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A SERVICEMAN'S R-C-L BRIDGE

A combination bridge for resistance, capacitance, and inductance measurements is as useful to the radio serviceman as to the laboratory technician. This handy instrument, commonly called an impedance bridge, permits the quick identification and testing of all capacitors, resistors, coils, and chokes employed in radio and television circuits. L-C-R bridges are not owned by more servicemen because of the high cost of these instruments as manufactured commercially.

This article gives constructional details of an efficient impedance bridge which can be built and calibrated by any serviceman. It is inexpensive, employs simple easily-obtained components, and requires no expensive equipment for its calibration. This instrument will measure resistance values from 1 ohm to 1 megohm, capacitance from 10 micromicrofarads to 100 microfarads, and inductance from 10 microhenries to 100 henries. Three resistance ranges, four capacitance ranges, and four inductance ranges are provided. The total capacitance range is sufficient to permit measurement of units extending from the lowest-capacitance silver mica types to the very-high-capacitance electrolytics. The inductance range covers all values from small r. f. coils to large iron-core chokes.

Most servicemen already have on hand sufficient spare parts for construction of the bridge. However, if

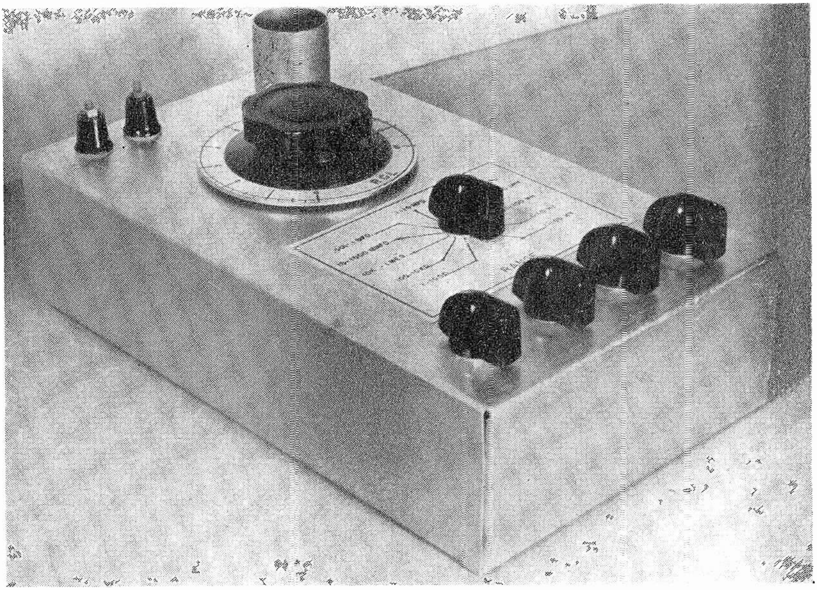

Fig. 1. Overall view of the Serviceman's impedance bridge.

The instrument is built into a standard metal chassis. Resistance, inductance, and capacitance measurements are afforded over a wide range.

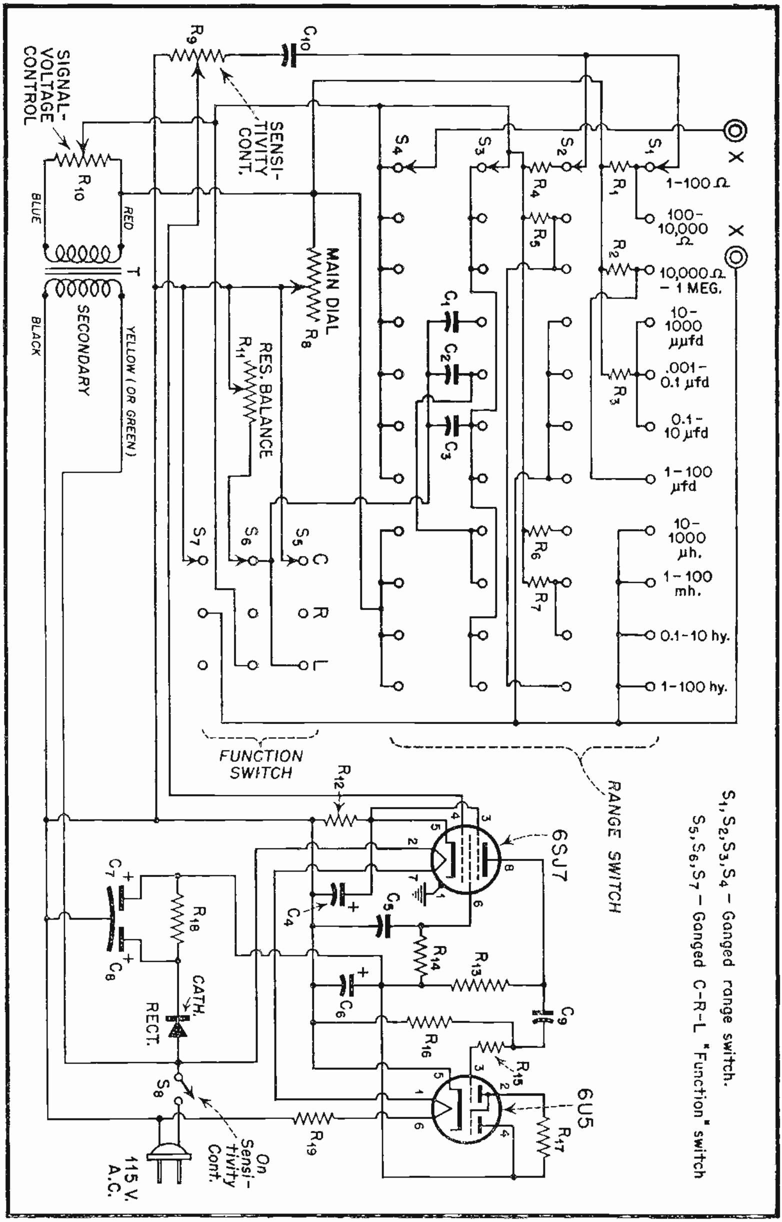

Fig. 2. Complete bridge circuit.

Key to Fig. 2

C_1—0.0001 ufd. silver mica — Cornell-Dubilier 2R 5T1

C_2—0.01 ufd. silver mica — Cornell-Dubilier 1R 3D5

C_3—1 ufd. oil-filled — Cornell- Dubilier DYR 6100

C_4—10 ufd. 25 d. c. w. v. tubular electrolytic — Cornell-Dubilier BR 102A

C_5—0.1 ufd. 400-v. tubular — Cornell-Dubilier DT 4P1

C_6—8 ufd. 450 d. c. w. v. tubular electrolytic — Cornell-Dubilier BR 845

C_7, C_8—Dual 8 ufd. 450 d. c. w. v. tubular electrolytic — Cornell-Dubilier BRL 8845

C_9, C_{10}—0.1 ufd. 400-v. tubular — Cornell-Dubilier DT 4P1

R_1—10,000 ohms 1 watt 1% tolerance

R_2—100 ohms 1 watt 1% tolerance

R_3—1,000 ohms 1 watt 1% tolerance

R_4—100 ohms 1 watt 1% tolerance

R_5—10,000 ohms 1 watt 1% tolerance

R_6—10 ohms 1 watt 1% tolerance

R_7—1,000 ohms 1 watt 1% tolerance

R_8—10,000-ohm linear-taper wirewound potentiometer — I.R.C. W-10,000

R_9—250,000-ohm potentiometer — I.R.C. Type CS

R_{10}—25,000-ohm wirewound potentiometer — Mallory M-25-MP

R_{11}—10,000-ohm linear-taper wirewound potentiometer — I.R.C. W-10,000

R_{12}—1,000 ohms 1 watt carbon — I.R.C. BT-1

R_{13}—250,000 ohms 1 watt carbon — I.R.C. BT-1

R_{14}—1 megohm 1 watt carbon — I.R.C. BT-1

R_{15}—1 megohm ½ watt carbon — I.R.C. BT-½

R_{16}—500,000 ohms ½ watt carbon — I.R.C. BT-½

R_{17}—1 megohm 1 watt carbon — I.R.C. BT-1

R_{18}—2,500 ohms 10 watts wirewound, insulated — Sprague 10KT

R_{19}—240-ohm line card resistor — J. F. D.

RECT—100-ma. selenium rectifier — Sylvania NC5

S_1-S_2-S_3-S_4—4-pole, 11-position, non-shorting, rotary selector switch — Centralab 1429

S_5-S_6-S_7—3-pole, 3-position, non-shorting, rotary selector switch — Centralab 1407

S_8—S.P.S.T. switch attached to potentiometer R_9

T—3:1 ratio interstage audio transformer — Thordarson T57A38

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all new, top-quality parts are purchased, the full price should not exceed 25 dollars.

The completed bridge is shown in the photograph, Figure 1.

Description of Circuit

The complete circuit schematic is given in Figure 2. A careful examination of this drawing will show that a 4-arm bridge arrangement is employed. The 4-pole, 11-position range switch (S_1-S_2-S_3-S_4) changes the components in three of the bridge arms in such a manner as to set up automatically three different bridge circuits — the Wheatstone circuit for resistance, a simple 4-arm circuit for capacitance, and the Maxwell circuit for inductance. The Maxwell bridge has the distinct advantage that it allows an unknown inductance to be checked against a known standard capacitor. This is desirable because standard inductors (required in other types of inductance bridges) are much more expensive and harder for the serviceman to obtain than are capacitors with close ratings.

The bridge is balanced by means of a 10,000-ohm potentiometer, R_8, to which the main dial is attached. The dial is marked off in a single set of figures which indicate directly micro-microfarads, microfarads, ohms, micro-henries, millihenries, and henries. This makes it unnecessary for the operator to perform calculations.

A separate potentiometer, R_{11}, is provided for balancing out the resistive component of the capacitor or coil under test. This is commonly called a power factor adjustment. The 3-pole, 3-position switch, S_5-S_6-S_7, connects this potentiometer in series with the standard capacitor when capacitor measurements are being made, and in parallel with the standard when inductance measurements are being made. When this switch is in its R position, the bridge is set for resistance measurements, and potentiometer R_{11} automatically is cut out of the circuit. Adjustment of R_{11} sharpens the null indication, after a balance first is obtained by adjustment of the main control, R_8. In the bridge shown in Figure 1, potentiometer R_{11} has not been provided with a direct-reading dial, since this dial normally would read per cent power factor and its indications would be misleading in inductance measurements. However, if an individual builder desires, he may attach a dial to this potentiometer and graduate it directly in ohms. The power factor of a capacitor, or the Q of a coil under test then may be calculated from the resistance setting of R_{11}.

The bridge signal is a 60-cycle voltage supplied by transformer T. The value of signal voltage applied to the bridge may be adjusted by means of potentiometer R_{10}.

The null indicater of the bridge is a 6U5 magic eye tube, ahead of which is a high-gain 6SJ7 amplifier. The sensitivity of the amplifier is regulated by means of potentiometer R_9.

D. C. voltages for the two tubes are supplied by a half-wave power unit comprised by the selenium rectifier (RECT), filter resistor R_{18}, and the dual electrolytic filter capacitor (C_7-C_8). The heaters of the two tubes are connected in series and are operated from the a. c. power line through dropping resistor R_{19} which is a part of the line cord. The ON-OFF power switch, S_8, is attached to potentiometer R_9 and is switched off when this potentiometer is turned to its extreme left-hand position shaft position.

The standard resistors are R_1 to R_7. These resistors must be chosen to have the exact values indicated in Figure 2. Under no circumstances should the values vary more than 1 per cent from those given. Carbon resistors may be used if they are picked for exact values; however, best results will be obtained if precision wirewound instrument-type resistors are employed.

The standard capacitors are C_1, C_2, and C_3. Like the standard resistors, these capacitors must be chosen to have the exact values indicated for them in Figure 2. The builder should order capacitors with not more than 1 per cent tolerance.

Constructional Features

Mechanical arrangement of the bridge may be observed from Figures 1, 3, and 4.

Our version of the instrument has been built into a standard radio chassis, 12″ long, 7″ wide, and 3″ high. The chassis made a flat, compact case. Any other suitable type of metal case of the reader's choice may be employed. Figure 1 shows arrangement of the various controls, test terminals, and magic eye hood on the "front panel." These controls are identified in Figure 3.

The main control is a standard 4-inch-diameter radio dial provided with a thin cardboard disc which has been fastened to the dial plate with Duco cement. The dial is graduated in R, C, and L units according to instructions given under Calibration later in this article.

The "unknown" test terminals, seen in the upper left-hand corner in Figure 1, are small-sized ceramic-insulated feed-through terminals. These terminals, which are mounted through ½″ diameter clearance holes, permit wide clearance between the terminal screws and the chassis through which they pass. This reduces terminal-to-

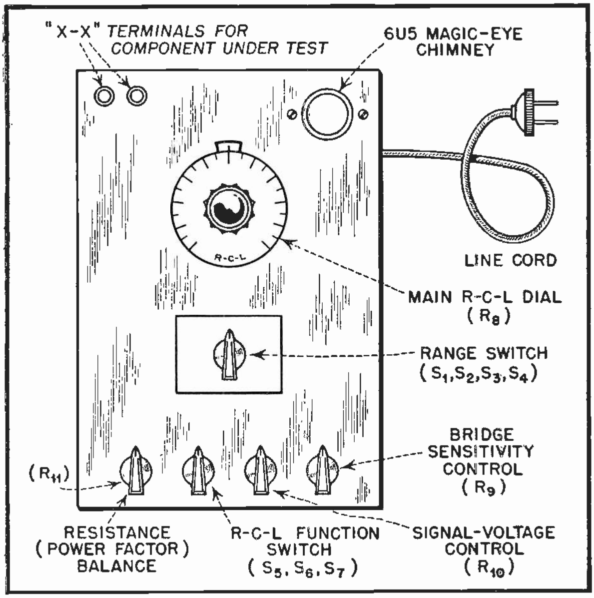

Fig. 3. Panel layout.

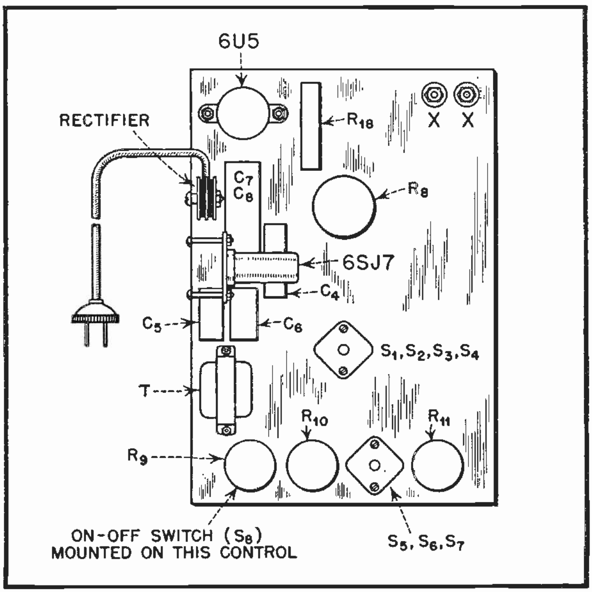

Fig. 4. Layout of components.

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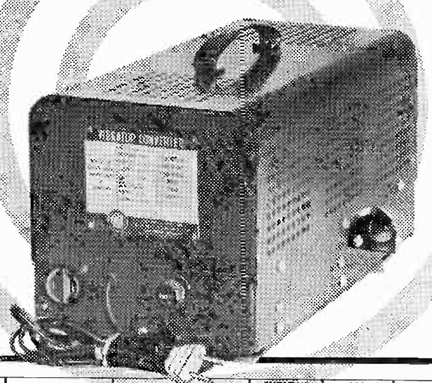

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6R5	6	110 V 60 cycle	50	Mobile	6¾ x 7¾ x 5⅞	12	$ 41.95	$25.17
6R10	6	110 V 60 cycle	100		7 x 12⅝ x 7½	19	59.50	35.70
12R8	12	110 V 60 cycle	80	Marine and	6¾ x 7¾ x 5⅞	12	41.95	25.17
12RU15	12	110 V 60 cycle	150	Mobile	7 x 12⅝ x 12½	22	78.95	47.37
32R8	32	110 V 60 cycle	80	Farm and	6¼ x 7⅝ x 5⅞	13¼	48.50	29.10
32RU15	32	110 V 60 cycle	150	Marine	6⅜ x 12⅜ x 7½	22¼	73.50	44.10
110PA5	110	110 V 60 cycle	50VA	Record	3¾ x 6¼ x 2¾	2	14.95	8.97
110PB5	110	110 V 60 cycle	50VA	Players	3¾ x 6¼ x 2¾	2	16.95	10.17
110RA15	110	110 V 60 cycle	150	Radio & TV	6¾ x 7¾ x 5⅞	13½	48.75	29.25
110R10	110	110 V 60 cycle	100	For AC	6⅜ x 7¾ x 5¼	10½	39.95	23.97
110R15	110	110 V 60 cycle	150	Power from	6¼ x 12¼ x 7½	15	66.95	40.17
110RT15*	110	110 V 60 cycle	150	DC Lines	6⅞ x 12¼ x 7½	16¾	65.00	39.00
110RT25*	110	110 V 60 cycle	250	in City	6½ x 12⅞ x 8½	22½	69.95	41.97
110RT35*	110	110 V 60 cycle	350	Areas	7½ x 14 x 8⅝	40½	119.50	71.70

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MODEL NO.	OUTPUT	WATTS	SIZE	WT. LBS.	LIST PRICE	DEALER'S NET
110BA6	6V DC @ 10A.	60	7⅝ x 12¼ x 8½	16	$54.95	$32.97
110BA12	6V DC @ 20A. 12V DC @ 10A.	120	7⅝ x 13 x 8½	24½	85.50	51.30

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chassis capacitance which appears in parallel with a capacitor under test.

The socket of the magic eye tube is "slung" beneath the chassis and the tube extends through a clearance hole into the protecting and light-shielding chimney seen in the upper right-hand corner in Figure 1. This chimney is a 1½-inch-diameter radio shield, 1½ inches high. It is secured to the chassis by means of spade bolts.

Figure 4 shows arrangement of the principal components inside the chassis. The standard capacitors (C_1, C_2, and C_3) and the standard resistors (R_1 to R_7) are grouped around the range switch (S_1-S_2-S_3-S_4) and are omitted from this drawing for the sake of clarity. The various other capacitors and resistors are mounted on insulated terminal strips. For convenience and to minimize the amount of drilling and bolting, these terminal strips are soldered directly to chassis.

While a compact, line-operated half-wave power supply has been shown in the circuit diagram, a transformer-type power supply may be used if this type is preferred and the size of the instrument case can accommodate it. The supply should deliver from 100 to 250 volts of filtered d. c.

The only special precautions necessary in wiring the bridge are (1) to keep all tube heater wiring close to the chassis, and (2) to employ solid No. 12 or No. 14 bus wire in all wiring except that in the power supply, amplifier, and eye-tube circuits. The lead running from the center contact of potentiometer R_9 to the 6SJ7 grid must be covered with shield braid and each end of the braid must be grounded to the B-minus terminal of the power supply.

Calibration

If the bridge dial is calibrated on the resistance range, it will serve without additional calibration also on the capacitance and inductance ranges. The following simple calibration procedure may be followed.

(1) Disconnect the center and right-hand contacts of potentiometer R_8 temporarily from the bridge circuit.

(2) Connect the center and left-hand contacts (viewed from the dial) of the potentiometer to a good ohmmeter or resistance bridge.

(3) By means of the ohmmeter, set potentiometer R_8 to 100 ohms. Mark this setting 1 on the dial.

(4) Advance the potentiometer to 1,000 ohms and mark this point 10 on the dial.

(5) Repeat the operation at each 1,000 ohms, marking the corresponding points 20, 30, 40, 50, 60, 70, 80, 90, and 100 on the dial. (NOTE: At the time the photograph, Figure 1, was made, the dial shown on this instrument had been calibrated in other units for a special purpose.)

(6) Repeat the operation at as many intermediate points as practicable to obtain fine divisions for the dial.

(7) Ink-in the figures and lines on the dial and reconnect potentiometer into the bridge circuit.

The accuracy with which the bridge may be calibrated by the method just described depends upon the accuracy of the ohmmeter used and also upon the care with which potentiometer R_8 is set to the various resistance values.

A second calibration method of high accuracy requires a decade resistance box of the laboratory type having units, tens, hundreds, and thousands decade units. The decade box is connected to the X-X terminals of the bridge, and the bridge is set up for resistance measurement by switching S_5-S_6-S_7 to position R, and setting the range switch (S_1-S_2-S_3-S_4) first to 1-100 ohms.

(1) Set the decade box to 1 ohm, advance potentiometer R_{10} a small amount, and set potentiometer R_9 to maximum. Adjust the main dial (potentiometer R_8) for null, as indicated by maximum opening of the 6U5 eye tube. Mark this point 1 on the dial.

(2) Set the decade box successively to equal resistance steps up to 100 ohms. Balance the bridge for each of these settings of the decade box, and mark the corresponding resistance on the dial. In using this method, follow

the instructions given under Using the Instrument for making the resistance balances.

Using the Instrument

Preliminary

(1) Insert the power plug into an a. c. outlet (Caution: the bridge will not operate on a d. c. line voltage, and in fact will be damaged by d. c.).

(2) Switch-on the power by advancing potentiometer R_9 sufficiently to click-on the ON-OFF switch, S_8.

(3) Wait for about 3 minutes for the tube heaters to reach normal operating temperature. Observe that the 6U5 eye tube will glow green.

(4) Set potentiometer R_9 at about half-scale, and potentiometer R_{10} to minimum.

Resistance

(1) Set the FUNCTION switch (R_5-R_6-R_7) to position R.

(2) Set the RANGE switch (S_1-S_2-S_3-S_4) to its 1-100-ohm position.

(3) Connect the unknown resistance to terminals X-X by means of short leads.

(4) Advance potentiometer R_{10} about 1/4 inch.

(5) Adjust the main dial throughout its range, watching for a sharp opening of the magic eye. If the opening is too fast, or "hair-trigger," for close adjustment of the dial to the null point, reduce the setting of the sensitivity control (R_9). If no eye opening is obtained, change the range switch setting to the next higher range and retune the main dial. Repeat this procedure on each resistance range until a null indication is obtained. At the point of exact null (widest opening of the eye), read the unknown resistance value by means of the main dial and the range switch setting.

(6) Always use the lowest possible setting of potentiometer R_{10} which will afford a clean, sharp eye opening, especially on the 1-100-ohm range. It may be necessary to jockey back and forth between settings of R_9 and R_{10} in order to obtain best bridge action.

Capacitance

(1) Set the function switch to position C.

(2) Set the range switch to the 10-1,000-uufd. range.

(3) Set potentiometer R_9 at about half-scale, and advance potentiometer R_{10} about 1/2 inch.

(4) Connect the unknown capacitor to terminals X-X by means of the shortest possible heavy leads.

(5) Adjust the main dial for a sharp opening of the magic eye. If a null is not obtained even when potentiometer R_9 is advanced to maximum, advance the range switch to each higher capacitance range and retune the main dial. Readjust R_9 and R_{10} for maximum bridge sensitivity.

(6) At null, adjust potentiometer R_{11} for a sharpening of the null response, and recheck the main dial setting for exact null.

(7) Read the unknown capacitance value from the main dial and the range switch settings.

Inductance

(1) Set the function switch to position L.

(2) Set the range switch to its 10-1,000 microhenry range.

(3) Set potentiometer R_9 to about half-scale, and advance potentiometer R_{10} about 1/2 inch.

(4) Connect the unknown coil to terminals X-X by means of the shortest practicable heavy leads.

(5) Adjust the main dial for a sharp opening of the magic eye. If a null is not obtained, even when potentiometer R_9 is set to maximum, try each next higher capacitance setting of the range switch, repeating tuning of the main dial. Readjust R_9 and R_{10} for best bridge action.

(6) At null, adjust potentiometer R_{11} for a sharpening of the null response, and retune the main dial for exact null.

(7) Read the unknown inductance value from the main dial and the range switch settings at null.