

THE GENERAL RADIO
EXPERIMENTER



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IN THIS ISSUE



Three New Capacitors



IET LABS, INC in the GenRad tradition
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THE GENERAL RADIO

EXPERIMENTER



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COVER



Calibrating Type 1423-A Precision Decade Capacitors in the General Radio Standardizing Laboratory using the Type 716-C Capacitance Bridge.



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A NEW 10-MICROFARAD CAPACITANCE STANDARD



Type 1424-A
Standard Polystyrene Decade Capacitor.

General Radio fixed capacitance standards are available from stock, in relative magnitudes of 1-2-5, from 0.01 pf to 1 μ f. TYPE 1401 and TYPE 1403 Air-Dielectric Models cover the range from 0.01 pf to 1000 pf, while the TYPE 1409, with silvered-mica dielectric, is available in values from 1000 pf to 1 μ f. There has for some time been a demand for capacitance standards having values well above 1 μ f. Carrying the silvered-mica standards above 1 μ f, however, is not very practical, since the resulting capacitor would be heavy, bulky, and very expensive. For these higher capacitance values, polystyrene dielectric offers many advantages.

Since a large polystyrene capacitor must for production reasons be built up of many smaller capacitors paralleled, it is very little extra trouble to switch the capacitors in one by one instead of connecting them all solidly together. In the new TYPE 1424-A Standard Polystyrene Decade Capacitor, ten 1- μ f

capacitors are switched in this manner to provide not one but ten standards, one at each integral microfarad from 1 to 10. Each of the 1- μ f capacitors is accurate to 0.25%. When all ten of these have been switched in parallel to make a 10- μ f unit, the laws of probability will make the majority of units as close as 0.1% to the nominal 10 microfarads.

Residual Impedances

The most important problems in the design are not so much those of packaging as of minimizing the unwanted residual impedances. Inductance must be minimized to keep the natural frequency of the shorted capacitor low, in order that the capacitor may be used with accuracy over a broad frequency range. If the capacitor is used at 1/20 of its natural frequency, the frequency error will be 0.25%, equal to the adjustment accuracy of the unit. To appreciate the importance of resistance, consider that the reactance of 10 microfarads at 10 kc is 1.6 ohms. Since the dissipation factor of good polystyrene capacitors rarely exceeds 0.0001, a series resistance of 0.16 milliohm would double the dissipation factor. Naturally it is desirable that both L and R be kept so low that their effects will be small, compared to adjustment accuracy and to dissipation factor, respectively.

In this new polystyrene decade, the range of natural frequencies with the terminals shorted is from 525 kc at 1 μ f to 235 kc at 10 μ f, corresponding to a series-inductance range of 91 to 46 m μ h.



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The series resistance, R , difficult to measure directly, is low enough not to affect dissipation factor adversely at 1 ke. The desirable reductions of L and R have been accomplished by generous use of current-sheet conductors, ribbon leads, switch-terminal replication, etc. The residual series inductances will be found to be comparable to those of other GR fixed standard capacitors as well as to those of the air-dielectric precision capacitors, even though the TYPE 1424-A is much larger and the conducting leads consequently longer. The paralleling of paths that helps to reduce the inductance is still more effective in reducing the resistance.

Charge Storage

One of the most important considerations in any application involving dc is the large amount of stored energy. With all capacitors switched in (10 microfarads) and charged up to the rated 500 volts dc, the stored energy is 1.25 watt-seconds. This is not only a great deal of energy at a comparatively high voltage, but it will stay in the capacitor a long, long time, because the leakage resistance is of the order of 100,000 megohms, signifying a time constant of 10^6 seconds, or 12 days. Caution notices are prominently engraved in red on the panel, and the clockwise position of the switch discharges the capacitor through a 100-kilohm resistor. The switch should be kept at the DISCHARGE position except when the capacitor is actually in use. This will assure that a minimum of residual absorbed energy will remain in the capacitor. Should it, through oversight, be left elsewhere after discharge, the low dielectric absorption of polystyrene assures that the residual voltage later acquired, as the absorbed charge comes out of the dielectric, will be small

and not hazardous, although it will not be negligible in a dc storage application such as an analog computer.

Sudden charge or discharge is potentially damaging to the capacitor. In the DISCHARGE switch position, the discharge current is limited, with a nominal time constant of one second. Limitation of charging current is accomplished by the charging of each section through a series resistor of 1000 ohms, which is not in series with the capacitor at any detented switch position. This kind of switching is done through the agency of a second switch wafer which inserts the resistor between the sections already charged (if any) and the section about to be charged, during the time of traverse between switch positions. This resistor limits the peak current to 0.5 ampere at full rated voltage in a circuit having a time constant of 1 millisecond, which is fast enough to control charging current reliably, even with fast rotation of the switch.

Construction

The TYPE 1424-A Standard Polystyrene Decade Capacitor uses twenty $0.5\text{-}\mu\text{f}$ capacitors, paired to get ten $1\text{-}\mu\text{f}$ $\pm 0.25\%$ sections. These are housed in two solder-sealed brass cases with Teflon-insulated high terminals, the case being common. These two cases and the switch are mounted to a subpanel, which is itself insulated from the main panel. Thus the capacitor may be used in either a 2- or a 3-terminal connection, with no significant difference in capacitance values. A calibration chart is provided giving the actual capacitance at each of the ten switch positions. Dissipation factor typically is 0.0002, and insulation resistance 10^6 ohm-farads.

Much care was required in the design





of the instrument to keep series L and R at manageable levels. The excellence of the TYPE 1424-A in these respects can be fully exploited only if in application the

inductance and resistance of the connecting means employed by the user are as carefully controlled.

— P. K. McELROY

SPECIFICATIONS

Nominal Value: 0 to 10 microfarads, in steps of 1 microfarad.

Adjustment Accuracy: $\pm 0.25\%$ at 1 kc.

Certificate: A certificate is supplied giving measured values, obtained by comparison to a precision better than $\pm 0.01\%$ with working standards maintained to an accuracy of $\pm 0.03\%$ in terms of NBS-certified reference standards.

Stability: Change is less than $\pm 0.05\%$ per year.

Frequency: Calibrated at 1 kc. Variation with frequency down to 60 cps is typically less than $+0.02\%$. At higher frequencies, terminal capacitance rises as resonant frequency is approached (see curves). The increase can be

calculated from $\frac{\Delta C}{C} = \left(\frac{f}{f_r}\right)^2$. Typical values of f_r are given in the calibration certificate.

Voltage Recovery: Less than 0.1%, final, of

original charging voltage after a charging period of one hour and a 10-second discharge through a resistance equal to one ohm per volt of charging.

Dissipation Factor: Less than .0003 at 1 kc. (See curves for variation with frequency.)

Temperature Coefficient: Approximately -110 ppm per degree C.

Maximum Operating Temperature: 65 C.

Insulation Resistance: Approximately one million ohm-farads.

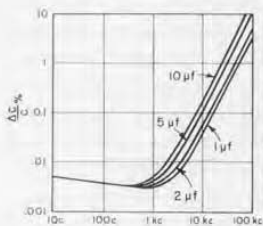
Maximum Voltage: 500 volts peak, up to 10 kc.

Mounting: Aluminum cabinet and panel, finished in gray.

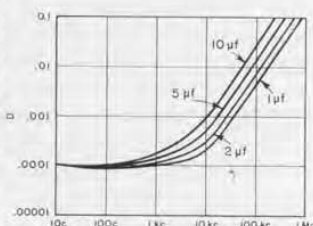
Terminals: A separate ground terminal is provided, permitting 2- or 3-terminal use.

Dimensions: Width 8, height $7\frac{3}{4}$, depth $9\frac{1}{2}$ inches (205 by 195 by 240 mm), over-all.

Net Weight: $16\frac{1}{2}$ pounds (7.5 kg).



Typical curves for Type 1424-A Capacitors. (left) Change in capacitance as a function of frequency. These changes are referred to the values which the capacitors would have if there were neither interfacial polarization nor series inductance. The 1-kc value on the plot should be used as a basis of reference in estimating frequency errors. (right) Dissipation factor as a function of frequency.



Type

1424-A

Standard Polystyrene Decade Capacitor

Code Word

BARN

Price

\$325.00

A NEW FOUR-DIAL PRECISION CAPACITOR

Fixed-value impedance standards are generally used for maximum accuracy and stability, while adjustable standards ordinarily provide convenience and flexibility at some sacrifice in stability and accuracy. The new TYPE 1423-A Precision Decade Capacitor, however, combines the high accuracy normally associated

only with fixed, reference-type standards with convenient decade construction, which makes available any desired value within the range of the capacitor. Four individual decade capacitors within the cabinet provide 11,110 discrete values of capacitance, each known to an accuracy of $\pm 0.05\%$. Any value of capacitance be-



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Type 1423-A Precision Decade Capacitor.

tween 100 pf and 1.111 μf in steps of 100 pf can be established quickly and easily by straightforward dial settings.

The new decade capacitor is packaged in a standard relay-rack-type cabinet with aluminum end frames for bench use. A new, in-line readout displays the selected value in large, bold numbers for maximum readability.

The decade switches and associated capacitors are mounted in an insulated metal compartment, which in turn is mounted in a complete metal cabinet. This double-shielded construction ensures that capacitance at the terminals is the same for either the three-terminal or the two-terminal method of connection (except for a difference of about one picofarad; see below).

The constituent capacitors are high-quality silvered-mica units, similar in design and construction to those used in the TYPE 1409 Standard Capacitors, but individually adjusted to values slightly below nominal. Precise final adjustment to nominal value is made by means of small "trimming" or "padding" capacitors within the instrument. On the two lowest decades (100 pf per step and 1000 pf per step), an air trimmer capacitor is provided for each of the 10 positions of the switch. Theoretically, then, each position can be adjusted precisely to nominal value. For the two higher decades (.01 μf per step and 0.1 μf per

step), individual point adjustment is neither practical nor necessary, since the variations in switch capacitance, which may be significant on the lower decades, is negligible here. Small fixed-value padding capacitors, individually selected, are used to adjust each of the four capacitors of each decade to the desired tolerance. The air trimmers are readily accessible for subsequent readjustment if necessary, and the terminals for the fixed padders are also accessible, although somewhat less readily. Thus this instrument is capable of readjustment, an important feature for those laboratories having facilities and reference standards accurate enough to detect shifts of value. Readjustment should rarely, if ever, be necessary, since many years' experience with such capacitors indicates a typical stability of better than $\pm 0.01\%$ per year.

The actual adjustment accuracy of the capacitor as shipped is limited only by the accuracy of our own working standards and measurement, and by the finite patience of the technician who makes the final adjustment. To allow for these factors and for any possible drift within the warranty period, the adjustment accuracy¹ is conservatively rated as $\pm 0.05\%$, which value is engraved on the panel.

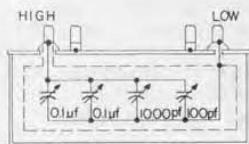
¹I. G. Easton, "Standards ± 1 Accuracy," *General Radio Experimenter*, 34, 6, June, 1950.





Terminal Arrangement

The terminals have been arranged to facilitate connection in a variety of ways. The HIGH and LOW terminals are widely separated on the panel so that ordinary unshielded leads may be used, provided the circuit to which the capacitor is connected will tolerate such a method of connection. A pair of grounded binding posts, each $\frac{3}{4}$ inch from an insulated binding post, allows use of cables terminated in TYPE 274 Double Plugs. Complete shielding of binding posts as well as of leads can be accomplished by the use of a TYPE 274-NK Shielded Plug Connector. A fifth binding post, connected to the panel, facilitates connection to external ground when the TYPE 274-NK Connector is used.



Schematic diagram of the Type 1423-A Precision Decade Capacitor

The above comments apply, of course, to the three-terminal connection. For two-terminal use, the LOW terminal must be connected to the case by the grounding link provided, and the capacitor connected by the HIGH terminal and any one of the other four binding posts, all now connected to the case.

The new TYPE 874-Q9 Adaptor has been designed to provide a completely shielded transition from the standard $\frac{3}{4}$ -inch-spaced binding posts to a TYPE 874 Coaxial Connector. This adaptor serves not only as the transition to



Type 874-Q9 Adaptor on the panel of the Type 1423 Capacitor.

coaxial systems, but also provides the fixed geometry² upon which the two-terminal calibration is based. Although the internal shielding of the capacitor is complete, the HIGH binding post external to the panel has a small capacitance to ground. The capacitance as a two-terminal device differs from the three-terminal capacitance by approximately this capacitance, about one picofarad.

This new instrument is a very flexible and versatile tool for calibration laboratories and for production-line measurements. With the TYPE 1605-A Impedance Comparator, for instance, it forms a complete capacitance measuring assembly, capable of rapid, highly accurate comparisons.

With the new TYPE 1424-A Standard Decade Capacitor extending the range to 10 μf , and the new TYPE 1422³ Precision Adjustable Capacitors available in the range below 100 pf, the GR line of capacitance standards can provide very accurately and conveniently any value of capacitance from a fraction of a picofarad to 10 μf .

— I. G. EASTON

²J. F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," *General Radio Experimenter*, 33, 7, July, 1959.

³To be described in a forthcoming issue of the *Experimenter* (also in Catalog Q).

SPECIFICATIONS

Nominal Values: 100 pf to 1.111 μf in steps of 100 pf.

Accuracy of Adjustment: $\pm 0.5\%$ at 1 kc, calibrated in the three-terminal connection

using TYPE 874-Q9 Adaptors (supplied). Two-terminal connection (made by inserting the capacitor into TYPE 874-Q9 Adaptor) adds about 1.3 pf to reading.





Certificate: A certificate is supplied certifying that each component capacitor was adjusted by comparison to a precision better than $\pm 0.01\%$ with working standards maintained to an accuracy of $\pm 0.02\%$ in terms of NBS-certified reference standards.

Dissipation Factor

<i>D not greater than</i>	<i>C range</i>
.001	100 pf to 1000 pf
.0005	1100 pf to 2000 pf
.0003	2100 pf to 1.1110 μ f

Temperature Coefficient of Capacitance: Approximately $+35$ ppm per degree Centigrade between 10 and 50 degrees C.

Insulation Resistance: Greater than 50,000 M Ω

to 0.1 μ f and greater than 5,000 M Ω from 0.1 μ f to 1.111 μ f.

Calibration Frequency: 1 kc.

Frequency Characteristic: The behavior of each individual capacitor is similar to that of a TYPE 1409 Capacitor.

Maximum Voltage: 500 volts peak, up to 10 kc.

Accessories Supplied: Two TYPE 874-Q9 Adaptors.

Mounting: Aluminum relay-rack-style cabinet in gray, supplied with metal end frames for bench mounting.

Dimensions: Width 19, height 7, depth 9 $\frac{3}{4}$ inches (485 by 180 by 250 mm), over-all.

Net Weight: 26 pounds (11.8 kg).

<i>Type</i>		<i>Code Word</i>	<i>Price</i>
1423-A	Precision Decade Capacitor	LEVEL	\$695.00

A FOUR-DIAL POLYSTYRENE DECADE CAPACITOR

In addition to the two decade capacitance standards already described in this issue, a new four-dial polystyrene decade capacitor, TYPE 1419-B, has been added to our listing and is now available from stock. The new decade is similar to the popular TYPE 1419-A, a three-dial decade announced about five years ago, except for the addition of a 100-pf-per-step decade, TYPE 980-D.

SPECIFICATIONS

Capacitance: 1.1110 μ f maximum, in steps of .0001 μ f.

Dielectric: Polystyrene (TYPE 980-A, -B, -C, and -D Decade Capacitor Units).

Zero Capacitance: 50 pf, two-terminal; 20 pf, three-terminal.

Accuracy: Capacitance increments from zero position are within the following percentages of the indicated value for any setting: (2-terminal) $\pm 1\%$ on three highest decades and $\pm (1\% + 2$ pf) on the smallest decade; (3-terminal) $\pm 1\%$ on two highest decades, $\pm 1.5\%$

on the .001- μ f-per-step decade, and $+1\%$, $-(2\% + 4$ pf) on the smallest decade.

Dissipation Factor: Less than .0002 at 1 kc.

Insulation Resistance: 10^{12} ohms at 100 v, 23 C, 50% RH.

Temperature Coefficient of Capacitance: -140 ppm per degree Centigrade, nominal.

Maximum Operating Temperature: 65 C.

Maximum Operating Voltage: 500 volts, dc or peak, up to 10 kc.

Frequency Characteristic: Similar to those for the TYPE 980 Decade Capacitor Units (see catalog), modified by the additional inductance and resistance of the box terminals and wiring.

Ratio of DC Capacitance to 1-kc Capacitance: Less than 1.001.

Voltage Recovery: Less than 0.1% final, of original charging voltage after a charging period of one hour and a 10-second discharge through a resistance equal to one ohm per volt of charging.

Terminals: Three TYPE 938 Binding Posts with grounding link.

Mounting: Aluminum panel and cabinet.

Dimensions: Width 4 $\frac{1}{4}$, length 16 $\frac{1}{4}$, height 5 inches (110 by 415 by 130 mm), over-all.

Net Weight: 8 $\frac{3}{8}$ pounds (3.8 kg).

<i>Type</i>		<i>Code Word</i>	<i>Price</i>
1419-B	Decade Capacitor	BEFIT	\$262.00

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