

Type 1426

FOUR-TERMINAL CAPACITANCE STANDARD

NOTE

The + and - signs near the terminals do not indicate dc polarity; they are for terminal identification when connection is made to a four-terminal bridge.

specifications

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

Accuracy: $\pm 1/4\%$, except $\pm 1/2\%$ for 100 mF and $\pm 1\%$ for 1 F; measured at 120 Hz at 23°C at <Max Volts 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.

| 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 |

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.

Mounting: Aluminum cabinet.

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).

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.

SECTION 1

INTRODUCTION

1.1 PURPOSE.

The 1426 capacitance standard is used to calibrate four-terminal, high-capacitance bridges, such as the GR 1617. The specified accuracy of the 1426 applies to four-terminal measurements, at 120 Hz, only.

Although the accuracy specifications do not apply for two-terminal measurements, the 1426 finds limited use, at settings of 10 mF and lower (at 120 Hz), as a two-terminal standard.

1.2 DESCRIPTION.

The internal components of the 1426 are housed in an aluminum cabinet and front panel. There are four-binding-post terminals on the panel: three are

insulated from the panel and cabinet, the other is grounded to the panel.

Seven capacitance settings, from 1 μF to 1 F, are available via a single knob. Accuracy and voltage limitations for each setting are clearly marked on the panel.

When set at the 1 μF position, the terminals are connected directly to a 1 μF polystyrene capacitor, and the standard is a true capacitor in every respect. In the other six positions, however, the terminals are connected to the same 1 μF capacitor through a transformer that, in effect, multiplies the effective capacitance. The resultant values of capacitance are adjusted to a specified accuracy through the use of factory-selected padding capacitors.

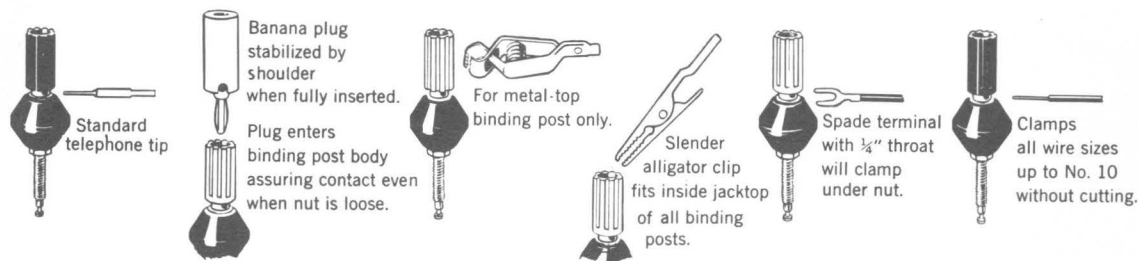


Figure 2-1. Methods of connection to binding-post terminals.

2.1 CONNECTIONS - GENERAL.

The terminals on the 1426 are standard 3/4-inch-spaced binding posts that accept banana plugs, standard telephone tips, alligator clips, crocodile clips, spade terminals and wire sizes up to No. 10. See Figure 2-1.

The banana-plug patch cords listed in Table 2-1 are GR catalog items available for use with bridges and standards equipped with 3/4-inch-spaced binding posts.

A special cable assembly (see Figure 2-2), designed for four-terminal connections, is also avail-

able. (This cable is normally supplied as an accessory with the GR 1617 Capacitance Bridge.)

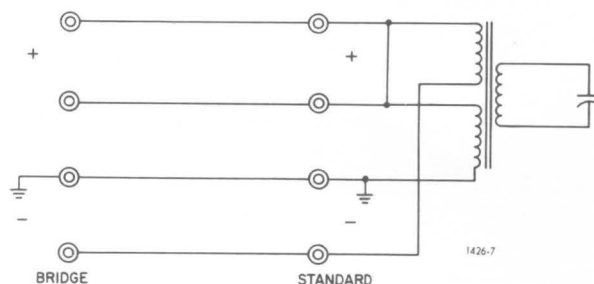


Figure 2-3. Four-terminal connection of 1426 standard to a four-terminal bridge.

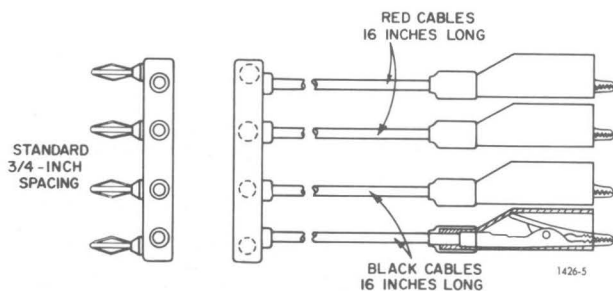






Figure 2-2. Cable assembly (P/N 1617-2210) for four-terminal measurements.

2.2 FOUR-TERMINAL CONNECTIONS.

To obtain the specified C and D accuracy, four-terminal connections are required for all settings above 1 μF . The terminals should be connected to the bridge as shown in Figure 2-3. Note that no shorting links are used between terminals on the bridge or on the standard.

| Table 2-1 | | | |
|---|---|----------------|--|
| PATCH-CORD ACCESSORIES | | | |
| Type | Description | Catalog Number | |
|  | 274-NQ Double-plug patch cord, in-line cord, 36'' long | 0274-9860 | |
| | 274-NQM Double-plug patch cord, in-line cord, 24'' long | 0274-9896 | |
| | 274-NQS Double-plug patch cord, in-line cord, 12'' long | 0274-9861 | |
|  | 274-NP Double-plug patch cord, right-angle cord, 36'' long | 0274-9880 | |
| | 274-NPM Double-plug patch cord, right-angle cord, 24'' long | 0274-9892 | |
| | 274-NPS Double-plug patch cord, right-angle cord, 12'' long | 0274-9852 | |
|  | 274-NL Shielded double-plug patch cord, 36'' long | 0274-9883 | |
| | 274-NLM Shielded double-plug patch cord, 24'' long | 0274-9882 | |
| | 274-NLS Shielded double-plug patch cord, 12'' long | 0274-9862 | |
|  | 274-LLB Single-plug patch cord, black, 36'' long | 0274-9468 | |
| | 274-LLR Single-plug patch cord, red, 36'' long | 0274-9492 | |
| | 274-LMB Single-plug patch cord, black, 24'' long | 0274-9847 | |
| | 274-LMR Single-plug patch cord, red, 24'' long | 0274-9848 | |
| | 274-LSB Single-plug patch cord, black, 12'' long | 0274-9849 | |
| | 274-LSR Single-plug patch cord, red, 12'' long | 0274-9850 | |

At the 1-F setting, the connecting-lead configuration becomes increasingly important, even when a four-terminal connection is used. Not only is it necessary to avoid D errors due to lead resistance, but sizeable capacitance errors caused by lead inductance must also be considered. While a four-lead connection removes the effect of the resistance and self-inductance of each lead, some care must be used to avoid mutual inductance between the outer two ("current") leads and the inner two ("potential") leads; see Figure 2-4. Mutual inductance here causes

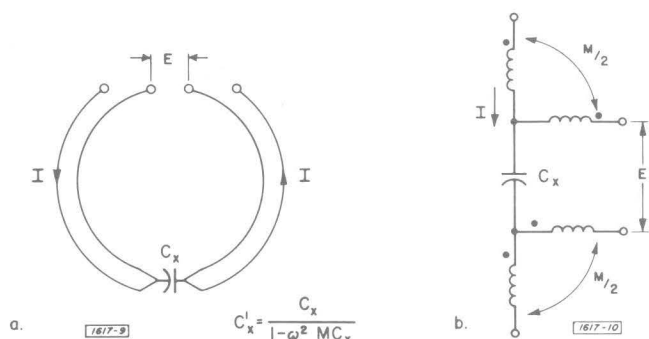


Figure 2-4. When "current" and "potential" leads form concentric loops (left), the resulting mutual inductance (right) affects the value of the capacitance being measured.

an induced voltage that increases the effective value of the standard. This mutual inductance can be greatly reduced by twisting together either the two outer leads or the two inner leads as shown in Figure 2-5.

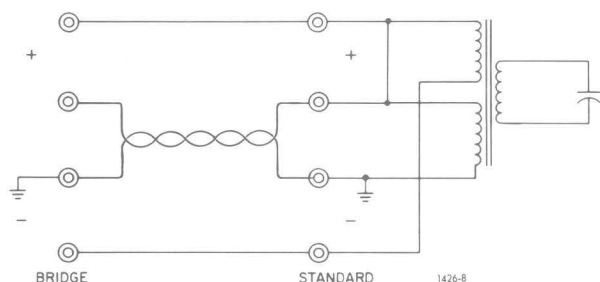


Figure 2-5. Four-terminal connection with reduction of the effect of mutual inductance in the leads.

This precaution against mutual inductance is also important when lower capacitance is measured at higher frequencies, because the error is a function of $\omega^2 M C_x$, where M is the total mutual inductance.

2.3 TWO-TERMINAL CONNECTION.

The 1426 can be used as a two-terminal standard provided certain limitations are acceptable. Two-terminal use should be restricted to the lower-valued settings (no higher than 10 mF). The standard should be calibrated at 120 Hz to allow for a somewhat higher effective capacitance and dissipation factor than normally specified for four-terminal use.

Figure 2-6 shows a two-terminal connection using a simplified schematic of the 1426 and the binding posts of a four-terminal bridge. Note the connecting links between the negative terminals of the 1426 as well as both sets of bridge terminals.

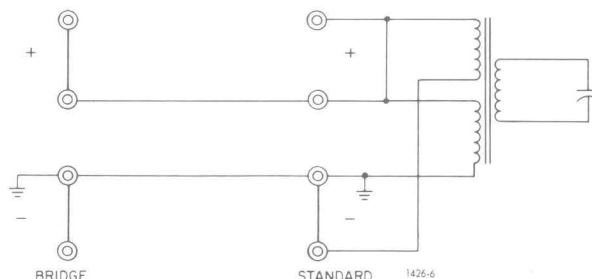


Figure 2-6. Two-terminal connection of the 1426 standard to a four-terminal bridge.

2.4 VOLTAGE LIMITATIONS.

Ac voltage limits are necessary because of the voltage rating of the standard capacitor used in the 1426 and because excessive voltage can change the effective value of the transformer parallel impedances (refer to paragraph 3.2). Such impedance changes can result in a small change in the measured value of capacitance.

The ac voltage limits appear on the 1426 panel, in the specifications, and in Table 2-2. As shown in the table, the 1426 can be operated at somewhat higher voltages without actual damage, but not without

TABLE 2-2
1426 VOLTAGE LIMITATIONS

| Capacitance Setting | 1 μF | 10 μF | 100 μF | 1 mF | 10 mF | 100 mF | 1 F |
|------------------------------------|-----------|------------|-------------|-------|-------|--------|--------|
| Max. Ac Voltage for Rated Accuracy | 100 V | 2 V | 1 V | 0.3 V | 0.2 V | 0.2 V | 0.05 V |
| Max. Safe Ac Voltage | 100 V | 20 V | 7 V | 2 V | 0.7 V | 0.5 V | 0.3 V |

a possible loss of accuracy. Voltages higher than the Maximum Safe Ac Voltages shown in Table 2-2 are not recommended because such voltages will probably exceed the voltage rating of the capacitor.

A dc voltage of 100 V may be applied to the 1 μF standard (see Figure 4-1). At other settings, the transformer makes a dc connection between the high and low terminals and a large dc current will flow if a dc voltage is applied. Excessive dc current (over 100 mA) can cause a small and permanent change (less than 1/4%) in capacitance.

2.5 FREQUENCY CHARACTERISTICS.

At the 1 μF setting (see Figure 4-1), the 1426 is a true capacitor and it is accurate over a wide frequency range. It has a resonant frequency at 170 kHz. At the other settings, the 1426 is quite frequency dependent. A typical response curve showing the percentage of capacitance change with a change of frequency is shown in Figure 2-7. Use the curve for all but the 1 μF setting.

Circuit-theory experts will quickly realize that the curve in Figure 2-7 cannot be explained by a

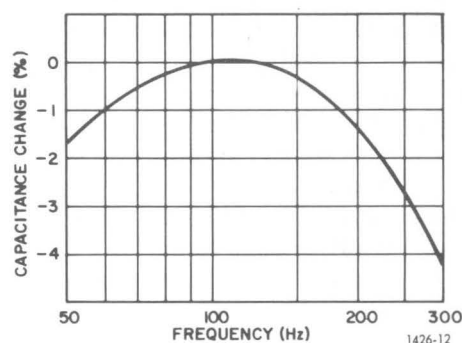


Figure 2-7. Typical frequency response of a 1426 Four-Terminal Capacitance Standard.

simple equivalent circuit with series and shunt inductance. The reduction of capacitance at high frequencies results from poorer coupling between the primary windings (N_1 and N_2 , Figure 3-3) than between the primaries and the secondary (N_1 and N_3). The poorer coupling is due to the physical location of the windings.

SECTION 3

PRINCIPLES OF OPERATION

3.1 GENERAL.

Electrolytic capacitors generally make poor capacitance standards because they vary so much with temperature, voltage and time. The higher-valued electrolytics also have a high loss (dissipation factor). Although other types of capacitors are usually more stable, those in the higher capacitance values tend to be extremely high priced. As a practical solution to these problems, the 1426 uses a stable 1 μF polystyrene capacitor for the lowest setting. This capacitor also serves as a reference value that is multiplied via the turns ratio of a transformer to obtain the other six settings.

3.2 THE CIRCUIT.

A schematic and equivalent circuit of a two-terminal capacitor that consists of a low-valued capacitor and a transformer is shown in Figure 3-1. The transformer in this circuit is used to multiply the 1 μF reference value to obtain an effective capacitance of 1 F.

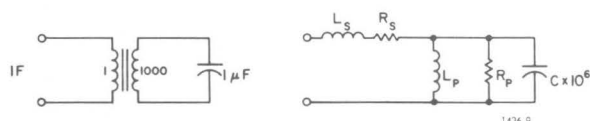


Figure 3-1. Schematic and equivalent circuit of a two-terminal capacitor similar to the 1426.

The series leakage inductance (L_s) increases the capacitance, the parallel inductance (L_p) decreases the capacitance, and both resistances (R_s and R_p) cause D to increase. The deterioration caused by these series and parallel impedances can be kept reasonably low for most capacitance values, but at the 1-F setting, which is only 1.3 m Ω at 120 Hz, the series impedances cannot be kept small enough. At 120 Hz (the standard test frequency), the resistance will increase D and an inductance of 0.2 μH , for example, will result in a 10-percent capacitance error.

The four-terminal bridge that is to be calibrated should be able to tolerate series resistance and inductance without significant error. The GR 1617, for example, can tolerate substantial series impedances as long as they are in a four-lead system. When a two-lead system is used, the series impedances affect the measured value (see Figure 3-2).

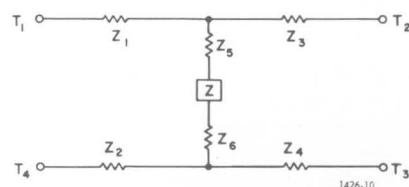


Figure 3-2. Impedance distribution in a four-terminal connection. Impedance components Z_1 through Z_4 affect two-terminal measurements, but not four-terminal measurements.

Figure 3-3 is an elementary schematic of the 1426. The lead impedance at the high-impedance side (secondary) of the transformer is low enough to cause negligible error. The four-terminal capacitance, as shown in Figure 3-3, is ideally represented by:

$$C = C_r \frac{N_3^2}{N_1 N_2}$$

where C = effective four-terminal capacitance

C_r = 1 μ F reference capacitor

N_1, N_2, N_3 = number of turns in winding.

Actually, magnetizing inductance, core loss, and secondary-impedance effects are not completely negligible, but they are taken into account in the calibration.

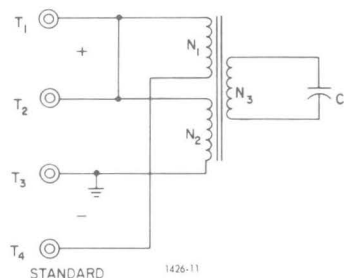


Figure 3-3. Elementary schematic of the 1426 Four-Terminal Capacitance Standard.

SECTION 4

SERVICE AND MAINTENANCE

4.1 WARRANTY.

We warrant that each new instrument manufactured and sold by us is free from defects in material and workmanship, and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards after examination by our factory, District Office, or authorized repair agency personnel will be repaired or, at our option, replaced without charge, except for tubes or batteries that have given normal service.

4.2 SERVICE.

The two-year warranty stated above attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated, please write or phone our Service Department, giving full information of the trouble and of steps taken to remedy it. Be sure to mention the type and serial numbers of the instrument.

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

4.3 CALIBRATION.

Bridges with adequate range and accuracy to check the calibration of the 1426 are not commercially available. The GR 1617 Capacitance Bridge (see

appendix) can be used to measure the 1426 to 1% accuracy, or to compare the 1426 against another standard of the same nominal value to about 1/4%. This standard could be another 1426, or at lower values, a GR 1409 (1 μ F), a GR 1424 (1 μ F and 10 μ F), or a GR 1425 (10 μ F and 100 μ F).

The construction of the 1426 makes separate recalibration of each setting unnecessary because any change can be due only to the following causes:

1. Change in the value of the standard 1 μ F capacitor (see Figure 4-1) which can change with time and temperature changes. However, this capacitor can be checked at 120 Hz, using any capacitance bridge of adequate accuracy (the GR 1615, for example). The capacitance values at all other settings will change proportionally and the same percent of correction used for the 1 μ F value will apply to the values at all other settings.
2. Change in the value of a padding capacitor (see Figure 4-1). These capacitors account for about 2% of the value at any setting. Thus, for a total change 1/4%, the padding capacitor would have to change 12.5%. Such a change is unlikely.
3. If a high dc current is applied to the input terminals, the transformer core may become magnetized, resulting in a slight change of inductance. However, the change would be very small (less than 1/4%) even if one ampere was applied to the input at any setting.

The 1426 may be returned to the factory for calibration to within catalog specifications.

4.4 PARTS REPLACEMENT.

4.4.1 GENERAL

Refer to the parts list for external parts that may be readily replaced by the user. It is recommended that the 1426 be returned to General Radio for major service and for replacement of internal parts.

4.4.2 KNOB REPLACEMENT.

●REMOVAL. To remove the knob and bushing:

- a. Set the knob at the 1 μ F position.
- b. Grasp the knob firmly with the fingers and pull it straight away from the panel.

CAUTION

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

- c. To remove the bushing: observe the position of the set screw with respect to the 1 μ F position on the panel, release the No. 3-32 set screw, and pull the bushing from the shaft.

NOTE

To remove the bushing from the knob (when both parts are removed from the capacitor): thread a machine tap a couple of turns into the bushing, grasp the tap in one hand and the bushing in the other, and pull the knob from the bushing.

●INSTALLATION. To install a bushing and knob:

- a. Mount the bushing on the shaft and position the set screw with respect to the 1 μ F position on the panel as observed in step c above.

- b. Make sure the bushing clears the panel and lock the No. 3-32 set screw.

NOTE

With the bushing properly installed, the end of the shaft should be recessed in the bushing hole or flush with the end of the bushing. If the shaft protrudes, it will interfere with proper seating of the knob.

- c. Install the knob on the bushing, with the markings on the knob positioned at 1 μ F, and push the knob in until it bottoms. Pull the knob back slightly to be sure that the detent spring is seated in the bushing groove.

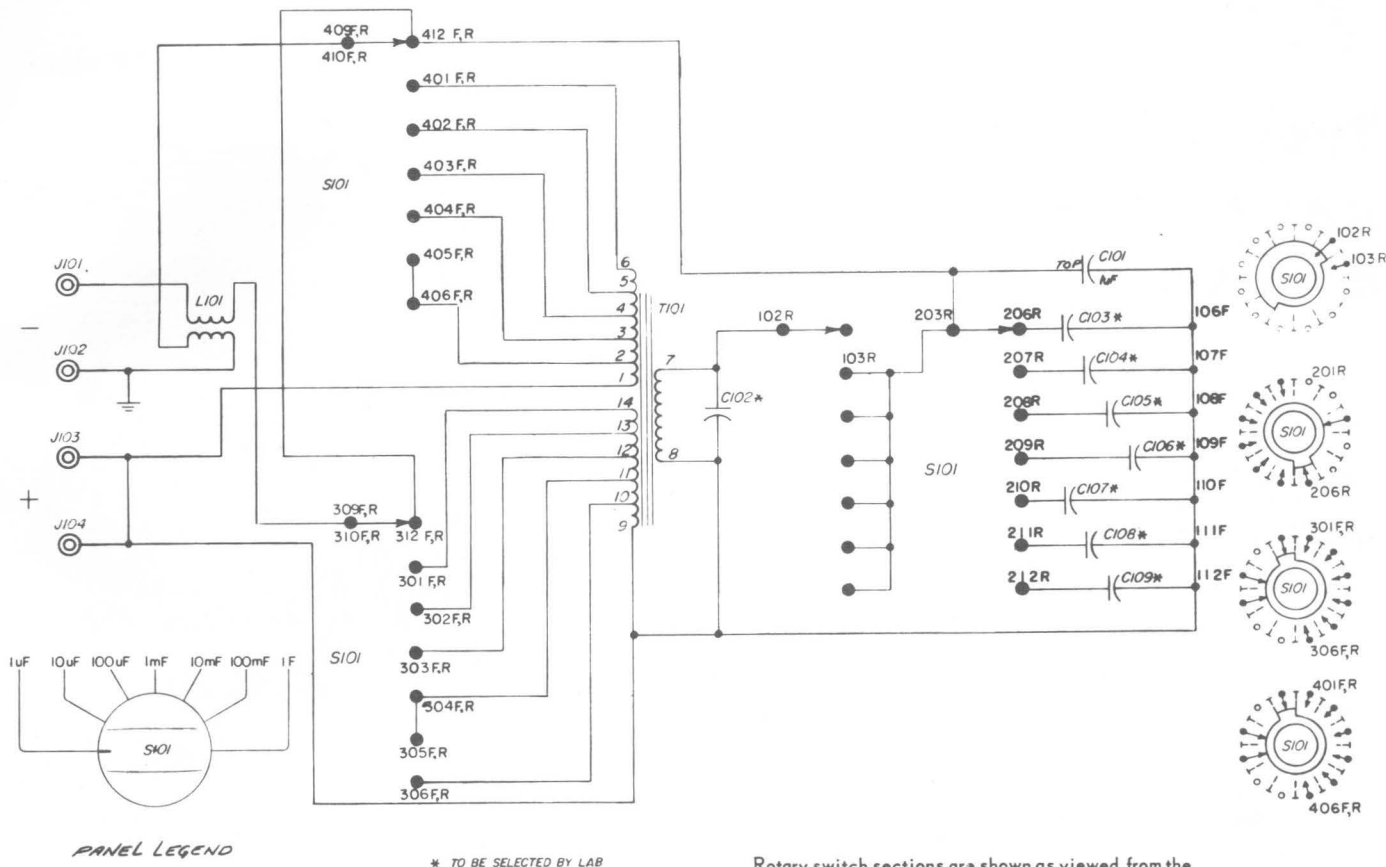


Figure 4-1. Schematic diagram of 1426
Four-Terminal Capacitance Standard.

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

PARTS LIST

| Ref. No. | Description | GR Part No. | Fed. Mfg. Code | Mfg. Part No. | Fed. Stock No. |
|------------------|-------------------------|-------------|----------------|---------------|----------------|
| J101 | BINDING POST, Assembly | 0938-3000 | 24655 | 0938-3000 | |
| | INSULATOR, Binding post | 0938-7130 | 24655 | 0938-7130 | |
| J102 | BINDING POST, Assembly | 0938-3000 | 24655 | 0938-3000 | |
| | SPACER, Binding post | 7800-0600 | 24655 | 7800-0600 | 5340-738-6516 |
| J103 | BINDING POST, Assembly | 0938-3000 | 24655 | 0938-3000 | |
| | INSULATOR, Binding post | 0938-7130 | 24655 | 0938-7130 | |
| J104 | BINDING POST, Assembly | 0938-3000 | 24655 | 0938-3000 | |
| | INSULATOR, Binding post | 0938-7130 | 24655 | 0938-7130 | |
| MECHANICAL PARTS | | | | | |
| | KNOB, Selector switch | 5500-5421 | 24655 | 5500-5421 | |
| | BUSHING, Knob | 4143-3161 | 24655 | 4143-3161 | |
| | FOOT, Assembly | 5260-1800 | 70485 | 832, 1/2" | 5340-854-6120 |

FEDERAL MANUFACTURERS CODE

From Federal Supply Code for Manufacturers Cataloging Handbooks H4-1
(Name to Code) and H4-2 (Code to Name) as supplemented through June, 1967.

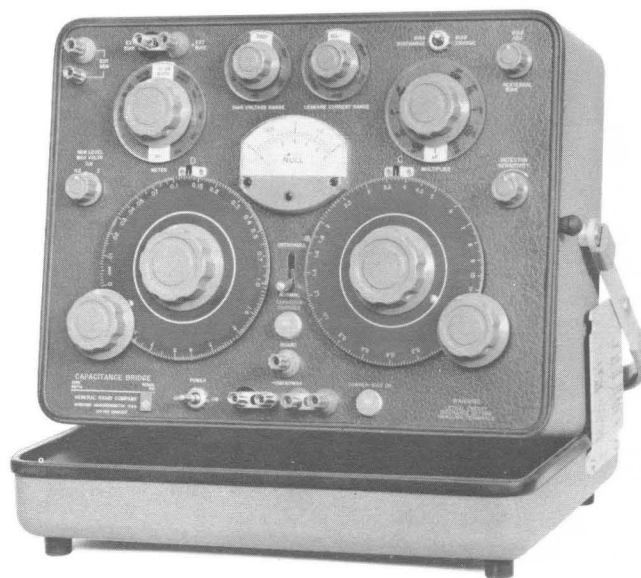
Code Manufacturers Name and Address
24655 General Radio Co., W. Concord, Mass. 01781

Code Manufacturers Name and Address
70485 Atlantic-India Rubber Works, Inc.,
Chicago, Ill. 60607

Type 1617-A

CAPACITANCE BRIDGE

The Type 1617-A was specifically designed for measuring capacitance, dissipation factor, and leakage current of electrolytic capacitors, but it will also find considerable use as a general-purpose 1% bridge. It is completely self-contained, including a 120-Hz generator, null detector, dc polarizing-voltage supply, and metering for bias voltage and leakage current. At frequencies other than 120 Hz, an external oscillator is needed.



specifications

| Quantity | Frequency | Range | Accuracy* |
|--------------------|---|--|---|
| Capacitance | 120 Hz internal | 0 to 0.11 F | $\pm 1\% \pm 1 \text{ pF}$, smallest division 2 pF; residual ("zero") capacitance approximately 4 pF |
| | | 0.11 F to 1.1 F | $\pm 2\%$ |
| | 40 Hz to 120 Hz external (useful down to 20 Hz with reduced accuracy) | 0 to 1.1 F | Same as above with suitable generator |
| | 120 Hz to 1 kHz external | 0 to 1 F $\left(\frac{100}{f\text{Hz}}\right)^2$ | $\pm 1\% \pm 1 \text{ pF}$ with suitable generator and precautions |
| Dissipation Factor | 120 Hz internal or 40 Hz to 120 Hz | 0 to 10 $\frac{f\text{Hz}}{120}$ | $\pm 0.001 \pm 0.01 C \pm 2\%$ |
| | 120 Hz to 1 kHz | 0 to 10 | $(\pm 0.001 \pm 0.01 C) \frac{f\text{Hz}}{120} \pm 2\%$ |

*C is expressed in farads.

Lead-Resistance Error (4-terminal connection): Additional capacitance error of less than 1% and D error of 0.01 for a resistance of 1Ω in each lead on all but the highest range, or 0.1Ω on the highest range.

FREQUENCY

Internal Test Signal: 120 Hz (synchronized to line) for 60-Hz model; 100 Hz for 50-Hz model. Selectable amplitude less than 0.2 V, 0.5 V, or 2 V. Phase reversible.

External Test Signal: 20 Hz to 1 kHz with limited range (see above).

DC VOLTAGE AND CURRENT

Internal DC Bias Voltage and Voltmeter: 0 to 600 V in 6 ranges.

Voltmeter Accuracy: $\pm 3\%$ of full scale.

Internal DC Bias Current: Approximately 15 mA maximum.

Ammeter Range: 0 to 20 mA in 6 ranges. Can detect $\frac{1}{2}\text{-}\mu\text{A}$ leakage.

Ammeter Accuracy: $\pm 3\%$ of full scale.

External Bias: 800 V maximum.

GENERAL

Power Required: 105 V to 125 V or 210 V to 250 V, 60 Hz, 18 W maximum. Models available for 50-Hz operation.

Accessories Supplied: Four-lead and shielded two-lead cable assemblies.

Accessories Required: None for 120-Hz measurements. The Type 1311-A Oscillator is recommended for measurement at spot frequencies, the Type 1310-A Oscillator for continuous frequency coverage.

Cabinet: Flip-Tilt; relay-rack model also is available.

Dimensions (width x height x depth): Portable, $16\frac{1}{4} \times 15 \times 9$ in (415 x 385 x 230 mm); rack, $19 \times 14 \times 6\frac{1}{8}$ in (485 x 355 x 160 mm).

Net Weight: Portable model, 26 lb (12 kg); rack model, 28 lb (13 kg).

Shipping Weight: Portable model, 34 lb (15.5 kg); rack model, 43 lb (20 kg).

| Catalog Number | Description |
|----------------|--------------------------------------|
| | Type 1617 Capacitance Bridge, |
| 1617-9701 | Portable Model (115 V, 60 Hz) |
| 1617-9286 | Portable Model (230 V, 60 Hz) |
| 1617-9206 | Portable Model (115 V, 50 Hz) |
| 1617-9266 | Portable Model (230 V, 50 Hz) |
| 1617-9820 | Rack Model (115 V, 60 Hz) |
| 1617-9296 | Rack Model (230 V, 60 Hz) |
| 1617-9216 | Rack Model (115 V, 50 Hz) |
| 1617-9276 | Rack Model (230 V, 50 Hz) |

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Form No. 1426-0100-A
February, 1968

PRINTED
IN
U.S.A.