

IMPEDANCE STANDARDS

• CAPACITANCE • INDUCTANCE • RESISTANCE

GENERAL RADIO

standard capacitors



PRECISION CAPACITOR

Type 1422

- variable air capacitor
- stability: better than 0.02% full scale per year
- settable to 40 ppm
- low temperature coefficient, low losses
- wide selection to suit needs



Panel and interior views of
1422-D Precision Capacitor.

The 1422 is a stable and precise variable air capacitor intended for use as a continuously adjustable standard of capacitance.

One of the most important applications is in ac bridge measurements, either as a built-in standard or as an external standard for substitution measurements. It is available in a variety of ranges, terminal configurations, and scale arrangements to permit selection of precisely the required characteristics.

TWO-TERMINAL

The 1422-D is a dual-range, two-terminal capacitor, direct reading in total capacitance at the terminals. For high-frequency use, the 1422-N, similar to the high-capacitance section of the 1422-D, is designed to have low residual inductance and resistance.

For convenience in making substitution measurements, two 1422's have scales reading in capacitance removed, i.e., the capacitance is maximum at the zero reading. These, the 1422-MD and 1422-ME, are also dual-range, two-terminal capacitors.

THREE-TERMINAL

The 1422-CB, -CC, -CL, -CD, and -CE are three-terminal capacitors with shielded coaxial terminals for use in three-terminal measurements. The calibrated direct capacitance is independent of terminal capacitances to ground, and losses are very low. The 1422-CL has approximately the same maximum capacitance as the -CC, but

with more constant and much lower terminal capacitances, so that it can be used in measurement circuits where high capacitance to guard can not be tolerated.

CONSTRUCTION

The capacitor assembly is mounted in a cast frame for rigidity. This frame and other critical parts are made of aluminum alloys selected to give the strength of brass with the lightness of aluminum. The plates of most models are also aluminum, so that all parts have the same temperature coefficient of linear expansion.

A worm drive is used to obtain high precision of setting. To avoid eccentricity, the shaft and the worm are accurately machined as one piece. The worm and worm wheel are also lapped into each other to improve smoothness. The dial end of the worm shaft runs in a self-aligning ball bearing, while the other end is supported by an adjustable spring mounting, which gives positive longitudinal anchoring to the worm shaft through the use of a pair of sealed, self-lubricating, preloaded ball bearings. Similar pairs of preloaded ball bearings provide positive and invariant axial location for the main or rotor shaft. Electrical connection to the rotor is made by means of a silver-alloy brush bearing on a silver-overlay drum to assure a low-noise electrical contact.

Stator insulation in all models is a cross-linked thermosetting modified polystyrene having low dielectric losses and very high insulation resistance. Rotor insulation, where used (Types 1422-CB, -CL, and -N), is grade L-4 steatite, silicone treated.

specifications

Initial Accuracy: See table. The errors tabulated are possible errors, i.e., the sum of error contributions from setting, adjustment, calibration, interpolation, and standards. When the capacitor is in its normal position with the panel horizontal, the actual errors are almost always smaller. The accuracy is improved when the readings are corrected using the 12 calibrated values of capacitance given on the correction chart on the capacitor panel and interpolating linearly between calibrated points. Better accuracy can be obtained from a precision calibration of approximately 100 points on the capacitor dial, which permits correction for slight residual eccentricities of the worm drive and requires interpolation over only short intervals. This precision calibration

is available for all models at an extra charge. Models so calibrated are listed with the additional suffix letter, P, in the type number. A plastic-enclosed certificate of calibration is supplied, giving corrections to one more figure than the tabulated accuracy.

Stability: The capacitance change with time is less than 1 scale division (0.02% of full scale) per year. The long-term accuracy can be estimated from the stability and the initial accuracy specifications.

Calibration: The measured values are obtained by comparison at 1 kHz, with working standards whose absolute values are known to an accuracy of $\pm(0.01\% + 0.0001 \text{ pF})$. Each comparison is



made to a precision better than $\pm 0.01\%$. The values of the working standards are determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

The indicated value of total capacitance of a two-terminal capacitor is the capacitance added when the 1422 Capacitor is plugged into a 777-Q3 Adaptor. The uncertainty of this method of connection is approx ± 0.03 pF.*

Resolution: Dial can be read and set to 1/5 of a small division.

The backlash is less than 1/5 small division, corresponding to 0.004% of full-scale value. If the desired setting is always approached in the direction of increasing scale reading, no error from this cause will result.

Temperature Coefficient: Approx $+20$ ppm/°C, for small temperature changes.

Residual Parameters: See table. The series resistance varies as the square root of the frequency above 100 kHz. Its effect is negligible below this frequency.

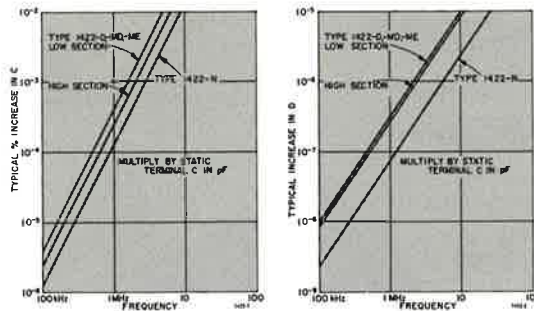
Frequency Characteristic: See curves for two-terminal models. The resonance frequency for the -CB and -CC models is approximately 20 MHz; for the -CD model, 60 MHz for each section; -CL, 40 MHz.

Dissipation Factor: The losses in the two-terminal capacitors are primarily in the stator supports, which are of low-loss polystyrene ($DC = 0.01 \times 10^{-12}$).

The very small dissipation factor of the direct capacitance of the three-terminal capacitors is difficult to measure and is estimated to be not greater than 20×10^{-6} for -CB and -CL, and 10×10^{-6} for -CC, -CD, and -CE.

Insulation Resistance: Under standard conditions (23°C, less than 50% RH), greater than 10^{12} ohms.

Max Voltage: All models, 1000 V, peak.



Variation with frequency of effective capacitance and dissipation factor per pF of capacitance for two-terminal 1422 Precision Capacitors.

Terminals: Jack-top binding posts are provided on 2-terminal models; standard 3/4-inch spacing is used. The rotor terminal is connected to the panel and shield. Locking GR874 Coaxial Connectors are used on three-terminal models.

Accessories Required: For connection to 3-terminal models, 2 GR874 Patch Cords or equivalent.

Accessories Available: 777-Q3 Adaptor (see Calibration above), for two-terminal units.

Mounting: Lab-Bench Cabinet.

Dimensions (width x height x depth): 9 1/2 x 7 x 8 1/2 in. (245 x 180 x 220 mm).

Weight: Net, 10 1/2 to 12 1/2 lb (4.8 to 5.7 kg), depending on model; shipping, all models, 15 lb (7 kg).

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

| TYPE 1422 | | Two-Terminal | | | | | | Three-Terminal | | | | | | |
|---|-----|-----------------------|-------|-------|-----------------------|-----------|-------|----------------|------|------|-------|--------|--------|---------|
| | | -D | | -N | -MD | | -ME | -CB | | -CC | -CL | -CD | | -CE |
| CAPACITANCE RANGE, pF | Min | 100 | 35 | 100 | 0 | 0 | 0 | 50 | 5 | 10 | 0.5 | 0.05 | 0.05 | 0.005 |
| | Max | 1150 | 115 | 1150 | 1050 | 105 | 10.5 | 1100 | 110 | 110 | 11 | 1.1 | 1.1 | 0.11 |
| SCALE, pF/Division: | | 0.2 | 0.02 | 0.2 | 0.2 | 0.02 | 0.002 | 0.2 | 0.02 | 0.02 | 0.002 | 0.0002 | 0.0002 | 0.00002 |
| INITIAL ACCURACY: \pm Picofarads Direct-Reading (Adjustment): Total Capacitance | | 0.6* | 0.1* | 0.6* | Differences from Zero | | | 0.6 | 0.15 | 0.1 | 0.04 | 0.008 | 0.008 | 0.0016 |
| Capacitance Difference | | 1.2 | 0.2 | 1.2 | 1 | 0.2 | 0.05 | 1.2 | 0.3 | 0.2 | 0.08 | 0.016 | 0.016 | 0.0032 |
| With Corrections from Calibration Chart (supplied): Total Capacitance | | 0.3* | 0.04* | 0.3* | | | | 0.3 | 0.04 | 0.04 | 0.01 | 0.002 | 0.002 | 0.0004 |
| Capacitance Difference† | | 0.6 | 0.08 | 0.6 | 0.6 | 0.08 | 0.02 | 0.6 | 0.08 | 0.08 | 0.02 | 0.004 | 0.004 | 0.0008 |
| With Corrections from Precision Calibration (extra charge): Total Capacitance | | 0.1* | 0.01* | 0.1* | | | | 0.1 | 0.01 | 0.01 | 0.001 | 0.0002 | 0.0002 | 0.00004 |
| Capacitance Difference† | | 0.2 | 0.02 | 0.2 | 0.2 | 0.02 | 0.004 | 0.2 | 0.02 | 0.02 | 0.002 | 0.0004 | 0.0004 | 0.00008 |
| RESIDUALS (typical values): Series Inductance, μ H | | 0.06 | 0.10 | 0.032 | 0.06 | 0.10 | 0.06 | 0.10 | 0.14 | 0.17 | 0.13 | 0.17 | 0.17 | 0.17 |
| Series Resistance, ohms at 1 MHz | | 0.04 | 0.05 | 0.012 | 0.04 | 0.05 | 0.04 | 0.05 | 0.1 | | 0.1 | | | |
| Terminal Capacitance, pF: | | high terminal to case | | | | min scale | | 36 | 850 | 34 | 98 | 25 | 37 | 28 |
| | | | | | | max scale | | 35 | 560 | 33 | 74 | 23 | 35 | 28 |
| | | low terminal to case | | | | min scale | | 58 | 920 | 58 | 117 | 115 | 81 | 81 |
| | | | | | | max scale | | 53 | 600 | 55 | 92 | 93 | 67 | 67 |
| Capacitance at Zero Scale Setting, pF: | | | | 1140 | 135 | 145 | 35 | | | | | | | |

* Total capacitance is the capacitance added when the capacitor is plugged into a 777-Q3 Adaptor. † Divide error by 2 when one setting is made at a calibrated point.

| Catalog Number | Description | Price in USA | Catalog Number | Description | Price in USA |
|--|-------------|--------------|----------------------------------|----------------|--------------|
| Precision Capacitors with precision calibration | | | with standard calibration | | |
| 1422-9904 | 1422-DP | \$620.00 | 1422-9704 | 1422-D | \$510.00 |
| 1422-9913 | 1422-MDP | 625.00 | 1422-9854 | 1422-MD | 515.00 |
| 1422-9955 | 1422-MEP | 620.00 | 1422-9855 | 1422-ME | 510.00 |
| 1422-9880 | 1422-NP | 565.00 | 1422-9714 | 1422-N | 495.00 |
| 1422-9902 | 1422-CBP | 550.00 | 1422-9916 | 1422-CB | 480.00 |
| 1422-9903 | 1422-CCP | 535.00 | 1422-9809 | 1422-CC | 465.00 |
| 1422-9508 | 1422-CLP | 535.00 | 1422-9933 | 1422-CL | 465.00 |
| 1422-9925 | 1422-CDP | 560.00 | 1422-9823 | 1422-CD | 450.00 |
| 1422-9580 | 1422-CEP | 620.00 | 1422-9833 | 1422-CE | 510.00 |
| | | | 0777-9803 | 777-Q3 Adaptor | 6.00 |

standard capacitors



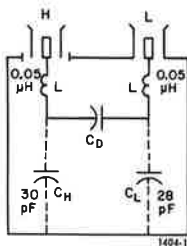
REFERENCE STANDARD CAPACITOR

Type 1404

- 10, 100, 1000 pF
- 20 ppm/year stability
- 3-terminal, coaxial connections
- hermetically sealed in dry nitrogen



These capacitors have been designed as primary reference standards of capacitance with which working standards can be compared. The 1615-A Capacitance Bridge is particularly well suited for this purpose and can be conveniently used to calibrate accurately a wide range of working standards in terms of a 1404 Reference Standard Capacitor. A single 1000- or 100-picofarad standard is also the only standard necessary to calibrate the bridge itself.



Equivalent circuit showing direct capacitance, C_D , and average values of residual inductance, L , and terminal capacitances, C_H and C_L . $C_D = 1000$ pF for 1404-A, 100 pF for 1404-B, and 10 pF for 1404-C.

In combination with an accurately known external resistor, this capacitor becomes a standard of dissipation factor.

All critical parts of the plate assembly are made of Invar for stability and low temperature coefficient. After heat cycling and adjustment, the assembly is mounted in a heavy brass container, which, after evacuation, is filled with dry nitrogen under pressure slightly above atmospheric and sealed. The container is mounted on an aluminum panel and protected by an outer aluminum case. Each capacitor is subjected to a series of temperature cycles to determine hysteresis and temperature coefficients and to stabilize the capacitance.

Two locking GR874 Coaxial Connectors are used as terminals. The outer shell of one is connected to the case, but the outer shell of the other is left unconnected to permit the capacitor to be used with an external resistor as a dissipation-factor standard.

— See *GR Experimenter* for Aug 1963 and Aug 1966.

specifications

Calibration: A certificate of calibration is supplied with each capacitor, giving the measured direct capacitance at 1 kHz and at $23^\circ \pm 1^\circ\text{C}$. The measured value is obtained by a comparison to a precision better than ± 1 ppm with working standards whose absolute values are known to an accuracy of ± 20 ppm, determined and maintained in terms of reference standards periodically measured by the National Bureau of Standards.

Adjustment Accuracy: The capacitance is adjusted before calibration with an accuracy of ± 5 ppm to a capacitance about 5 ppm above the nominal value relative to the capacitance unit maintained by the General Radio reference standards.

Stability: Long-term drift is less than 20 parts per million per year. Maximum change with orientation is 10 ppm and is completely reversible.

Temperature Coefficient of Capacitance: 2 ± 2 ppm/ $^\circ\text{C}$ for 1404-A and -B, 5 ± 2 ppm/ $^\circ\text{C}$ for 1404-C, from -20°C to $+65^\circ\text{C}$. A measured value with an accuracy of ± 1 ppm/ $^\circ\text{C}$ is given on the certificate.

Temperature Cycling: For temperature cycling over range from -20°C to $+65^\circ\text{C}$, hysteresis (retraceable) is less than 20 ppm at 23°C .

Dissipation Factor: Less than 10^{-5} at 1 kHz.

Residual Impedances: See equivalent circuit for typical values of internal series inductances and terminal capacitances.

Max Voltage: 750 V.

Terminals: Two locking GR874 coaxial connectors; easily convertible to other types of connectors by attachment of locking adaptors. Outer shell of one connector is ungrounded to permit capacitor to be used with external resistor as a dissipation-factor standard.

Accessories Required: For connection to 1615-A Capacitance Bridge, 2 Type 874-R20A or 874-R22LA Patch Cords.

Dimensions (width x height x depth): $6\frac{3}{4} \times 6\frac{5}{8} \times 8$ in. (175 x 170 x 205 mm).

Weight: Net, 8½ lb (3.9 kg); shipping, 14 lb (6.5 kg).

| Catalog Number | Description | Price in USA |
|----------------|-------------------------------------|--------------|
| | Reference Standard Capacitor | |
| 1404-9701 | 1404-A, 1000 pF | \$225.00 |
| 1404-9702 | 1404-B, 100 pF | 225.00 |
| 1404-9703 | 1404-C, 10 pF | 225.00 |



STANDARD CAPACITOR

Type 1409

- 0.001 to 1 μF
- $\pm 0.01\%$ /year stability
- calibration accuracy $\pm 0.02\%$
- two- and three-terminal calibration provided



Type 1409-T



Type 1409-X



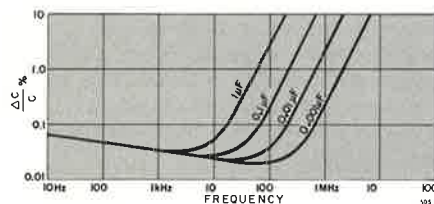
Type 1409-Y

The 1409 Standard Capacitors are fixed mica capacitors of very high stability for use as two- or three-terminal reference or working standards in the laboratory.

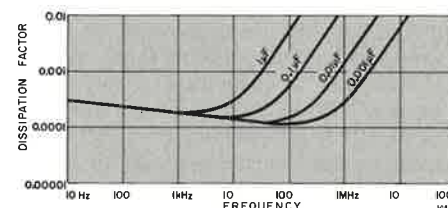
Typical capacitors, observed over more than ten years, have shown random fluctuations of less than $\pm 0.01\%$ in measured capacitance with no evidence of systematic drift.

These capacitor units consist of a silvered-mica and foil pile, spring-held in a heavy metal clamping structure

for mechanical stability. The units are selected for low dissipation factor and are stabilized by heat cycling. They are housed, with silica gel to provide continuous desiccation, in cast aluminum cases, sealed with high-temperature potting wax. A well is provided in the wall of the case for the insertion of a dial-type thermometer. Three jack-top binding posts are provided on the top of the case and removable plugs on the bottom, for convenient parallel connection without error.



(Left) Change in capacitance as a function of frequency for typical Type 1409 Capacitors. The 1-kHz value on the plot should be used as a basis of reference in estimating frequency errors. (Right) Dissipation factor as a function of frequency.



specifications

Adjustment Accuracy: Within $\pm 0.05\%$ of the nominal capacitance value (two-terminal) marked on the case. Accuracy is guaranteed for two years under the terms of our standard warranty if the capacitor has not been damaged by excessive current or voltage.

Calibration: A certificate of calibration is supplied with each unit, giving both two- and three-terminal measured capacitances at 1 kHz and at a specified temperature. The measured value is the capacitance added when the standard is plugged directly into General Radio binding posts. This value is obtained by comparison, to a precision better than $\pm 0.01\%$, with working standards whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Stability: Capacitance change is less than 0.01% per year.

Temperature Coefficient of Capacitance: $+35 \pm 10$ ppm per degree between 10° and 70°C .

Dissipation Factor: Less than 0.0003 at 1 kHz and 23°C (see curves). Measured dissipation factor at 1 kHz is stated in the certificate to an accuracy of ± 0.00005 .

Series Inductance: Typically 0.050 μH for 1409-F through -M, 0.055 μH for -R through -X, and 0.070 μH for 1409-Y.

Series Resistance at 1 MHz: 0.02 ohm, except for 1409-Y, which is 0.03 ohm.

Frequency Characteristics: See curves. Series resistance varies as the square root of the frequency for frequencies above 100 kHz.

Approx Terminal Capacitance: From H terminal to case (G), 12 to

50 pF. From L terminal (outside foils of capacitor) to case, 300 to 1300 pF.

Leakage Resistance: 5000 ohm-farads or 100 G Ω , whichever is the lesser.

Max Voltage: 500 V pk below the limiting frequencies tabulated below. At high frequencies the allowable voltage is approx inversely proportional to frequency. These limits correspond to a temperature rise of 40°C for power dissipations of 5, 6, and 7.5 W for the small, medium, and large cases, respectively.

Dimensions (width x height x depth): 1409-Y, $3\frac{1}{4} \times 5\frac{5}{8} \times 2\frac{1}{16}$ in. (85 x 145 x 70 mm); 1409-X, $3\frac{1}{4} \times 4 \times 2\frac{1}{16}$ in. (85 x 105 x 70 mm); others, $3\frac{1}{4} \times 4 \times 2$ in. (85 x 105 x 50 mm).

Weight: Net, $1\frac{1}{4}$ lb (0.6 kg); shipping, 4 lb (1.9 kg). Add approx $\frac{1}{2}$ lb (0.2 kg) for 1409-X, and approx 1 lb (2.2 kg) for 1409-Y.

| Catalog Number | Type | Nominal Capacitance μF | Frequency Limit for Max Volts | Price in USA |
|----------------|--------|-----------------------------------|-------------------------------|--------------|
| 1409-9706 | 1409-F | 0.001 | 4.7 MHz | \$ 55.00 |
| 1409-9707 | 1409-G | 0.002 | 2.7 MHz | 55.00 |
| 1409-9711 | 1409-K | 0.005 | 1.3 MHz | 55.00 |
| 1409-9712 | 1409-L | 0.01 | 750 kHz | 55.00 |
| 1409-9713 | 1409-M | 0.02 | 430 kHz | 60.00 |
| 1409-9718 | 1409-R | 0.05 | 210 kHz | 65.00 |
| 1409-9720 | 1409-T | 0.1 | 120 kHz | 70.00 |
| 1409-9721 | 1409-U | 0.2 | 70 kHz | 80.00 |
| 1409-9724 | 1409-X | 0.5 | 35 kHz | 120.00 |
| 1409-9725 | 1409-Y | 1.0 | 17 kHz | 200.00 |

standard capacitors



PRECISION DECADE CAPACITOR

Type 1423-A

- 100 pF to 1.111 μ F
- $\pm 0.05\%$ accuracy
- two- or three-terminal connection

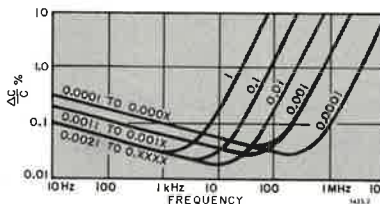


This capacitor is a versatile tool for calibration laboratories and production-line testing. With it a bridge can be standardized to an accuracy exceeded only by that of the highest quality, individually certified laboratory standards such as the GR 1404 Reference Standard Capacitors. Used with a limit bridge, such as the GR 1605-A Impedance Comparator, the 1423 facilitates fast and accurate production-line measurements of arbitrary capacitance values with minimum setup time.

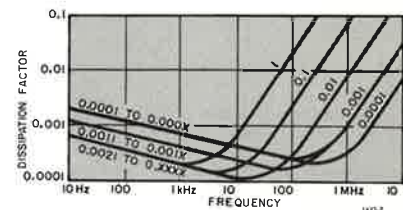
Any value of capacitance from 100 pF to 1.111 μ F, in steps of 100 pF, can be set on the four decades and will be known to an accuracy of 0.05%. The terminal capacitance values are set precisely to the nominal value and

can be readjusted later at calibration intervals, if necessary, without disturbance of the main capacitors.

The 1423 consists of four decades of high-quality silvered-mica capacitors similar to those used in the GR 1409 Standard Capacitors. The capacitors and associated switches 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 constant difference of about one picofarad). This external capacitance can be included in the two-terminal calibration by the adjustment of a single trimmer.



(Left) Change in capacitance as a function of frequency. These changes are referred to the values that the capacitors would have if there were neither interfacial polarization nor series inductance. The 1-kHz value on the plot should be used as a basis of reference in estimating frequency errors. (Right) Dissipation factor as a function of frequency.



specifications

Nominal Values: 100 pF to 1.111 μ F in steps of 100 pF.

Accuracy: $\pm(0.05\% + 0.05\text{pF})$ at 1 kHz, calibrated in the three-terminal connection. Two-terminal connection (capacitor inserted into Type 777-Q3 Adaptor) adds about 1.3 pF reading.

Stability: $\pm(0.01\% + 0.05\text{pF})$ per year.

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 whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Frequency: See curves for typical variation of capacitance and dissipation factor with frequency.

Dissipation Factor: Not greater than 0.001, 0.0005, and 0.0003 for capacitances of 100 to 1000 pF, 1100 to 2000 pF, and 2100 pF to 1.111 μ F, respectively.

Temperature Coefficient of Capacitance: Approx +20 ppm per degree between 10° and 50°C.

Insulation Resistance: $>5 \times 10^{10} \Omega$ to 0.1 μ F and $>5 \times 10^9 \Omega$ from 0.1 μ F to 1.111 μ F.

Maximum Voltage: 500 V peak, up to 10 kHz.

Accessories Supplied: Two Type 777-Q3 Adaptors.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench, 19 x 7 $\frac{1}{4}$ x 10 $\frac{1}{2}$ in. (485 x 185 x 270 mm); rack, 19 x 7 x 8 $\frac{1}{2}$ in. (485 x 180 x 220 mm).

Weight (both models): Net, 26 lb (12.0 kg); shipping, 39 lb (18 kg).

| Catalog Number | Description | Price in USA |
|----------------|--|--------------|
| 1423-9801 | Precision Decade Capacitor 1423-A, Bench Model | \$800.00 |
| 1423-9811 | 1423-A, Rack Model | 800.00 |



- stable to 0.05% per year
- for rf impedance calibrations

COAXIAL CAPACITANCE STANDARDS

Type 1406

The 1406 Coaxial Capacitance Standards are stable, low-loss air capacitors with small, stable and known series inductance. This permits the accurate, traceable calibration of high-frequency bridges and other impedance-measuring instruments.

REPEATABLE COAXIAL CONNECTION

GR900® precision coaxial connectors are used on the 1406's; their stability and repeatable performance have been proven in use at frequencies as high as 9 GHz. The use of coaxial connectors also meets the high-frequency calibration requirements of the National Bureau of Standards.

INSTRUMENT CALIBRATION

The 1406 standards can be connected directly to instruments equipped with GR900 precision connectors and to others through appropriate adaptors. The Type 900-Q9 adaptor is offered to facilitate connection to 1/4" x 28 threaded studs or tapped holes on 3/4" to 1" centers. Series inductance and resistance have been kept low in the 900-Q9 and, when other adaptors are used, these quantities should be known to permit correcting for their effects at high frequencies.

These standards can be calibrated at audio frequencies

with the GR 1615 Capacitance Bridge and the 1615-P2 Coaxial Adaptor, which has an adjustment for compensating for its capacitance and that of the binding posts and thus permits direct-reading measurements.

specifications

Calibration: A certificate of calibration is supplied with each unit, giving the measured capacitance at 1 kHz and at a specified temperature and relative humidity. The measured capacitance is the capacitance at the reference plane of the GR900 connector. This value is obtained by comparison, to a precision better than $\pm 0.01\%$, with working standards whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Stability: The capacitance change is less than 0.05% per year.

Accuracy: Capacitance adjusted to within 0.1% of nominal value.

Residual Impedances: See table. Dissipation factor varies as the 3/2 power of frequency above about 100 kHz. Insulation resistance is greater than 10^{12} ohms at 23°C and less than 50% RH.

Temperature Coefficient of Capacitance: Typically 10 to 20 ppm/°C between 20°C and 70°C.

Accessories Available: Adaptors 1615-P2 for convenience in calibrating with 1615-A Capacitance Bridge and 900-Q9 for connecting 1406 to 1/4-in. x 28 threaded stud (GR 938 Binding Post) or tapped hole.

Terminal: GR900 precision coaxial connector.

Mounting: Aluminum panel and cylindrical case.

Dimensions (diameter x height): 3 1/8 x 5 1/4 in. (78 x 135 mm).

Weight: Net, 1 1/2 lb (0.7 kg); shipping, 4 lb (1.9 kg).

| Catalog Number | Type | Nominal Capacitance | Peak Volts | Typical Dissipation Factor | | Typical Inductance | Price in USA |
|----------------|---|---------------------|------------|----------------------------|---------------------|--------------------|--------------|
| | | | | 1 kHz (40% RH) | 1 MHz | | |
| 1406-9701 | 1406-A | 1000 pF | 700 | 3×10^{-6} | 50×10^{-6} | 8.6 nH | \$120.00 |
| 1406-9702 | 1406-B | 500 pF | 900 | 5×10^{-6} | 30×10^{-6} | 8.4 nH | 115.00 |
| 1406-9703 | 1406-C | 200 pF | 1200 | 20×10^{-6} | 25×10^{-6} | 8.1 nH | 110.00 |
| 1406-9704 | 1406-D | 100 pF | 1500 | 30×10^{-6} | 20×10^{-6} | 7.6 nH | 105.00 |
| 1406-9705 | 1406-E | 50 pF | 1500 | 50×10^{-6} | 15×10^{-6} | 6.7 nH | 100.00 |
| 1615-9602 | 1615-P2 Coaxial Adaptor, GR900 to 1615 Bridge | | | | | | 75.00 |
| 0900-9874 | 900-Q9 Adaptor, GR900 to binding posts | | | | | | 50.00 |



- 1, 2, and 5 pF
- rf standards
- GR900® connectors

COAXIAL CAPACITANCE STANDARDS

Type 1405

Extending the available values of rf capacitance downward, the 1405 standards permit impedance-measuring instruments to be calibrated at even higher frequencies accurately and with traceability to the National Bureau of Standards.

specifications

Calibration: A certificate of calibration is supplied with each unit, giving the measured capacitance at 1 kHz and at a specified temperature and relative humidity. The measured capacitance is the capacitance at the reference plane of the GR900 connector. This value is obtained by comparison, to a precision better than ± 0.001 pF, with working standards whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Accuracy: Capacitance adjusted to within tolerance given in table.

Residual Impedances: Dissipation factor at 1 kHz, $< 30 \times 10^{-6}$ for -C, -D; $< 40 \times 10^{-6}$ for -E; insulation resistance is $> 10^{12} \Omega$ at 23°C, $< 50\%$ RH. Effect of series inductance and other factors is given in table below in terms of the frequency at which it causes a 10% increase in measured capacitance.

Accessories Available: Adaptors 1615-P2 for calibrating with GR 1615 bridge and 900-Q9 for connecting standard to 1/4-inch x 28 threaded stud (GR 938 Binding Post) or tapped hole.

Terminal: GR900 precision coaxial connector.

Dimensions (diameter x height): 1 1/8 x 2 3/8 in. (27 x 59 mm).

Weight: Net, 4 oz (103 g); shipping, 5 oz (150 g).

| Catalog Number | Type | Nominal Capacitance | Accuracy | Peak Volts | Frequency for 10% C Increase | Price in USA |
|----------------|--------|---------------------|----------------|------------|------------------------------|--------------|
| 1405-9702 | 1405-C | 5 pF | ± 0.010 pF | 1 kV | 0.75 GHz | \$55.00 |
| 1405-9701 | 1405-D | 2 pF | ± 0.005 pF | 1 kV | 1.4 GHz | 55.00 |
| 1405-9700 | 1405-E | 1 pF | ± 0.005 pF | 3 kV | 1.7 GHz | 55.00 |

standard capacitors



STANDARD AIR CAPACITOR

Type 1403

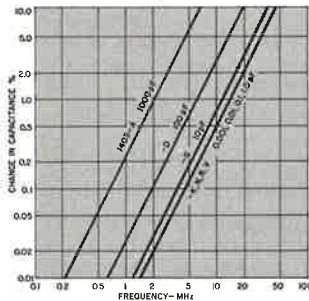
- 1000 pF to 0.001 pF
- calibration accuracy:
±0.02% ±0.01 fF



The 1403 Standard Air Capacitors are stable, three-terminal standards in decimal values from 0.001 to 1000 pF. Their terminals are arranged to plug directly into the UNKNOWN terminals of the 1615-A Capacitance Bridge.

specifications

Calibration: A certificate of calibration is supplied with each unit giving the measured capacitance at 1 kHz and at a specified temperature. The measured value is the direct capacitance between shielded terminals when the capacitor has at least one



Typical increase (percent) in effective direct capacitance, with frequency produced by residual inductance.

lead completely shielded and its case connected to a guard point. This value is obtained by comparison, to a precision better than ±(0.01% + 0.00001 pF), with working standards whose absolute values are known to an accuracy typically ±0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Stability: Capacitance change is less than 0.05% per year.

Residual Impedances: See curves for high-frequency use.

Dissipation Factor: 20×10^{-6} max at 1 kHz and 50% or less relative humidity.

Peak Voltage: 1500 V, except for 1403-A, which is 700 V.

Temperature Coefficient of Direct Capacitance: Typically 20 to 40 ppm per degree between 20° and 70°C. The larger coefficients apply to the smaller capacitance values.

Terminals: GR874 coaxial connectors, which provide complete shielding of the leads.

Dimensions: Diameter 3 1/8 in. (78 mm), height 5 1/4 in. (135 mm), over-all.

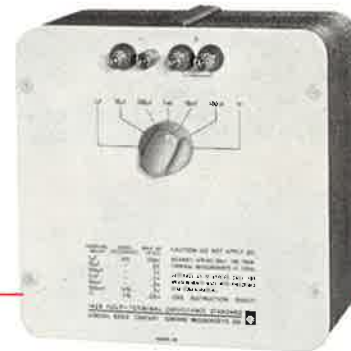
Weight: Net, 1 lb (0.5 kg); shipping, 4 lb (1.9 kg).

| Catalog Number | Type | Nominal Capacitance - pF | Adjustment Accuracy - % | Price in USA |
|----------------|--------|--------------------------|-------------------------|--------------|
| 1403-9701 | 1403-A | 1000 | 0.1 | \$95.00 |
| 1403-9704 | 1403-D | 100 | 0.1 | 80.00 |
| 1403-9707 | 1403-G | 10 | 0.1 | 65.00 |
| 1403-9711 | 1403-K | 1.0 | 0.1 | 65.00 |
| 1403-9714 | 1403-N | 0.1 | 0.1 | 70.00 |
| 1403-9718 | 1403-R | 0.01 | 0.3 | 70.00 |
| 1403-9722 | 1403-V | 0.001 | 1.0 | 70.00 |

FOUR-TERMINAL CAPACITANCE STANDARD

Type 1426

- 1 μF to 1 farad in decade steps
- accuracy 1/4%, 1% at 1 F



The 1426 capacitance standard is of great value in calibrating four-terminal, high-capacitance bridges like the GR 1617. With calibration, the 1426 can be used as a two-terminal standard at 120 Hz and at settings up to 1 mF.

The 1426 consists of a 1-μF polystyrene capacitor and a transformer that multiplies the effective capacitance to higher values. This arrangement gives stability unattainable with very-high-value true capacitors. Such construction prohibits general circuit applications and particularly uses with dc applied to the capacitor.

specifications

Capacitance: 1 μF to 1 F in 7 switch-selected decade values.

Accuracy: ±1/4%, except ±1/2% for 100 mF and ±1% for 1 F; measured at 120 Hz at 23°C at <math><Max\ Volts</math> specified below. Measurements must use 4-terminal connections with all but the 1-μF value; at 1 F, lead arrangement must be as prescribed in operating instruction manual.

Dissipation Factor: 0.0003 for 1 μF at 120 Hz; 0.1 for larger values.

Max Ac Voltage: Voltage 10:1 larger than specified will not damage standards above 1 μF but will cause an error of approx 1%.

| Capacitance | 1 μF | 10 μF | 100 μF | 1 mF | 10 mF | 100 mF | 1 F |
|--------------|-------|-------|--------|-------|-------|--------|--------|
| Max Ac Volts | 100 V | 2 V | 1 V | 0.3 V | 0.2 V | 0.2 V | 0.05 V |

Max Dc Voltage: No dc permissible as values above 1 μF are dc short circuits and could be changed in value by dc current; 100 V max for 1-μF standard only.

Temperature Coefficient: 140 ppm/°C typical.

Frequency Characteristic: 1-μF standard is true capacitor with 170-kHz resonance; other values very frequency dependent. Add 1/4% error at 100 Hz, add 1% from 60 to 150 Hz.

Dimensions (width x height x depth): 8 x 5 7/8 x 8 in. (205 x 150 x 205 mm).

Weight: Net, 7 1/2 lb (3.5 kg); shipping, 11 lb (5 kg).

| Catalog Number | Description | Price in USA |
|----------------|---|--------------|
| 1426-9700 | 1426 Four-Terminal Capacitance Standard | \$275.00 |



DECADE CAPACITORS



Type 1424-A. Type 1424-M is similar in appearance.



Type 1425-A

- 10- μ F Standard Decade — Polystyrene Dielectric — Type 1424-A
- 100- μ F Standard Decade — Polystyrene Dielectric — Type 1425-A
- 10- μ F Decade — Paper Dielectric — Type 1424-M

TYPE 1424-A

Polystyrene capacitors, combined in 10 1- μ F units, are housed in two hermetically sealed, non-ferrous metal cases with Teflon*-insulated high terminals, the cases being the common (LOW) terminal. The aluminum outer cabinet and panel are insulated from both capacitor terminals, so that either two- or three-terminal connections can be used.

Residual series inductance and resistance have been minimized by the use of current-sheet conductors, ribbon leads, and multiple switch contacts.

TYPE 1424-M

This capacitor is a 1-microfarad-per-step decade, which

* Registered trademark of E. I. duPont de Nemours and Company.

has less rigorous performance specifications than the 1424-A and a correspondingly lower price. Sealed foil-paper capacitors of noninductive extended-foil construction are used with a viscous impregnant to improve stability.

TYPE 1425-A

Polystyrene capacitors are connected in 10- μ F steps. The configuration and dimensions of binding posts, bus, studs, and current-sheet connectors are arranged to minimize residuals. Switching resistance is kept low through the use of tapered plug connectors, rather than rotary switches. Binding posts have large contact areas and are easily tightened by hand to minimize contact resistance.

— See *GR Experimenter* for July 1965.

specifications

Accuracy: The accuracy stated in the table below is guaranteed for two years under the terms of our standard warranty, if the capacitor has not been damaged by excessive current or voltage.

Certificate: 1424-A and 1425-A: A certificate is supplied giving measured values obtained by comparison, to a precision better than $\pm 0.01\%$, with working standards whose absolute values are known to an accuracy better than $\pm 0.05\%$, determined and main-

tained in terms of reference standards periodically measured by the National Bureau of Standards. 1424-M: A certificate is supplied, certifying the accuracy of adjustment in terms of reference standards, periodically measured by the National Bureau of Standards.

Frequency Characteristic: Calibration and adjustment are made at 1 kHz. Plots of typical change in capacitance and dissipation factor with frequency are given in the calibration certificate.

| Type | 1424-A | 1425-A | 1424-M |
|--|-----------------------------|-----------------------------|-----------------------------|
| Total Capacitance | 10 μ F | 100 μ F | 10 μ F |
| Capacitance per Step | 1 μ F | 10 μ F | 1 μ F |
| Dielectric | Polystyrene | Polystyrene | Paper |
| Adjustment Accuracy at 1 kHz | $\pm 0.25\%$ | $\pm 0.25\%$ | $\pm 1\%$ |
| Stability | $\pm 0.05\%$ /year | $\pm 0.05\%$ /year | $\pm 0.35\%$ /year |
| Dissipation Factor at 1 kHz | <0.0003 | <0.0004 | <0.005 |
| Insulation Resistance | >10 ⁹ Ω F | >10 ⁹ Ω F | >10 ⁹ Ω F |
| Voltage Recovery * | <0.1% | <0.1% | <5% |
| Temp Coefficient of Capacitance (typical) ppm/°C | -140 | -140 | +180 |
| Max Operating Temperature °C | 65 | 65 | 90 |
| Max Safe Voltage | 500 V, peak, below 10 kHz | 25 V, peak, below 10 kHz | 500 V, peak, up to 2 kHz |
| Dimensions Width, height, depth, inches (mm) | 9½, 7¾, 8 (245, 195, 205) | 9¾, 19¼, 8½ (240, 485, 205) | 9½, 6, 8 (245, 150, 205) |
| Net Weight lb (kg) | 16½ (7.5) | 46½ (21.5) | 7¾ (3.6) |
| Shipping Weight lb (kg) | 19 (9) | 67 (31) | 11 (5) |
| Catalog Number | 1424-9701 | 1425-9701 | 1424-9713 |
| Price in USA | \$410.00 | \$1950.00 | \$210.00 |

* Dielectric absorption.



standard capacitors

DECADE CAPACITORS

Type 1419



- 100 pF to 1.1 μ F
- choice of models
- two- or three terminal connection

Type 1419 Decade Capacitors are offered in four models using three different dielectric materials to satisfy a variety of needs.

Types 1419-A and -B (Polystyrene)

Capacitance and dissipation factor constant with frequency, essentially noninductive, very low dielectric absorption. The dielectric is specially prepared of purified high-molecular-weight polystyrene, having very high resistance and freedom from interfacial polarization. Moisture sealing with Teflon* feed-through insulators assures high performance under adverse humidity conditions.

Type 1419-K (Silvered Mica)

Higher accuracy, low dissipation factor, and $+35 \pm 10$ ppm/ $^{\circ}$ C temperature coefficient (10-50 $^{\circ}$ C) for use in higher ambient temperatures.

Type 1419-M (Molded Silvered Mica and Paper)

For economy and excellent performance characteristics, sealed foil-and-paper capacitors are used in the highest-value decade and EIA Characteristic-C molded silvered micas in the smaller two.

* Registered trademark of E. I. duPont de Nemours and Company.

specifications

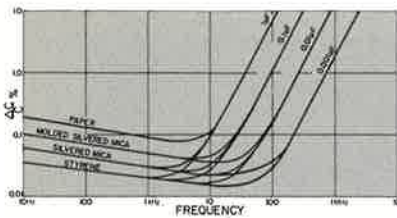
| TYPE NUMBER | 1419-A | 1419-B | 1419-K | 1419-M |
|--|---|---|---|---|
| Dielectric | Polystyrene | Polystyrene | Silvered Mica | Paper and Silvered Mica (Molded) |
| Maximum Capacitance of Box (μ F) | 1.110 | 1.1110 | 1.110 | 1.110 |
| In Steps of (μ F) | 0.001 | 0.0001 | 0.001 | 0.001 |
| Dials | 3 | 4 | 3 | 3 |
| Zero Capacitance, typical | | | | |
| 2-terminal connection | 37 pF | 50 pF | 41 pF | 35 pF |
| 3-terminal connection | 15 pF | 20 pF | 13 pF | 16 pF |
| Accuracy ¹ | | | | |
| 2-terminal connection ² | $\pm 1\%$ | $\pm(1\% + 2 \text{ pF})$ | $\pm 0.5\%$ | $\pm 1.5\%$ on highest decade $\pm 1\%$ on others |
| 3-terminal connection | $\pm 1\%$ except $\pm 1.5\%$ on smallest decade | $+1\%$ or $-(2\% + 4 \text{ pF})$ | $\pm 0.5\%$ except $\pm 1\%$ on smallest decade | $\pm 1.5\%$ on highest decade $\pm 1\%$ on others |
| Dissipation Factor at 1 kHz | <0.0002 | | <0.0003 | <0.005 |
| Insulation Resistance at 100 V, 25 $^{\circ}$ C, 50% RH, (ohms), typical | >10 ¹² | | >5 $\times 10^9$ | >10 ⁹ |
| Max Voltage ³ (dc or peak) | 500 V up to 35 kHz | | 500 V up to 10 kHz | 500 V up to 1 kHz |
| Max Operating Temperature (C) | 65 | | 75 | 90 |
| Voltage Recovery ⁴ | <0.1% | | <3% | <5% on highest decade |
| Resonant Frequencies (typical) | 1 μ F—400 kHz; 0.1 μ F—1MHz; 0.01 μ F—2.7 MHz; 0.001 μ F—7.8 MHz; 0.0001 μ F—23 MHz | | | |
| Dc Cap/1-kHz Cap | <1.001 | | Typically 1.03 | |
| Cabinet | Lab-bench | | | |
| Over-all Dimensions — in. (mm) | 13 x 4 $\frac{3}{8}$ x 5 (330 x 110 x 130) | 16 $\frac{1}{8}$ x 4 $\frac{3}{8}$ x 5 (415 x 110 x 130) | 14 $\frac{1}{8}$ x 5 $\frac{1}{2}$ x 6 (359 x 140 x 153) | 14 $\frac{1}{8}$ x 5 $\frac{1}{2}$ x 6 (359 x 140 x 153) |
| Net Weight — lb (kg) | 8 $\frac{3}{8}$ (3.8) | 10 $\frac{1}{2}$ (4.8) | 11 $\frac{1}{4}$ (5.5) | 6 $\frac{1}{4}$ (2.9) |
| Shipping Weight — lb (kg) | 10 (4.6) | 11 (5) | 18 (8.5) | 8 (3.7) |
| Catalog Number | 1419-9701 | 1419-9702 | 1419-9711 | 1419-9713 |
| Price in USA | \$210.00 | \$270.00 | \$435.00 | \$200.00 |

¹ Capacitance increments from zero position are within this percentage of the indicated value for any setting at 1 kHz.

² Units are checked with switch mechanism high, electrically, and the common lead and case grounded.

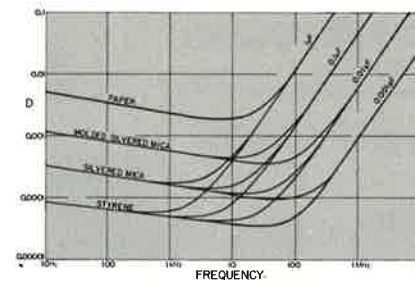
³ At frequencies above the indicated max, the allowable voltage decreases and is (approx) inversely proportional to frequency. These limits correspond to a temperature of 40 $^{\circ}$ C at max setting of each decade in box.

⁴ 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.



1419 Decades

(Left) Typical plot of change in capacitance at maximum setting of each decade as a function of frequency. The capacitance curves are referred to the value the capacitor would have if there were no interfacial polarization and no series inductance. Since the capacitors are adjusted to their rated accuracy at 1 kHz, the 1-kHz value on the plots should be used as a basis of reference in estimating the frequency error. (Right) Typical plot of dissipation factor as a function of frequency.



- 50 pF to 1.11115 μ F
- better than 1-pF resolution
- accuracy $\pm(1\% + 5 \text{ pF})$
- low loss, leakage, dielectric absorption

DECADE CAPACITOR Type 1412-BC

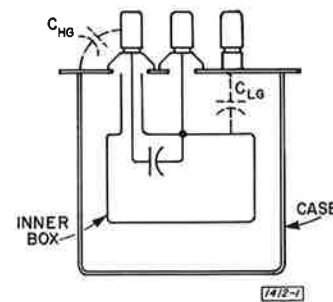


The wide capacitance range and high resolution of this decade capacitance box make it exceptionally useful in both laboratory and test shop. Owing to its fine adjustment of capacitance, it is a convenient variable capacitor to use with the 1605-A Impedance Comparator. The polystyrene dielectric used in the decade steps is necessary for applications requiring low dielectric absorption and constancy of both capacitance and dissipation factor with frequency.

Four decades of polystyrene capacitors and a variable air capacitor are used, mounted in a double-shield box. The double shielding provides 2-terminal and 3-terminal capacitances that are the same except for the capacitance between the terminals. The variable air capacitor with a linear ΔC of 100 pF and a resolution of better than 1 pF

provides continuous adjustment between the 100-pF steps of the smallest decade.

— See *GR Experimenter* for August 1966.



The double shielding used in the 1412-BC Decade Capacitor keeps C_{H0} very small. This capacitance is the difference between the 3-terminal and 2-terminal capacitance of the box; C_{L0} is approx 125 pF.

specifications

Capacitance: 50 pF to 1.11115 μ F in steps of 100 pF with a 0- to 100-pF variable air capacitor providing continuous adjustment with divisions of 1 pF. Capacitances for 2- and 3-terminal connections differ by about 1 pF.

Min Capacitance: 50 pF with all controls set at zero.

Dielectric: Polystyrene for decade steps.

Accuracy: $\pm(1.0\% + 5 \text{ pF})$ at 1 kHz, for total capacitance including 50-pF minimum.

Temperature Coefficient: $-140 \text{ ppm}/^\circ\text{C}$ (nominal).

Frequency Characteristics: Dc Cap/1-kHz Cap <1.001 . At higher frequencies the increase is approx $\Delta C/C = (f/f_0)^2$. The resonant frequency, f_r , varies from over 400 kHz for a capacitance of 1 μ F to about 27 MHz for a capacitance of 150 pF when connections are made to the front terminals. f_r is about 300 kHz and 70 MHz for rear connections and the same capacitances.

Max Operating Temperature: 65 $^\circ\text{C}$.

Dielectric Absorption (Voltage Recovery): 0.1% max.

Dissipation Factor: 150 to 1000 pF, 0.001, max, at 1 kHz; over 1000 pF, 0.0002, max, at 1 kHz.

Insulation Resistance: 10^{12} ohms, min.

Max Voltage: 500 V peak up to 35 kHz.

Terminals: Four 938 Binding Posts with grounding link are provided on the panel. Two of the binding posts are connected to the case and located for convenient use with patch cords in 3-terminal applications. Access is also provided to rear terminals for relay-rack applications.

Mounting: Lab-Bench Cabinet. Brackets are provided for rack mounting.

Dimensions (width x height x depth): 17 $\frac{1}{4}$ x 3 $\frac{1}{2}$ x 6 in. (440 x 89 x 155 mm).

Weight: Net, 8 $\frac{1}{2}$ lb (3.9 kg); shipping, 10 lb (4.6 kg).

| Catalog Number | Description | Price in USA |
|----------------|--------------------------|--------------|
| 1412-9410 | 1412-BC Decade Capacitor | \$250.00 |

standard inductors



STANDARD INDUCTOR

Type 1482

- stable within $\pm 0.01\%$ per year
- low, known temperature coefficient
- minimized connection errors
- toroidal — free from external fields



1482-A



1482-D

The 1482 is an accurate, highly stable standard of self inductance for use as a low-frequency reference or working standard in the laboratory. Records extending over 11 years, including those of inductors that traveled to national laboratories in several countries for calibration, show long-term stabilities well within $\pm 0.01\%$.

Each inductor is a uniformly wound toroid on a ceramic core. It has a negligible external magnetic field and hence essentially no pickup from external fields. The inductor is resiliently supported in a mixture of ground cork and

silica gel, after which the whole assembly is cast with a potting compound into a cubical aluminum case.

Sizes of $500\ \mu\text{H}$ and above have three terminals, two for the inductor leads and the third connected to the case, to provide either a two- or three-terminal standard. The $50\text{-}, 100\text{-},$ and $200\text{-}\mu\text{H}$ sizes have three additional terminals for the switching used to minimize connection errors, as described in the introduction to the inductance section.

For comparing other inductors with these standards, the 1632-A Inductance Bridge is recommended.

specifications

Inductance Range: See table.

Accuracy of Adjustment: See table.

Calibration: A certificate of calibration is provided with each unit, giving measured values of inductance at 100, 200, 400, and 1000 Hz, with temperature and method of measurement specified. These values are obtained by comparison, to a precision, typically, of better than $\pm 0.005\%$, with working standards whose absolute values, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards, are known to an accuracy typically $\pm(0.02\% + 0.1\ \mu\text{H})$ at 100 Hz.

Stability: Inductance change is less than $\pm 0.01\%$ per year.

Dc Resistance: See table for representative values. A measured value of resistance at a specified temperature is given on the certificate of calibration.

Low-Frequency Storage Factor Q: See table for representative values of Q at 100 Hz (essentially from dc resistance). An indi-

vidual value of Q, calculated from the measured dc resistance, is given on each certificate of calibration.

Temperature Coefficient of Inductance: Approx 30 ppm per $^{\circ}\text{C}$. Minute temperature corrections may be computed from dc resistance changes. A 1% increase in resistance, produced by a temperature increase of 2.54°C , corresponds to 0.0076% increase in inductance.

Resonant Frequency: See table for representative values. A measured value is given on the certificate of calibration.

Max Input Power: For a rise of 20°C , 3 W; for precise work, a rise of 1.5°C , 200 mW. See table for corresponding current limits.

Terminals: Jack-top binding posts on $3/4\text{-in.}$ spacing with removable ground strap.

Mounting: Aluminum cabinet with handle and rubber feet.

Dimensions (width x height x depth): $6\frac{1}{2} \times 6\frac{1}{2} \times 8$ in. (165 x 165 x 205 mm).

Weight: Net, $11\frac{1}{2}$ lb (5.5 kg); shipping, 13 lb (6 kg).

| Catalog Number | Description | Nominal Inductance | Adjustment Accuracy (Percent) | *Resonant Frequency (kHz) | *Dc Resistance (Ohms) | *Q at 100 Hz | Milliamperes, rms for, | | Price in USA |
|--------------------------|---------------|--------------------|-------------------------------|---------------------------|-----------------------|--------------|------------------------|------|-----------------|
| | | | | | | | 200 mW | 3 W | |
| Standard Inductor | | | | | | | | | |
| 1482-9701 | 1482-A | 50 μH | ± 0.5 | 3100 | 0.039 | 0.81 | 2260 | 8770 | \$195.00 |
| 1482-9702 | 1482-B | 100 μH | ± 0.25 | 2250 | 0.083 | 0.76 | 1550 | 6010 | 195.00 |
| 1482-9703 | 1482-C | 200 μH | ± 0.25 | 1400 | 0.15 | 0.84 | 1150 | 4470 | 195.00 |
| 1482-9704 | 1482-D | 500 μH | ± 0.1 | 960 | 0.38 | 0.83 | 725 | 2810 | 195.00 |
| 1482-9705 | 1482-E | 1 mH | ± 0.1 | 800 | 0.84 | 0.75 | 490 | 1890 | 175.00 |
| 1482-9706 | 1482-F | 2 mH | ± 0.1 | 580 | 1.52 | 0.83 | 360 | 1400 | 155.00 |
| 1482-9707 | 1482-G | 5 mH | ± 0.1 | 320 | 3.8 | 0.83 | 230 | 890 | 150.00 |
| 1482-9708 | 1482-H | 10 mH | ± 0.1 | 220 | 8.2 | 0.77 | 156 | 600 | 145.00 |
| 1482-9710 | 1482-J | 20 mH | ± 0.1 | 145 | 14.5 | 0.87 | 117 | 450 | 145.00 |
| 1482-9711 | 1482-K | 50 mH | ± 0.1 | 84 | 36.8 | 0.85 | 74 | 280 | 145.00 |
| 1482-9712 | 1482-L | 100 mH | ± 0.1 | 71 | 81 | 0.78 | 50 | 192 | 150.00 |
| 1482-9713 | 1482-M | 200 mH | ± 0.1 | 39.0 | 109 | 1.15 | 43 | 166 | 155.00 |
| 1482-9714 | 1482-N | 500 mH | ± 0.1 | 24.5 | 280 | 1.12 | 27 | 103 | 160.00 |
| 1482-9716 | 1482-P | 1 H | ± 0.1 | 14.6 | 616 | 1.02 | 18 | 70 | 190.00 |
| 1482-9717 | 1482-Q | 2 H | ± 0.1 | 10.6 | 1125 | 1.12 | 13.3 | 52 | 220.00 |
| 1482-9718 | 1482-R | 5 H | ± 0.1 | 6.8 | 2920 | 1.08 | 8.3 | 32 | 290.00 |
| 1482-9720 | 1482-T | 10 H | ± 0.1 | 4.9 | 6400 | 0.98 | 5.6 | 22 | 385.00 |

* Representative values. Actual values given on certificate.



VARIABLE INDUCTOR

Type 107



- 20:1 continuous variation with series or parallel connections
- mutual- and self-inductance calibration

The 107 finds its greatest uses in the laboratory as an adjustable standard of moderate accuracy for measurements of self and mutual inductance, and as a circuit element in bridges, oscillators, and similar equipment.

Rotor and stator coils are mounted concentrically. The effective inductance depends upon the position of the rotor with respect to the stator.

In most models stranded wire is used, in which the separate strands are insulated from one another. The coils are impregnated and baked in a synthetic varnish before being securely mounted on the phenolic panel.

Dial is direct reading in inductance for the series connection of the coils. Inductance for the parallel connection is one-fourth the value shown by the dial.

specifications

Inductance Range: See table below. Dial is direct reading in inductance for the series connection.

Accuracy: Series connection, $\pm 1\%$ of full scale at 1 kHz. Inductance for parallel connection is one-fourth the series value within $\pm(1\% + 0.01 \mu\text{H})$ of the former. Mutual-inductance accuracy is $\pm 2.5\%$ of full-scale (mutual) value. The formula for mutual inductance is engraved on the nameplate. Under our standard warranty, this accuracy is guaranteed for 2 years.

Frequency Characteristics: The fractional increase in inductance with frequency will be f^2/f_0^2 where f is the operating frequency and f_0 the natural frequency, which can be calculated from

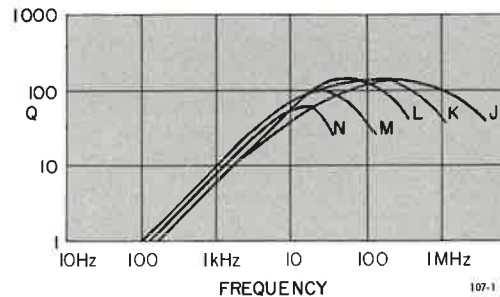
$$f_0 = \frac{1}{2\pi\sqrt{LC_0}}$$

Values of C_0 are tabulated below. See plot for change in Q with frequency.

Max Power and Current: Current for 15 W max dissipation, corresponding to a temperature rise of 40°C , is given in the table below and is engraved on the nameplate.

Dc Resistance: See table below. These series-connection values are engraved on the nameplate. For parallel connections the resistance is approx $1/4$ the tabulated values.

Terminals: Standard $3/4$ -in. spacing, jack-top binding posts pro-



Storage factor, Q , versus frequency at full-scale series connection.

vide separate connections to rotor and stator. Series and parallel connections are made by means of links.

Mounting: All units are mounted on phenolic panels and enclosed in unshielded hardwood cabinets.

Dimensions: $6\frac{1}{2} \times 6\frac{1}{2} \times 8\frac{3}{4}$ in. (165 x 165 x 220 mm).

Weight: Net, 5 lb (2.3 kg); shipping, 10 lb (4.6 kg).

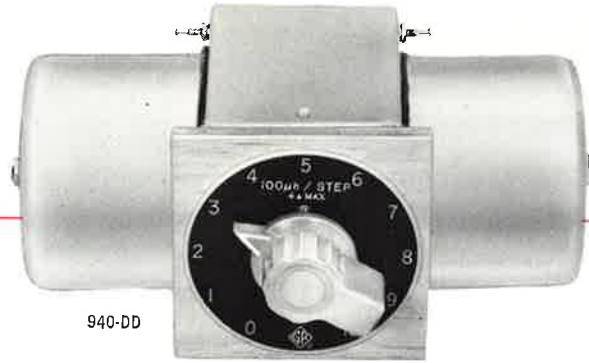
| Catalog Number | Description | Self-Inductance | | Mutual Inductance | Typical C_0 Values | | Dc Resistance ohms | Maximum Current amperes | Price in USA |
|--------------------------|--------------|----------------------|-------------------------|----------------------|----------------------|----------|--------------------|-------------------------|-----------------|
| | | Series | Parallel | | Series | Parallel | | | |
| Variable Inductor | | | | | | | | | |
| 0107-9710 | 107-J | 9-50 μH | 2.25-12.5 μH | 0-10.8 μH | 35 pF | 57 pF | 0.05 | 16 | \$150.00 |
| 0107-9711 | 107-K | 90-500 μH | 22.5-125 μH | 0-110 μH | 40 pF | 72 pF | 0.38 | 6 | 150.00 |
| 0107-9712 | 107-L | 0.9-5 mH | 0.225-1.25 mH | 0-1.1 mH | 39 pF | 73 pF | 5.0 | 1.7 | 150.00 |
| 0107-9713 | 107-M | 9-50 mH | 2.25-12.5 mH | 0-11 mH | 34 pF | 41 pF | 36 | 0.65 | 150.00 |
| 0107-9714 | 107-N | 90-500 mH | 22.5-125 mH | 0-110 mH | 34 pF | 41 pF | 450 | 0.17 | 150.00 |

standard inductors



DECADE-INDUCTOR UNIT

Type 940



Each 940 Decade-Inductor Unit is an assembly of four inductors (relative values, 1, 2, 2, 5) wound on molybdenum-permalloy dust cores, which are combined by switching to give the eleven successive values from 0 to 10. The decade switch has high-quality ceramic stator-and-rotor members and well-defined ball-and-socket detents. All contacts are made of a silver alloy and have a positive wiping action.

specifications

Accuracy: Each unit is adjusted so that its inductance at zero frequency and initial permeability will be the nominal value within the accuracy tolerance given in the following table:

| Unit | 940-DD | 940-E | 940-F | 940-G | 940-H |
|---------------------|-------------|-----------|-----------|-------------|-------------|
| Inductance per step | 100 μ H | 1 mH | 10 mH | 100 mH | 1 H |
| Accuracy | $\pm 2\%$ | $\pm 2\%$ | $\pm 1\%$ | $\pm 0.6\%$ | $\pm 0.6\%$ |

Under our standard warranty, this accuracy is guaranteed for 2 years if the inductor has not been damaged.

Frequency Characteristics: For any specific operating frequency, Figure 2 shows the percentage increase in effective series inductance (above the value when $f = 0$), which is encountered with the extreme settings of each of the five decade-inductor units when the chassis is floating. Interpolation may be used for intermediate settings.

Change in Inductance with Current: Fractional change in initial inductance with ac current for each type of toroid is shown in the normal curves, Figure 1, in terms of the ratio of the operating current, I , to I_1 , the current for 0.25% change, solid line (0.1%, broken line). For ratios below unity, inductance change is directly

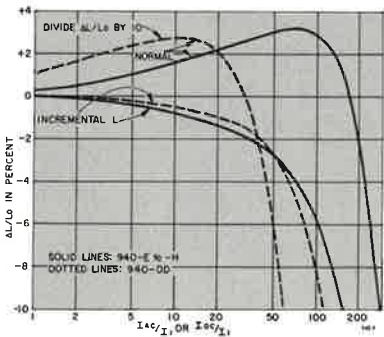


Figure 1. Percentage change in normal and incremental inductance with ac and bias current. Incremental curve is limited to an ac excitation less than I_1 .

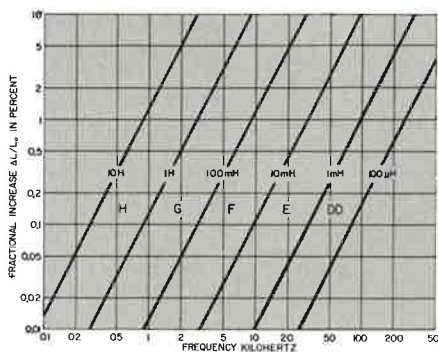


Figure 2. Change in effective inductance with frequency for the 940 Decade-Inductor Units.

proportional to current. Values of I_1 , listed below, are approximate and are based on the largest inductor in the circuit for each setting.

Incremental Inductance: Dc bias current I_b will reduce the initial inductance as shown in the incremental curves, Figure 1.

| Switch Setting | RMS I_1 (mA) | | | | |
|-------------------|----------------|----------------|-------|-------|-------|
| | 0.1% Increase | 0.25% Increase | | | |
| | 940-DD | 940-E | 940-F | 940-G | 940-H |
| 1 | 141 | 17 | 5.4 | 1.7 | 0.54 |
| 2, 3, 4 | 100 | 12 | 3.8 | 1.2 | 0.38 |
| 5, 6, 7, 8, 9, 10 | 63 | 8 | 2.4 | 0.8 | 0.24 |

Storage Factor Q: See Figure 3;

Dc Resistance: Approx 45 Ω per henry.

Temperature Coefficient: Approx -25 ppm per degree C between 16° and 32° C.

Max Safe Current: Approx 200 times the pertinent I_1 value (30 times for the 940-DD). Max current engraved on dial.

Terminals: Solder lugs. Circuit insulated from chassis.

Mounting: Hardware included, with dial plate and knob.

Dimensions (width x height x depth): 8 x $3\frac{1}{2}$ x $4\frac{1}{4}$ in. (205 x 90 x 110 mm).

Weight: Net, $3\frac{1}{2}$ lb (1.6 kg); shipping, 6 lb (2.8 kg).

| Catalog Number | Description | Inductance | | Price in USA |
|------------------------|---------------|------------|-------------|-----------------|
| | | Total | Steps | |
| Decade Inductor | | | | |
| 0940-9810 | 940-DD | 1 mH | 100 μ H | \$180.00 |
| 0940-9705 | 940-E | 0.01 H | 0.001 H | 170.00 |
| 0940-9706 | 940-F | 0.1 H | 0.01 H | 120.00 |
| 0940-9707 | 940-G | 1 H | 0.1 H | 180.00 |
| 0940-9708 | 940-H | 10 H | 1 H | 195.00 |

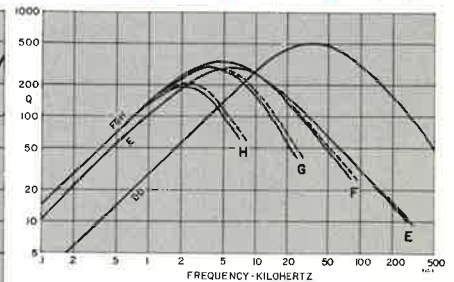


Figure 3. Variation of Q for the maximum inductance of each 940 Decade-Inductor Unit at low excitation levels. Dashed curves correspond to use with chassis floating.



DECADE INDUCTOR

Type 1491

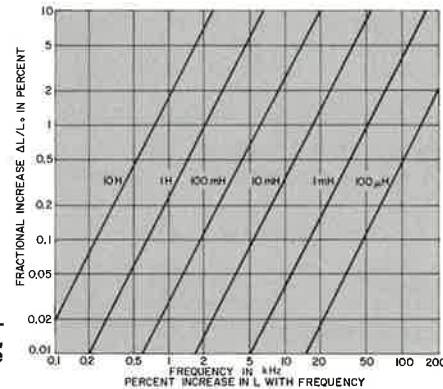


- high-Q
- shielded toroidal cores for small mutual inductance
little effect from external fields
- sealed against moisture

1491-G

The 1491 Decade Inductor is an assembly of several 940 Decade-Inductor Units in a single metal cabinet. The units have no electrical connection to the panel, but a separate ground terminal is provided, which can be connected to the adjacent low terminal, leading to the smallest decade.

These inductance decades are convenient elements for use in wave filters, equalizers, and tuned circuits throughout the range of audio and low radio frequencies. As components in oscillators, analyzers, and similar equipment, they are especially useful during the preliminary design period, when the ability to vary circuit elements over relatively wide ranges is necessary to determine optimum operating values. As moderately precise standards of inductance they have values of low-frequency storage factor, Q, that are much larger than those of air-core coils.



Variation of inductance with frequency, for the 1491 Decade Inductors.

specifications (see also specifications for 940 decade units)

Frequency Characteristics: Percentage increase in effective series inductance (above the zero-frequency value, L_0) may be obtained by interpolation in accompanying graph for any setting of the highest-value decade used, when LOW terminal is grounded to cabinet.

Zero Inductance: Approx 1 μ H.

Max Voltage: 500 V rms. Switch will break circuit at 500 V if turned rapidly, but voltages above 150 V may cause destructive arcing with switch between detent positions.

Terminals: Binding posts on 3/4-in. centers; separate ground terminal provided.

Mounting: Lab-Bench Cabinet.

Dimensions (width x height x depth):

| | | | |
|-----------------------|-------|-------------------|--------------------|
| 1491-A, -B, -C | Bench | 12¾ x 8¾ x 6½ in. | 325 x 225 x 170 mm |
| | Rack | 19 x 8¾ x 47⅝ in. | 485 x 225 x 125 mm |
| 1491-D, -F, -G | Bench | 17 x 8¾ x 6½ in. | 435 x 225 x 170 mm |
| | Rack | 19 x 8¾ x 47⅝ in. | 485 x 225 x 125 mm |

Weight (bench models; add 1¾ lb (0.8 kg) for rack models):

| | Net | Shipping (est) |
|-----------------------|------------------|-----------------|
| 1491-A, -B, -C | 18 lb (8.5 kg) | 25 lb (11.7 kg) |
| 1491-D, -F | 23 lb (10.5 kg) | 30 lb (13.7 kg) |
| 1491-G | 26½ lb (12.5 kg) | 34 lb (15.5 kg) |

| Catalog Number | | Description | Inductance | | 940's Included | Price in USA | |
|------------------------|-----------|---------------|------------|----------|----------------|--------------|----------|
| Bench | Rack | | Total | Steps | | Bench | Rack |
| Decade Inductor | | | | | | | |
| 1491-9701 | 1491-9711 | 1491-A | 0.111 H | 0.0001 H | DD, E, F | \$515.00 | \$540.00 |
| 1491-9706 | 1491-9716 | 1491-F | 1.111 H | 0.0001 H | DD, E, F, G | 715.00 | 735.00 |
| 1491-9703 | 1491-9713 | 1491-C | 1.11 H | 0.001 H | E, F, G | 540.00 | 565.00 |
| 1491-9707 | 1491-9717 | 1491-G | 11.111 H | 0.0001 H | DD, E, F, G, H | 895.00 | 915.00 |
| 1491-9704 | 1491-9714 | 1491-D | 11.11 H | 0.001 H | E, F, G, H | 725.00 | 745.00 |
| 1491-9702 | 1491-9712 | 1491-B | 11.1 H | 0.01 H | F, G, H | 600.00 | 625.00 |

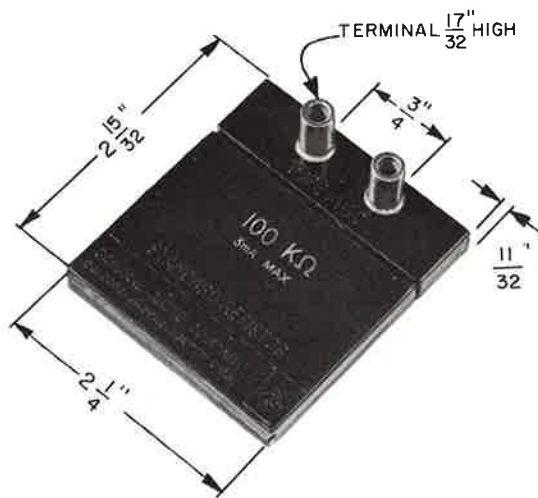


standard resistors

STANDARD RESISTOR

Type 1440

- accuracy $\pm 0.01\%$
- stability ± 10 ppm per year
- low thermal emf to copper



These extremely stable resistors are intended for use as laboratory or production standards for calibrating resistance bridges and for substitution measurements.

They are card-type, wire-wound resistors, carefully wound and adjusted. Low-temperature-coefficient Evanohm* wire is used for values above 10 ohms, manganin for the lower-resistance units. All units are heat cycled to reduce strains and are repeatedly checked to elimi-

nate any that show abnormal behavior. They are encased in sealed, oil-filled, diallylphthalate boxes to promote long-term stability and to provide mechanical protection.

The 1440 resistors have low-thermal-emf binding posts and removable banana plugs to provide the four terminals necessary for accurate measurements at low values of resistance. A label on the reverse side lists initial calibration and date, space for future calibration data, and serial number.

* Registered trademark of the Wilbur B. Driver Company.

— See **GR Experimenter** for October 1965.

specifications

Accuracy: $\pm 0.01\%$ for all units except those of 1 Ω , which are $\pm 0.02\%$. This accuracy is guaranteed for our standard warranty period of two years, unless the resistor has been damaged by excessive current. Measurements on the low-value units should be made with a four-terminal connection. All measurements at 23°C.

Calibration Accuracy: Resistors are calibrated by comparison, to a precision of ± 20 ppm, with working standards whose absolute values are known typically to ± 10 ppm as determined and measured in terms of reference standards periodically measured by the National Bureau of Standards. The measured deviation from nominal value, at 23°C and 0.01 watt, is entered on the label on the reverse side of the resistor.

Stability: Typically ± 10 ppm per year.

Temperature Coefficient (Max): ± 10 ppm/°C for resistances above 10 Ω ; ± 20 ppm/°C for 10 Ω and below.

Power Rating: 1 W. The corresponding current is indicated on the resistor and in the table below. This dissipation will cause a temperature rise of approx 25°C and a resulting temporary resistance change due to the temperature coefficient. If this rating is exceeded, permanent changes may result.

Residual Impedances: Approx shunt capacitance (2-terminal measurement), 2.5 pF; less for 3-terminal measurement. Typical series inductance, see table.

Approx Frequency Characteristic: See table.

Terminals: Gold-plated jack-top copper binding posts (3/4-in. spacing) with banana plugs that are removable and can be replaced by 6-32 screws for installation of soldering lugs.

Dimensions (less terminals): 2 3/4 x 2 1/2 x 1 1/2 in. (58 x 64 x 10 mm).

Net Weight (approx): 2 oz (60 g).

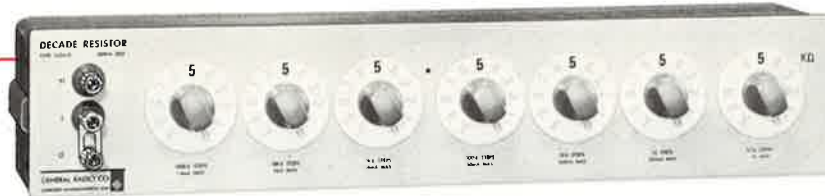
| Catalog Number | Resistance | Max Current | Typical Inductance | Approx Frequency for 0.1% Resistance Change | | Price In USA |
|----------------|----------------|-------------|--------------------|---|------------|--------------|
| | | | | Series R | Parallel R | |
| 1440-9601 | 1 Ω | 1.0 A | 0.12 μ H | 300 kHz | 30 kHz | \$30.00 |
| 1440-9611 | 10 Ω | 310 mA | 0.13 μ H | 1 MHz | 300 kHz | 30.00 |
| 1440-9621 | 100 Ω | 100 mA | 0.20 μ H | 3 MHz | 1 MHz | 30.00 |
| 1440-9631 | 1 k Ω | 30 mA | 2.5 μ H | 2 MHz | 1 MHz | 30.00 |
| 1440-9641 | 10 k Ω | 10 mA | | 200 kHz | 1 MHz | 30.00 |
| 1440-9651 | 100 k Ω | 3 mA | | 20 kHz | 100 kHz | 33.00 |
| 1440-9661 | 1 M Ω | 1 mA | | 2 kHz | 10 kHz | 37.00 |



- ±0.05% accuracy
- 5-, 6-, or 7-dial settability
- excellent stability, low cost

DECADE RESISTOR

Type 1434



These laboratory-quality, budget-priced decade boxes are designed for maximum usefulness and economy in laboratory measurement, testing, and development work. Their accuracy is adequate for all but the most exacting applications and their small size and clear readout should be particularly useful in experimental setups using small, modern components.

The 1434-M, -N, and -P contain five step decades of resistance in a small cabinet. The 1434-B and -X, 6-dial boxes, permit small as well as large values of resistance to be set with 3- or 4-place resolution and accuracy. The 1434-QC, a "best buy," has four step decades plus a rheostat to provide 1-ohm resolution in a 1-megohm box.

The larger, seven-decade, 1434-G box is easily converted into a 3½-inch relay-rack unit by the addition of angle brackets and dress strips, which are furnished. This box has lug terminals available at the rear, as well as at panel binding posts.

DESCRIPTION

High-quality, wire-wound resistors are used in these decades. The low price is made possible by the use of only six resistors per decade instead of ten. These are combined by switching in such a way that there are no discontinuities, that is, the resistance increases stepwise just as if ten resistors were used. The switches have solid-silver-alloy contacts for low resistance and long life.

Resistors are of low-temperature-coefficient Evanohm* wire, except the 1-ohm/step decade, which uses manganin wire, and the 0.1-ohm/step decade, which uses manganin ribbon. The resistors of the 100-ohm/step, 10-ohm/step, and 1-ohm/step decades are Ayrton-Perry wound to minimize inductance.

— See **GR Experimenter** for October 1965.

* Registered trademark of the Wilbur B. Driver Company.

specifications

Accuracy

Long-term: Two-year warranty applies to the tolerances given barring damage by excessive current. Tolerances apply at low currents and at dc or low-frequency ac.

Over-all: The resistance difference between that at any setting and at the zero setting is equal to the indicated value ±(0.05% + 5 mΩ).

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

Zero Resistance: Approx 3 mΩ per dial at low frequencies except for the 1434-QC for which it is approx 30 mΩ.

Max Current: See table; these values also appear on the panel of each decade box. When this max current is passed through a decade, the temporary change in value will be less than the accuracy specification. Currents appreciably higher than this will cause permanent damage.

| Total Resistance of Decade | Resistance Per Step | Incremental Accuracy* | Max Current |
|----------------------------|---------------------|-----------------------|-------------|
| 1 Ω | 0.1 Ω | ±3.0% | 1 A |
| 10 Ω | 1.0 Ω | ±0.3% | 0.3 A |
| 100 Ω | 10 Ω | ±0.08% | 160 mA |
| 1 kΩ | 100 Ω | ±0.05% | 50 mA |
| 10 kΩ | 1 kΩ | ±0.05% | 16 mA |
| 100 kΩ | 10 kΩ | ±0.05% | 5 mA |
| 1 MΩ | 100 kΩ | ±0.05% | 1.6 mA |
| 100-Ω Rheostat** | 1 Ω/div | ±1 Ω | 200 mA |

* At low currents and low frequencies.

** Used in 1434-QC.

Temperature Coefficient: <±10 ppm/°C at room temperature, except for the low-valued units where the +0.4%/°C temperature coefficient of the zero resistance must be added.

Frequency Characteristics: Generally similar to those of the 1433 Decades.

Switches: Multiple, solid-silver-alloy switches are used to obtain low and stable zero resistance.

Terminals: Jack-top binding posts on standard ¾-in. spacing. A shield terminal is also provided. The 1434-G has lug connections accessible from the rear.

Mounting: All types except the 1434-G are in small cabinets for bench use. The 1434-G is also designed for bench use but, with the addition of mounting hardware, becomes 3½-in. high, 19-in. relay-rack unit.

Mechanical Data:

| Models | Width | | Height | | Depth | | Net Weight | | Shipping Weight | |
|-------------|-------|-----|--------|----|-------|-----|------------|-----|-----------------|-----|
| | in. | mm | in. | mm | in. | mm | lb | kg | lb | kg |
| M, N, P, QC | 11¾ | 300 | 2¾ | 70 | 4¼ | 110 | 3 | 1.4 | 4 | 1.9 |
| B, X | 13¾ | 350 | 2¾ | 70 | 4¼ | 110 | 3¼ | 1.5 | 4 | 1.9 |
| G (bench) | 17¾ | 442 | 3½ | 89 | 5 | 130 | 6 | 2.8 | 7 | 3.2 |
| G (rack) | 19 | 485 | 3½ | 89 | 3½ | 89 | 6 | 2.8 | 7 | 3.2 |

| Catalog Number | Description | Total Resistance (Ω) | Resistance Per Step | Number of Decades | Price in USA |
|------------------------|----------------|----------------------|---------------------|-------------------|--------------|
| Decade Resistor | | | | | |
| 1434-9714 | 1434-N | 11,111 | 0.1 Ω | 5 | \$124.00 |
| 1434-9713 | 1434-M | 111,110 | 1.0 Ω | 5 | 119.00 |
| 1434-9716 | 1434-P | 1,111,100 | 10 Ω | 5 | 137.00 |
| 1434-9576 | 1434-QC | 1,111,105 | 1 Ω/div | 4 + rheostat | 124.00 |
| 1434-9702 | 1434-B | 1,111,100 | 1.0 Ω | 6 | 165.00 |
| 1434-9724 | 1434-X | 111,111 | 0.1 Ω | 6 | 155.00 |
| 1434-9707 | 1434-G | 1,111,111 | 0.1 Ω | 7 | 193.00 |



DECADE RESISTOR

Type 1433

- $\pm 0.02\%$ accuracy
- good frequency characteristics
- low temperature coefficient
- excellent stability
- low zero resistance



The 1433 Decade Resistors are primarily intended for precision measurement applications where their excellent accuracy, stability, and low zero resistance are important. They are convenient resistance standards for checking the accuracy of resistance-measuring devices and are used as components in dc and audio-frequency impedance bridges. Many of the models can be used up into the radio-frequency range. While they are also useful as substitution boxes for optimizing electronic circuitry, the less expensive Type 1434 Decade Resistors are recommended for such less exacting applications.

The individual decades (510 Decade-Resistance Units) are available for applications requiring only one decade or as components to be built into experimental equipment, production test equipment, or commercial instruments.

specifications

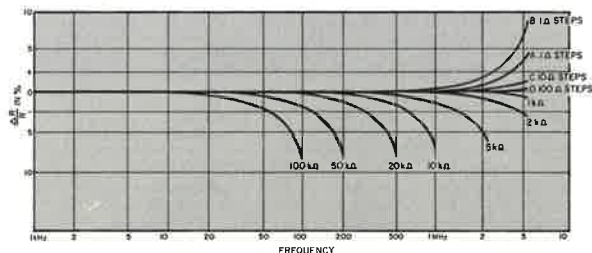
Long-Term Accuracy: Our two-year warranty applies to the tolerances given below unless the resistor is damaged by excessive current. These tolerances apply for low-current measurement at dc or low-frequency ac (see below).

Over-all Accuracy: The resistance difference between that at any setting and at the zero setting is equal to the indicated value $\pm(0.02\% + 2 \text{ m}\Omega)$.

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



Max percentage change in series resistance as a function of frequency for Type 510 Decade-Resistance Units.

DESCRIPTION

The 1433 Decade Resistor is an assembly of 510 Decade-Resistance Units in a single cabinet. Mechanical as well as electrical shielding of the units and switch contacts is provided by the attractive aluminum cabinet and panel. The resistance elements have no electrical connection to the cabinet and panel, for which a separate shield terminal is provided.

Each Type 510 Decade-Resistance Unit is enclosed in an aluminum shield, and a knob and etched-metal dial plate are supplied. Each decade has ten resistors in series; the contacts in the lower-valued decades have a silver overlay to ensure stability of resistance, and all the decades have a silver contact on the zero setting to give low and constant zero resistance. Winding methods are chosen to reduce the effects of residual reactances.

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, while 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.

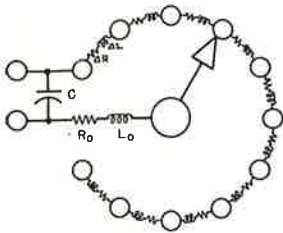
Characteristics of the 1433's are similar to those of the individual 510's modified by the increased series inductance, L_s , and shunt capacitance, C , due to the wiring and the presence of more than one decade in the assembly. At total resistance settings of approx 1000 ohms or less, the frequency 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 \pm 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



Equivalent circuit of a resistance decade, showing location and nature of residual impedances.

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 $\frac{3}{8}$ -in. diameter in such a manner as to avoid cutting but yet give a good wiping action. A cam-type detent is provided. There are eleven contact points (0 to 10 inclusive). The switch resist-

ance 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 on the mica-filled phenolic form used in the 510-G and 510-H units.

Max Voltage to Case: 2000 V pk.

Terminals: For 1433, low-thermal-emf jack-top binding posts on standard $\frac{3}{4}$ -in. spacing; also provisions for rear-panel connections. Shield terminal is provided; 510's have soldering lugs.

Mounting: 1433's in lab-bench cabinet, rack models include mounting hardware; 510's complete with dial plate, knob, template, and mounting screws.

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 $\frac{1}{4}$ (315) | 14 $\frac{3}{4}$ (375) | 17 $\frac{1}{4}$ (445) | |
| Height | 3 $\frac{1}{2}$ (89) | | 5 $\frac{1}{4}$ (135) | |
| Depth | 5 in. over-all, 4 in. behind panel | | | |
| Net Wt* | 4 $\frac{3}{4}$ (2.2) | 5 $\frac{3}{4}$ (2.7) | 7 (3.2) | 8 $\frac{3}{4}$ (4.0) |
| Ship. Wt* | 5 $\frac{1}{2}$ (2.5) | 6 $\frac{1}{2}$ (3.0) | 8 $\frac{1}{2}$ (3.9) | 10 $\frac{1}{4}$ (4.7) |

*Data given for bench models. All rack models same except 19 in. wide. Add approx 1 lb for rack-mount hardware.

Type 510's 3 $\frac{1}{8}$ in. (78 mm) diameter, 3 $\frac{3}{8}$ in. (85 mm) behind panel, 11 oz (0.4 kg) net weight.

| Catalog Number | | Type | Total Ohms | Ohms per Step | No. of Dials | Type 510 Decades Used | Price in USA | |
|----------------|-----------|--------|------------|---------------|--------------|-----------------------|--------------|----------|
| Bench | Rack | | | | | | Bench | Rack |
| 1433-9700 | 1433-9701 | 1433-U | 111.1 | 0.01 | 4 | AA, A, B, C | \$120.00 | \$128.00 |
| 1433-9702 | 1433-9703 | 1433-K | 1111 | 0.1 | 4 | A, B, C, D | 122.00 | 130.00 |
| 1433-9704 | 1433-9705 | 1433-J | 11,110 | 1 | 4 | B, C, D, E | 125.00 | 133.00 |
| 1433-9706 | 1433-9707 | 1433-L | 111,100 | 10 | 4 | C, D, E, F | 120.00 | 128.00 |
| 1433-9708 | 1433-9709 | 1433-Q | 1,111,000 | 100 | 4 | D, E, F, G | 154.00 | 162.00 |
| 1433-9710 | 1433-9711 | 1433-T | 1111.1 | 0.01 | 5 | AA, A, B, C, D | 146.50 | 154.50 |
| 1433-9712 | 1433-9713 | 1433-N | 11,111 | 0.1 | 5 | A, B, C, D, E | 144.00 | 152.00 |
| 1433-9714 | 1433-9715 | 1433-M | 111,110 | 1 | 5 | B, C, D, E, F | 147.50 | 155.50 |
| 1433-9716 | 1433-9717 | 1433-P | 1,111,100 | 10 | 5 | C, D, E, F, G | 182.50 | 190.50 |
| 1433-9718 | 1433-9719 | 1433-Y | 11,111,000 | 100 | 5 | D, E, F, G, H | 247.50 | 255.50 |
| 1433-9720 | 1433-9721 | 1433-W | 11,111.1 | 0.01 | 6 | AA, A, B, C, D, E | 168.50 | 176.50 |
| 1433-9722 | 1433-9723 | 1433-X | 111,111 | 0.1 | 6 | A, B, C, D, E, F | 166.50 | 174.50 |
| 1433-9724 | 1433-9725 | 1433-B | 1,111,110 | 1 | 6 | B, C, D, E, F, G | 210.00 | 218.00 |
| 1433-9726 | 1433-9728 | 1433-Z | 11,111,100 | 10 | 6 | C, D, E, F, G, H | 276.00 | 284.00 |
| 1433-9729 | 1433-9730 | 1433-F | 111,111.1 | 0.01 | 7 | AA, A, B, C, D, E, F | 191.00 | 199.00 |
| 1433-9731 | 1433-9732 | 1433-G | 1,111,111 | 0.1 | 7 | A, B, C, D, E, F, G | 229.00 | 237.00 |
| 1433-9733 | 1433-9734 | 1433-H | 11,111,110 | 1 | 7 | B, C, D, E, F, G, H | 303.50 | 311.50 |



DECADE-RESISTANCE UNITS

Type 510

| Catalog Number | 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_0 μH | Price in USA |
|----------------|---------|-----------------------|---|-----------------------------------|------------------------|----------------------|--------------------|---------|---------------|--------------|
| 0510-9806 | 510-AA | 0.1 | 0.01 | $\pm 2\%$ | 4 A | 0.16 | 0.01 | 7.7-4.5 | 0.023 | \$23.00 |
| 0510-9701 | 510-A | 1 | 0.1 | $\pm 0.4\%$ | 1.6 A | 0.25 | 0.014 | 7.7-4.5 | 0.023 | 17.50 |
| 0510-9702 | 510-B | 10 | 1 | $\pm 0.1\%$ | 800 mA | 0.6 | 0.056 | 7.7-4.5 | 0.023 | 26.00 |
| 0510-9703 | 510-C | 100 | 10 | $\pm 0.04\%$ | 250 mA | 0.6 | 0.11 | 7.7-4.5 | 0.023 | 27.00 |
| 0510-9704 | 510-D | 1000 | 100 | $\pm 0.02\%$ | 80 mA | 0.6 | 0.29 | 7.7-4.5 | 0.023 | 25.00 |
| 0510-9705 | 510-E | 10,000 | 1000 | $\pm 0.02\%$ | 23 mA | 0.5 | 13 | 7.7-4.5 | 0.023 | 20.50 |
| 0510-9706 | 510-F | 100,000 | 10,000 | $\pm 0.02\%$ | 7 mA | 0.5 | 70 | 7.7-4.5 | 0.023 | 21.00 |
| 0510-9707 | 510-G | 1,000,000 | 100,000 | $\pm 0.02\%$ | 2.3 mA | 0.5 | — | 7.7-4.5 | 0.023 | 61.00 |
| 0510-9708 | 510-H | 10,000,000 | 1,000,000 | $\pm 0.02\%$ | 0.7* mA | 0.5 | — | 7.5-4.5 | 0.023 | 92.00 |
| 0510-9604 | 510-P4 | Switch only | | | | | | | | 11.00 |
| 0510-9511 | 510-P4L | Switch only | | | | | | | | 12.00 |

*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.

GENERAL RADIO

West Concord, Massachusetts 01781

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