432-Q	1,111,000 ohms total, in steps of 100 ohms	4	D, E, F, G	DEPOT	113.00
1432-P	1,111,100 ohms total, in steps of 10 ohms	5	C, D, E, F, G	DETER	133.00

TYPE 510 DECADE-RESISTANCE UNIT

For building into the equipment, the individual resistance decades used in the TYPE 1432 Decade Resistors are available as the TYPE 510 Decade Resistance Units.

Accuracy specifications are given in the table on page 2. Other specifications remain unchanged from previous models. Units are supplied complete with dial plate, knob, and drilling template. See also photograph on page 1.

Type	*Resistance*		*Code Word*	*Price*
	Total	*Per Step*		
510-A	1 ohm	0.1 ohm	ELATE	$12.00
510-B	10 ohms	1 ohm	ELDER	14.00
510-C	100 ohms	10 ohms	ELEGY	14.00
510-D	1,000 ohms	100 ohms	ELBOW	16.50
510-E	10,000 ohms	1,000 ohms	ELECT	18.50
510-F	100,000 ohms	10,000 ohms	ELVAN	21.50
510-G	1,000,000 ohms	100,000 ohms	ENTER	40.00

A MULTIRANGE FILTER FOR AUDIO AND ULTRASONIC AMPLIFIERS

The TYPE 1231-B Amplifier and Null Detector has proved a useful instrument for balancing impedance bridges at audio and ultrasonic frequencies up to about 100 kc. In order to eliminate harmonics and minimize background noise, amplifier selectivity, even at the expense of some insertion loss, is almost universally desirable. Antiresonant *L-C* filters, tuned for 60 cycles (TYPE 1231-P2) and for either 400 cycles or 1 kc (TYPE 1231-P3), have been available to convert the TYPE 1231-B into a tuned amplifier at these specific frequencies.

The new TYPE 1231-P5 Filter extends the frequency range and provides tuning at eleven discrete frequencies at which impedance measurements are frequently made, namely, 50, 100, 200, and 500 cycles and 1, 2, 5, 10, 20, 50, and 100 kc. This filter is particularly useful in dielectric measurements with the TYPE

716-C Capacitance Bridge, since it provides fixed tuning at 0.1, 1, 10, and 100 kc for which the bridge is direct reading. By the addition of external capacitance, this filter can also be tuned to any other frequency within the range from 20 cycles to 100 kc.

While designed primarily to plug into the TYPE 1231-B Amplifier, the TYPE 1231-P5 Filter can also be used as an antiresonant *L-C* element in the grid circuit of *any* low-level Class A amplifier where it is not subjected to a d-c current. The resulting selectivity and insertion loss will then be a function of frequency and the parameters of the amplifier circuit.

High selectivity over such an extended frequency range, combined with reasonable insertion loss, necessitates the use of four separate inductors: *L*-1 (20 henrys) for 50 and 100 cycles, *L*-2 (2 henrys) for 200 and 500 cycles, *L*-3 (300 millihenrys) for 1, 2, and 5 kc, and *L*-4 (15 millihenrys) for 10, 20, 50, and 100 kc. Each inductor is a symmetrically wound toroid and is distinctly more astatic than the shell-type inductors used in the older TYPES 1231-P2 and -P3 Filters. Low-loss polystyrene or mica capacitors are used throughout.

The *L*-3 and *L*-4 inductors utilize molybdenum-permalloy dust cores having effective permeabilities of 125 (*L*-3) and 26 (*L*-4). These have negligible temperature and voltage coefficients of inductance and are ideal for the purpose. The *L*-4 inductor is wound with Litzendraht to minimize eddy current copper losses at the high frequencies used.

To achieve the desirable high *Q* at 500 cycles and below, a "solid" core is required. Accordingly, the *L*-1 and *L*-2 inductors are wound on "centricores" fabricated by spiral-winding thin tape on a mandrel with appropriate insulation and subsequent annealing. A ferromagnetic alloy having a small voltage coefficient of inductance is used.

Figure 1. Panel view of the Type 1231-P5M Filter.

The filter elements and selector switch are enclosed in an aluminum chassis which, in turn, is mounted in an aluminum cabinet having an external black crackle finish and rubber feet. Good electrostatic as well as electromagnetic shielding is thereby provided. A shielded cord terminated with a standard telephone-type plug permits the selected filter circuit to be introduced into the grid circuit of the last stage of the TYPE 1231-B Amplifier. The filter circuits have a common terminal which is grounded to the chassis. Both terminals of the filter are available on the front panel for attaching external capacitors if desired.

The sixteen-position selector switch has an off position (giving an aperiodic amplifier), eleven positions providing, directly, the aforementioned discrete frequency values, and four positions which individually connect the four inductors across the filter terminals with only a small amount of internal capacitance.

An antiresonant filter network must be designed as a compromise between a tolerable insertion loss and a desirable discrimination against, say, the second harmonic of the operating frequency. Typical data obtained with the four inductors, precisely tuned and inserted into the TYPE 1231-B Amplifier, are shown in Figures 2 and 3. The dots indicate the eleven discrete frequency values. These data were taken at low level when the open-circuit output voltage of the amplifier was 0.2 volt. As the operating level is raised, hysteresis core loss necessarily increases the insertion loss at a given frequency and decreases the discrimination. From these data one can choose which inductor to tune for any desired operating frequency.

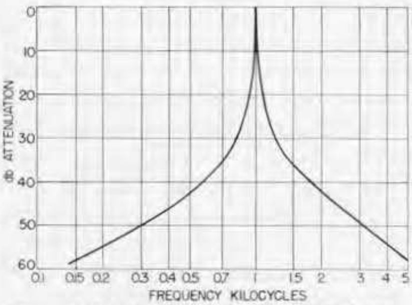


Figure 4. Selectivity curve for the 1-kc filter and Type 1231-B Amplifier. Values of second harmonic discrimination for the other filters are given in Table I, below.

Typical low-level characteristics of the TYPE 1231-P5 Filter, when used with the TYPE 1231-B Amplifier and Null Detector, are given in Table I which lists the resonant impedance in megohms, the resonant Q, the insertion loss (or gain) in db, and the selectivity, i.e., the discrimination in db against the second harmonic.

TABLE I

Frequency	*Inductor Used*	*Resonant* Z MΩ	*Resonant Q*	*Insertion db*	*Discrimination vs. 2nd Harmonic db*
50 c	*L*-1	0.28	45	6.4 loss	33
100 c	*L*-1	1.02	81	2.7 loss	31
200 c	*L*-2	0.21	84	7.3 loss	40
500 c	*L*-2	0.52	83	4.2 loss	35
1 kc	*L*-3	0.26	138	7.8 loss	42
2 kc	*L*-3	0.86	228	3.0 loss	40
5 kc	*L*-3	2.70	287	1.9 gain	34
10 kc	*L*-4	0.17	175	3.8 loss	46
20 kc	*L*-4	0.50	262	2.2 gain	44
50 kc	*L*-4	1.06	214	5.6 gain	37
100 kc	*L*-4	2.13	192	7.4 gain	28

Figure 2. Low-level insertion loss versus resonant frequency for each of the four inductors.

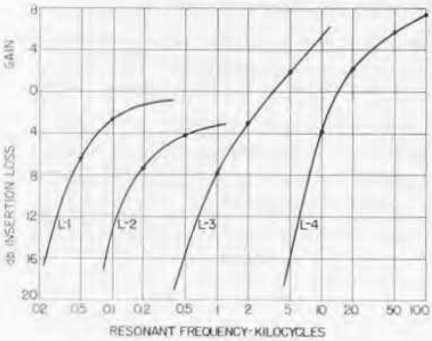
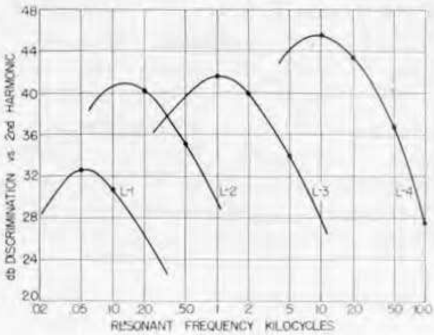


Figure 3. Low-level second harmonic discrimination versus resonant frequency for each of the four inductors.



As seen from Figures 2 and 3, a higher discrimination, at the expense of increased insertion loss, can be obtained at 100 cycles, 500 cycles, and 5 kc by tuning the *L*-2, *L*-3, and *L*-4 inductors with appropriate external capacitance. Plotted on a logarithmic scale, Figure 4, the selectivity curves (attenuation vs. frequency) are roughly symmetrical except as modified by the transmission curve of the amplifier.

The filter elements are calibrated with sufficient precision so that resonant peaks occur within ±2% of each of the eleven nominal frequency values. Within these limits, which are ordinarily close enough for the majority of bridge measurements, this filter may be used to set an adjustable non-calibrated or crudely calibrated oscillator at the desired operating frequency. On the other hand, it must be remembered that, without external capacitance, these eleven *L-C* circuits are highly resonant fixed-frequency filters, so that the operating frequency must be close to the nominal value if a minimum insertion loss (i.e., maximum amplifier gain) is to be realized.

The filter circuits are calibrated at normal room temperature and at close to zero level, which is the pertinent consideration for use as a resonant filter in a null detector. Unavoidably, the centricore inductors *L*-1 and *L*-2 (50, 100, 200, and 500 cycle filters) have noticeable positive temperature and voltage coefficients of inductance. The corresponding negative temperative coefficient of frequency is about 0.08% per degree Centigrade. The voltage coefficient, which is due to the increase of normal permeability with induction, reduces the resonant frequency by about 6% per volt impressed on the filter at 50 cycles and proportionately less at higher frequencies. These coefficients are ordinarily negligible in the dust-core inductors *L*-3 and *L*-4.

Figure 5. View of the Type 1231-P5R Filter arranged for relay-rack mounting with the Type 1231-B Amplifier and Null Detector. The filter panel attaches to the amplifier panel to make the assembly the correct width for mounting in a 19-inch relay rack. The narrow strip between the two panels carries a switch for the a-c power supply that is optional with the amplifier.

CAUTION: This Type 1231-P5 Filter should at no time be subjected to any d-c current. The very appreciable magnetic memory possessed by the centricore inductors would result in a residual magnetization. It would then be difficult to remove this and to restore the initial permeability at which these inductors were calibrated. A definite, more-or-less permanent, offset of the resonant frequencies from their nominal values would thereby occur. When used with the Type 1231-B Amplifier and Null Detector, the inductors do not carry any d-c current.

— Horatio W. Lamson

SPECIFICATIONS

Nominal Operating Frequencies: 50, 100, 200, 500 cycles; 1, 2, 5, 10, 20, 50, 100 kc.

Frequency Calibration: Within ±2%.

Insertion Loss: Between 6-db loss and 6-db gain, depending upon frequency.

Selectivity: Better than 30 db against the second harmonic.

Terminals: Shielded cord and plug for connection to TYPE 1231 Amplifier and Null Detector. Jack top terminals for connecting external capacitors.

Mounting: Aluminum cabinet for bench use. Also available for relay rack mounting in conjunction with TYPE 1231-B Amplifier and Null Detector. See price list below.

Dimensions: Front panel, (height) 7″ x (width) 6⅛″. Cabinet, (depth) 9¾″. Internal shield box, (height) 6¼″ x (width) 4½″ x (depth) 9″.

Net Weight: Complete 9 lb. 12 oz.

Type		*Code Word*	*Price*
1231-P5M	**Adjustable Filter (cabinet model)**	ALDER	**$215.00**
1231-P5R	**Adjustable Filter (relay-rack model)**	ADOBE	**215.00**

MISCELLANY

SPEAKERS — Harold B. Richmond, Chairman of the Board, General Radio Company, was the principal banquet speaker at the National Conference on Airborne Electronics sponsored by the Dayton Section, I.R.E., at Dayton, Ohio, May 23-25. His subject — "Diplomacy and the Changing Radio Relationships Between the United States and Europe."

Also at the Airborne Electronics Conference, Robert A. Soderman and W. M. Hague, Jr., of General Radio's Engineering Department presented a paper entitled, "Measurements to 2000 MC, with the V-H-F Admittance Meter."

HUMIDITY — Each year with the coming of warmer, more humid weather in the northern hemisphere, we remind our readers that high relative humidity sometimes has baffling and annoying effects on electrical measurements. A reprint from the *Experimenter*, entitled "The Effect of Humidity on Electrical Measurements," is helpful in identifying these effects and in preventing them. Ask for a copy.

SUMMER CLOSING

VACATION — During the weeks of July 22 and July 29 most of our employees will be vacationing. Manufacturing departments will be manned by a skeleton staff. Every effort will be made to take care of urgent business, but repairs cannot be made, except in hardship cases. Our Service Department requests that shipments of material to be repaired be either scheduled to reach us well before this vacation period or delayed until afterward.

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