1504

INSTRUCTIONS AND APPLICATIONS

Deviation Bridge Type 1504

Adapted for the checking of resistors, capacitors and inductors, in industrial production and laboratories.

- Accelerometers
- Acoustic Standing Wave Apparatus
- Artificial Ears
- Artificial Voices
- Audio Frequency Response Tracers
- Audio Frequency Spectrometers
- Audio Frequency Vacuum-Tube Voltmeters
- Automatic A. F. Response and Spectrum Recorders
- Automatic Vibration-Exciter Control Generators
- Band-Pass Filter Sets
- Beat Frequency Oscillators
- Complex Modulus Apparatus
- Condenser Microphones
- Deviation Bridges
- Distortion Measuring Bridges
- Frequency Analyzers
- Frequency Measuring Bridges
- Hearing Aid Test Apparatus
- Heterodyne Voltmeters
- Level Recorders
- Megohmmeters
- Microphone Accessories
- Microphone Amplifiers
- Microphone Calibration Apparatus
- Mobile Laboratories
- Noise Generators
- Noise Limit Indicators
- Pistonphones
- Polar Diagram Recorders
- Preamplifiers
- Precision Sound Level Meters
- Recording Paper
- Strain Gage Apparatus and Accessories
- Surface Roughness Meters
- Variable Frequency Rejection Filters
- VHF-Converters
- Vibration Pick-ups
- Vibration Pick-up Preamplifiers
- Wide Range Vacuum Tube Voltmeters

BRÜEL & KJÆR

Nærum, Denmark . ☏ 80 05 00 . BRUKJA, Copenhagen . Telex: 5316

BB 1504

Deviation Bridge

Type 1504

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Contents.

1. Description

General.

The Deviation Bridge is a measuring bridge for testing resistors, capacitors and inductors.

It consists of a Wheatstone Bridge with two fixed resistors and four input terminals for connection of an external standard and the unknown component. The bridge is operated from a built-in generator. The diagonal voltage is, via a two-stage amplifier, fed to a phase-sensitive demodulator, the output voltage of which is measured on a moving coil instrument with large, interchangeable scales. The scale-reading is the positive and negative deviation in per cent and the positive and negative phase angle in radians between the standard and the unknown component.

Four calibrated, and two blank scales for special calibration purposes are supplied with the Bridge.

Oscillator and Bridge Section.

The oscillator, which is of the Hartley type, operates at a frequency of 1 kc/s. The output voltage is fed to an output amplifier via a resistor or an R-C network. The selection is made by means of the switch marked IMPEDANCE, PHASE ANGLE. When switched in, the R-C network introduces a 90° phase shift of the output signal.

Via a potentiometer marked RANGE ADJUSTMENT the signal is fed to the output amplifier consisting of a pentode. In order to avoid any phase shift being produced in this stage, the load must be true resistive. By a capacitive load (i.e. when measurements are carried out on capacitors) the small extra phase shift causes an error which is corrected for by the table given on page 22. To stabilize the output amplifier this is supplied with negative feedback.

The two fixed resistors incorporated in the Wheatstone Bridge are wire-wound resistors of 100 Ω, the mutual point of which is grounded. The two other arms of the bridge are fed to two pairs of terminals marked STANDARD and UNKNOWN. None of the apparatus terminals are connected to chassis. The upper of the left terminals and the right terminal at the bottom are connected to chassis through the resistors of 100 Ω, having an AC potential of maximum 2 volts with respect to chassis. The other two terminals, marked in white, are mutually connected and led to the input circuit of the amplifier. The bridge arrangement, furthermore, involves a switch marked R & L, C, the purpose of which is to interchange the standard and the unknown component. This is to permit direct reading in % deviation of capacity (and not of impedance), and is necessary because the impedance of a capacitor is inversely proportional to the capacity.

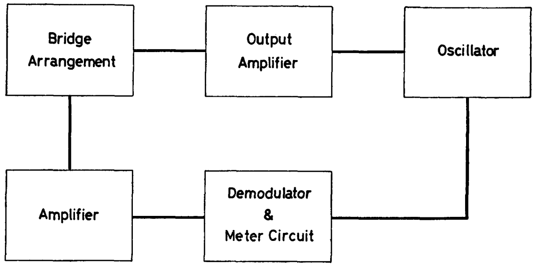


Fig. 1.1. Block diagram of Type 1504.

Amplifier and Demodulator Section.

Whenever a difference in magnitude or phase angle is present between the standard and the unknown component, a diagonal voltage occurs in the bridge arrangement. This voltage is fed directly to the input of a two-stage resistance-coupled amplifier, which is supplied with negative feedback to obtain a stable operation and a high input impedance. (When measuring too high impedance values, the input impedance of the amplifier will load the bridge, and consequently cause erroneous measurements. See correction curves on p. 26). The output of the amplifier is connected to a demodulation circuit which makes the instrument insensitive to hum and noise voltages to a certain degree, because the demodulator preferably responds to signals of

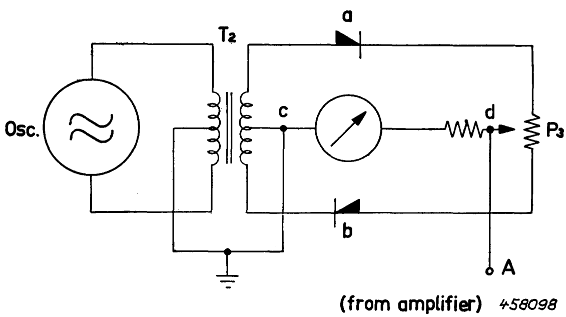


Fig. 1.2. Principle diagram of the demodulator circuit.

the same frequency as that of the oscillator. Additionally, positive and negative deflections are obtained for positive or negative deviation from the standard, respectively.

In Fig. 1.2 is shown a basic diagram of the demodulator circuit. It can be seen from the figure that a part of the oscillator voltage is rectified by means of the rectifiers a and b, and that by adjusting P_3 (marked ZERO ADJUSTMENT) a position of the moveable arm of the potentiometer can be found, for which no current will flow through the meter, when no signal is fed to A. Whenever a diagonal voltage occurs in the bridge arrangement, the corresponding amplified signal, with no additional phase shift, is present at A.

If this voltage is in phase with the voltage E_T across the secondary of the transformer T_2 as indicated in Fig. 1.3 and the rectifiers a and b are open, only a small current will pass through the meter due to the shunting effect of the rectifiers.

When the diodes are blocked the current will flow from c to d, having a magnitude which is much greater than when the diodes are open. A DC component of the output voltage from the amplifier will thus be present across the meter, causing this to deflect.

If the voltage at A is in antiphase with the voltage E_T across T_2 the sign of the DC component developed across the meter is reversed. This can be seen from Fig. 1.4.

With the output voltage from the amplifier 90° out of phase, relative to the voltage E_T, the voltage developed across the meter will be as indicated in Fig. 1.5. No DC component is then present, and the deflection on the meter will be zero.

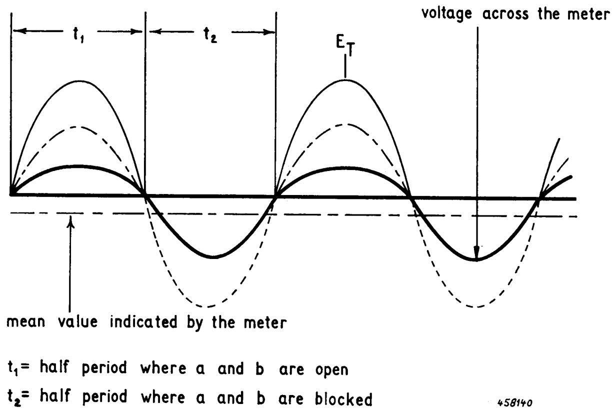


Fig. 1.3. Operating principle of the phase-sensitive demodulator. Oscillator and bridge output voltage in phase.

Consequently only the in-phase (or in-antiphase) component of the voltage will be indicated by the meter. By measuring both components, the magnitude as well as the phase angle of the diagonal voltage are determined. With the switch marked IMPEDANCE, PHASE ANGLE in position "Impedance", the in-phase (or in-antiphase) component is measured, and with the switch in position "Phase Angle" the 90° out of phase component is indicated. In Fig. 1.6 a vector diagram of the voltages appearing in the Wheatstone Bridge arrangement during measurements is shown.

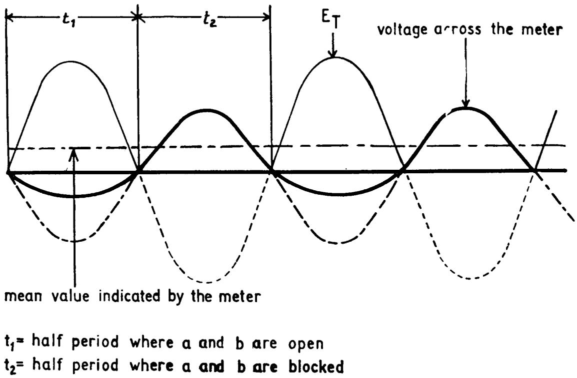


Fig. 1.4. Operating principle of the phase-sensitive demodulator. Oscillator and bridge output voltage in anti-phase.

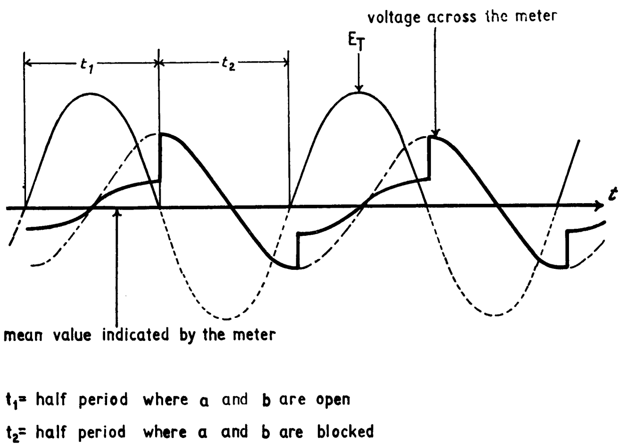


Fig. 1.5. Operating principle of the phase sensitive demodulator. Oscillator and bridge output voltage 90° out of phase.

The vectors AB and BC represent the voltages across the two fixed resistors, respectively, the vectors AD and DC the voltages across the "standard" and the "unknown" impedances respectively, and the vector BD the voltage applied to the amplifier.

When impedance measurements are taken, only the voltage represented by the vector BD_1 is indicated by the meter.

For phase-angle measurements the meter indication will be proportional to the voltage BD_2.

It is seen from the diagram that the point D might move along a line drawn through the points $D — D_1$ without influencing the magnitude of the vector BD_1.

Analogously the magnitude of the vector BD_2 will not be influenced if the point D moves along a line drawn through the points $D — D_2$.
This means that:

1. When the phase angle of the "unknown" is very much different from the phase angle of the "standard" the measurement of impedance deviation is inaccurate.
2. When the impedance of the "unknown" is very much different from the impedance of the "standard" the measurement of phase angle deviation will be inaccurate.

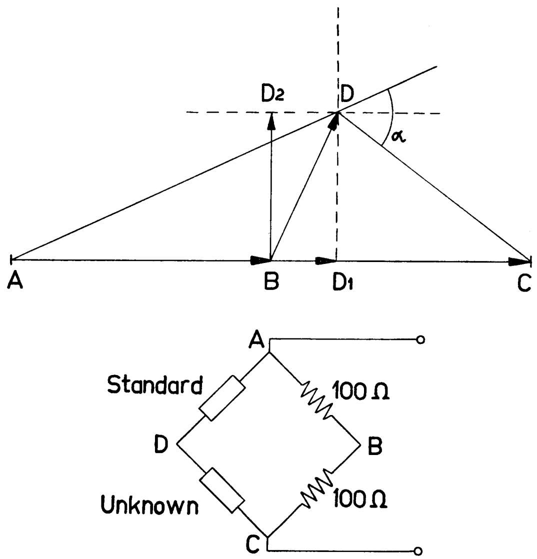


Fig. 1.6. Vector diagram of bridge voltages.

The maximum inaccuracy will be present when both phase angle and impedance measurements show maximum deviation between "standard" and "unknown".

Meter Section.

As previously mentioned, different dials can be inserted in the large square-type indicating meter.

The four calibrated scales, supplied with the instrument cover the following ranges of deviation measurements:

Impedance Deviation	*Phase Angle Deviation(tan δ)*	*Range Adjustment*
— 1.5 % to + 1.6 %	— 1.5 to + 1.5 $\times 10^{-2}$	1 %
— 7 % to + 8 %	— 7 to + 7 $\times 10^{-2}$	5 %
— 25 % to + 35 %	— 30 to + 30 $\times 10^{-2}$	20 %
— 50 % to + 100 %	— 80 to + 80 $\times 10^{-2}$	20 %

The moving coil instrument is slightly under-critically damped to secure maximum speed, and is perfectly protected against overload.

To be able to calibrate the apparatus for the different ranges in a quick way, reference voltages are provided.

When the 1 % range is to be used the OPERATION SWITCH is set to position "Ref. 1 %". By turning the knob marked RANGE ADJUSTMENT until the meter pointer deflects to the red mark on the scale, a voltage is applied to the input of the amplifier, with a magnitude corresponding to the one obtained when the impedance deviation between the standard and unknown impedance is 1 %.

Reference voltages for the 5 %, 20 % and the 100 % ranges are also available.

Power Supply.

The Deviation Bridge is intended for use with 100, 115, 127, 150, 220 or 240 volts AC, 50—400 c/s. The power consumption is about 40 watts. The plate voltage to the oscillator is stabilized by a neon tube. A variation of 10 % in the power supply voltage will influence the meter deflection by less than 3 %, the zero point being independent of the line voltage.

2. Control Knobs and Terminals

STANDARD TERMINALS: For the connection of a standard component (R, L, or C), against which some unknown component will be compared. This is one arm of a Wheatstone bridge.

For convenience, mount the standard component inside a Box for Standards ZR 1702. This box plugs directly into the terminals.

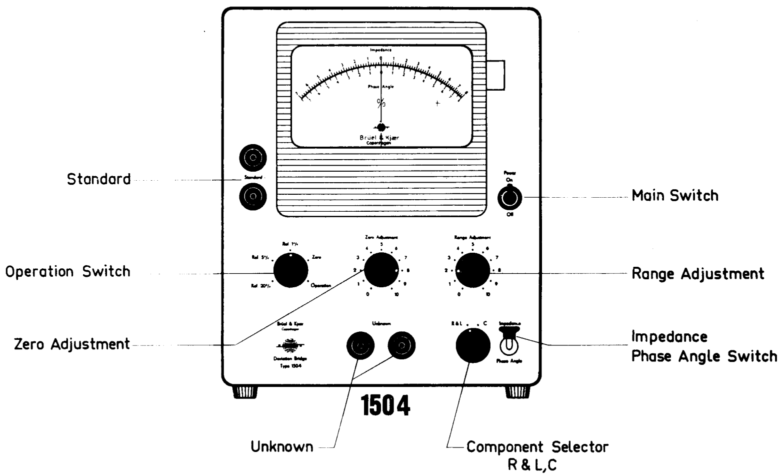


Fig. 2.1. Control knobs and terminals on the Deviation Bridge Type 1504.

OPERATION SWITCH: The position of this knob determines whether the meter reads:

1. The bridge signal ("Operation").
2. A signal to be nulled ("Zero" adjustment).
3. Various reference signals corresponding to the possible ranges ("Ref. 1 %, 5 % or 20 %. The last is used for both 35 % and 100 % scales).

ZERO ADJUSTMENT: When the OPERATION SWITCH is on "Zero" there is no signal being fed to the demodulator. This device can then be aligned by means of the ZERO

ADJUSTMENT so that no reading appears on the meter.

MAINS SWITCH: Controls the supply of power to the instrument.

RANGE ADJUSTMENT: Controls the oscillator voltage applied to the bridge. It is adjusted only in conjunction with a "Reference" setting on the OPERATION SWITCH.

IMPEDANCE/ PHASE ANGLE: To be correctly positioned according to the information required. In the condition "Phase Angle", the bridge voltage is in quadrature with the oscillator signal and the meter reading is a measure of the tangent of the phase angle.

UNKNOWN TERMINALS: For connecting a component of unknown value, so that it forms one arm of a Wheatstone bridge and can thus be compared against the standard.

COMPONENT SELECTOR: Switch to "R or L" when measuring resistors or inductances, but use on "C" for capacitors. The latter setting makes allowance for the fact that impedance is inversely proportioned to capacity.

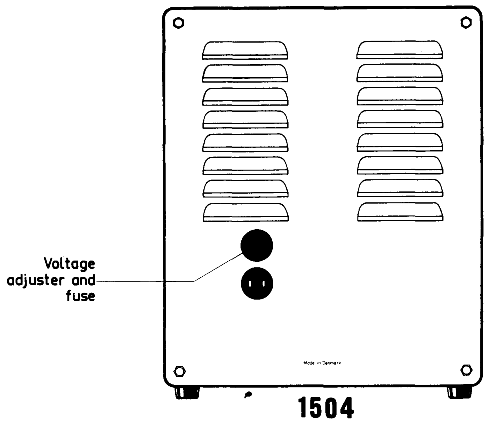


Fig. 2.2. Rear view of the instrument.

The proper voltage is selectable by a switch-fuse combination situated at the rear of the instrument. To select the voltage it is necessary to remove the fuse by turning the hexagonal disc head in the centre of the switch anti-clockwise. Then turn the head of the voltage adjuster with a coin until the white mark is aligned with the required voltage. The fuse is then replaced.

3. Operation

General Remarks.

During measurement it is advantageous to ground the apparatus, and when measuring high impedances it is absolutely necessary, it may also be necessary to screen the terminals STANDARD and UNKNOWN to avoid overdriving of the amplifier by hum. The standard and the objects to be measured should be placed together with the bridge on a grounded metal plate.

If the object to be tested is grounded, the grounded pole should be connected to the right "Unknown" terminal, and the grounding of the cabinet be omitted. The capacity of the apparatus to ground is then connected across one of the built-in ratio resistors and should consequently be kept as low as possible.

When high impedances are being measured (large resistors and inductances, and small capacitors, respectively) the connections to the bridge should be taken into account.

In addition no extra capacity must be introduced between chassis and the two terminals marked in white.

Operation Procedure.

1. Make sure that the Deviation Bridge is adjusted to the correct mains voltage.
2. Connect the power cable to the mains and place the toggle switch marked POWER in position "On". The light on the meter comes on immediately.
3. Allow a few minutes warm-up time.
4. Set the switch marked IMPEDANCE/PHASE ANGLE in position "Impedance".
5. Place the meter scale corresponding to the desired measuring range (1 %, 5 %, 20 % or 100 %) in the meter frame. (The scale is removed from the frame by pulling to the right).
6. Turn the OPERATION SWITCH (knob to the left) to "Zero". By means of the knob marked ZERO ADJUSTMENT the meter pointer is set to 0.
7. Connect the standard component to the terminals marked STANDARD and the component to be checked to the terminals UNKNOWN.
8. Set the OPERATION SWITCH to the desired Ref. value ("Ref. 1 %", "Ref. 5 %", "Ref. 20 %"). Turn the knob marked RANGE ADJUSTMENT until the meter pointer is on the red mark on the scale.

Note:
When measuring high impedances, the values obtained from the adjustment curves, shown on p. 26, should be used for the range adjustments, instead of the red mark on the scale.

9. Turn the COMPONENT SELECTOR to the correct position (for resistors and inductances in position "R & L" and for capacitors in position "C"). For the influence of capacitive loading see appendix.
10. Turn the OPERATION SWITCH to position "Operation" and the instrument is ready for use.
11. For *phase angle measurements* set the switch marked IMPEDANCE, PHASE ANGLE in position "Phase Angle". It is locked in this position by pushing it downwards and to the left.
    Note:
    To avoid overloading of the amplifier a check should be made that the meter deflection is kept within full scale deflection both with the press-button switch in position "Impedance", and in position "Phase Angle".
12. The components to be tested are now successively connected to the two terminals marked "Unknown" and the meter deflection will give the deviation from the Standard directly in %.

Deflection to the right means positive deviation (unknown bigger than Standard), and deflection to the left negative deviation (unknown smaller than Standard).

4. Accessories

Test Jig Type 3902.

The Test Jig Type 3902 is designed to be used in conjunction with the Deviation Bridge for rapid production control of resistors, capacitors, and inductances. It consists of a wooden board on which the Deviation Bridge should be placed. On the board in front of the instrument are placed two posts which are designed with spring loaded-contacts. The opening of the

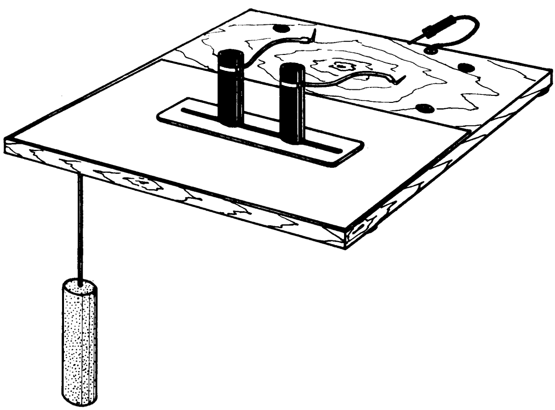


Fig. 4.1. The Test Jig Type 3902.

contacts is controlled by means of a lever, and the contacts can be directly connected to the terminals marked "Unknown". The lever is intended to be operated by means of the operators left knee. That part of the wooden board which is in front of the instrument is, in addition, supplied with a steel plate. This may be connected to the instrument cover or to ground. The distance between the posts is adjustable to any spacing between 0 and 14 cm (5½ inch.). The measurements are carried out by engaging the lever for operating the silver contacts, placing the component to be measured between the two posts, and releasing the lever. The instrument then immediately shows the deviation from the standard-component employed.

5. Applications

Production Check oı Components.

Production check oı components in the following ranges: Resistance: 10 Ω — 10 MΩ; Capacitance: 50 pF — 10 μF; Inductance: 2 mH — 100 H, may be

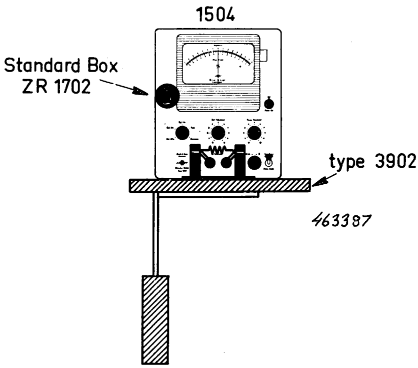


Fig. 5.1. Production check of components.

carried out by means of the Deviation Bridge Type 1504. The practical arrangement for component measurements is shown in Fig. 5.1. (Resistance measurement).

By means of this arrangement it is possible to compare the components to a standard component ,and then divide the components into several groups with certain tolerances.

Direct-Reading Measurements of Capacitances.

The Deviation Bridge type 1504 may be used as a direct-reading instrument for measuring capacitances. Two equal condensers of exactly known capacitances are, as shown in Fig. 5.2, connected across the STANDARD and UNKNOWN terminals, one to each terminal. The capacitance to be found is measured as a per cent increase of the fixed known value. By choosing the fixed condensers as pure powers of 10 the direct readings will be simplified. To make the adjustment easier it will be practical to have part of the capacitance on "Standard" placed as a small trimmer condenser.

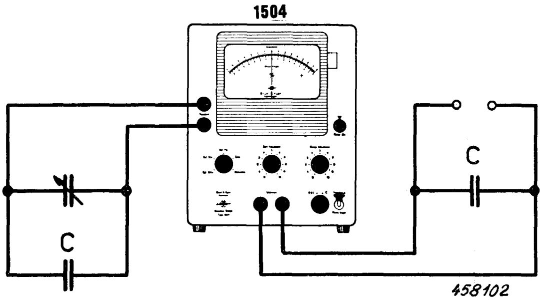


Fig. 5.2. Direct reading measurements of capacity values.

Direct-Reading Measurements of Resistances.

In a similar way as for capacitances it is possible to use the Deviation Bridge as a direct-reading ohmmeter. As illustrated in Fig. 5.3 two fixed resistors have to be used, but the resistance under test has to be connected

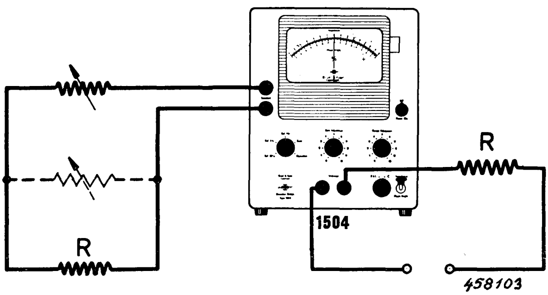


Fig. 5.3. Direct reading measurements of resistance values.

in series with one of the fixed resistances. The small adjustable fraction of the other fixed R may be connected either in series or in parallel with R. If a series connection is used, the adjustable R need only be a few per cent of the total value of the fixed resistance, while it has to be great compared to the total resistance if connected in parallel.

Adjustment of L and Q for Inductors.

A standard inductor is used as the standard, and the measuring object is connected to the UNKNOWN terminals. With the switch on "Impedance" the inductance is adjusted to give zero reading. The switch is then set to "Phase Angle" and the Q of the inductor is adjusted (with series or parallel resistors or by some other appropriate method) to give 0 phase angle deviation. In some cases the L and Q adjustments are not independent of each other and the procedure should be repeated to give the best results.

Loss in capacitors.

Most paper condensers have a tan δ of approx. 1 %. The loss can easily be measured with the bridge on its $\pm$ 1.5 % range, provided that the standard has negligible loss and the capacity of the measuring object is also within that deviation from the capacity of the standard. If the paper condensers are only within the usual tolerance of $\pm$ 10 %, the bridge must be set to impedance measurement, and the standard condenser adjusted to give 0 reading on the meter. After that, the swich is depressed to phase angle measurements and the tan δ is read off the scale. The loss of high-K ceramic condensers will also be within the range of the bridge, whereas the loss in low-K ceramic and polystyrene condensers is too small to be measured by this method.

Checking of Transformers.

The Deviation Bridge is also a suitable apparatus for checking transformers for amplifiers, hearing aids, etc. The set-up is shown in Fig. 5.4. The trans-

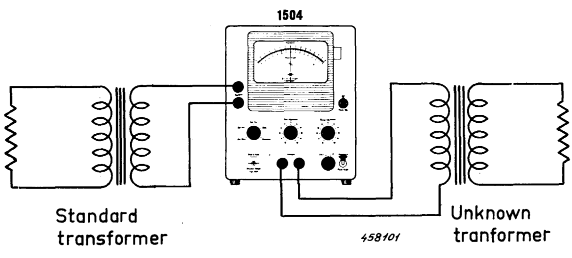


Fig. 5.4. Production testing of transformers.

former with its correct load on the output side is connected to the terminals marked UNKNOWN. A perfect transformer loaded with the same impedance is used as the standard, and defects in either coils, turn numbers or laminations may then be observed. When measuring high-impedance transformers it may happen that the capacity is so high that it will disturb the measurements. Such transformers have to be measured at a very low frequency (1503).

Checking of Coils for Short-Circuit Turns.

For checking coils in transformers, chokes, inductances etc., a set-up as indicated in Fig. 5.5 is very useful. Two identical measuring coils with long

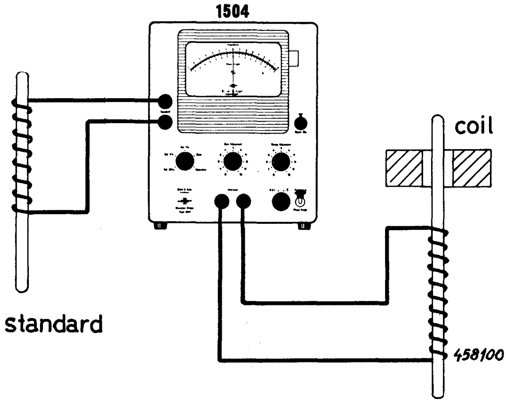


Fig. 5.5. Checking of coils.

iron cores are balanced on the bridge, and the coil under test is then placed over the end of one of the cores.

If there is a short-circuit in the coil, the induction in the coil will react with the balanced coil, and deflect the meter pointer. In most cases a phase angle measurement will give the highest sensitivity.

Balance of Ganged Variable Potentiometers.

For adjustment of coupled variable potentiometers the set-up shown in Fig. 5.6 will be practical. The two end terminals are connected respectively to the upper left and lower right terminals of the bridge, while the moveable arms may be connected together and joined to one of the two remaining terminals. The balance expressed in % deviation may then be checked for all positions of the moveable arm.

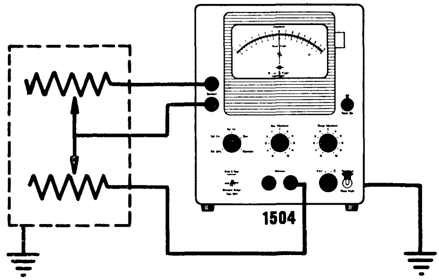


Fig. 5.6. Matching of potentiometers.

Checking of Focusing Magnets for TV.

Fig. 5.7 shows a set-up for testing the homogenity in the magnetic field around an axial-magnetized, ring-shaped magnet.

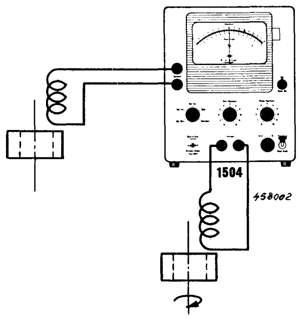


Fig. 5.7. Set-up for checking focusing magnets for TV sets.

To the STANDARD and the UNKNOWN terminals are connected two identical coils. The iron cores of which must be so, that the inductances of the coils are altered by varying the magnetization of the iron cores. In front of one of the coils with its axis parallel to that of the coil but displaced by half a ring-diameter the ring is rotated. Any change in the meter deflection of the 1504 is then due to a non-homogenity in the magnetic field.

Measurement of Resistors and Capacitors in Laboratories.

In laboratories where resistors and capacitors are frequently measured, it will be a practical advantage to set up a couple of measuring bridges of type 1504 permanently connected to the resistor and capacitor standard, as indicated in Fig. 5.8.

Resistors are measured on the 1504; the "Unknown" being connected to the Bridge, and the standard resistor being varied until the bridge is balanced. The unknown resistance can then be immediately found by reading off the

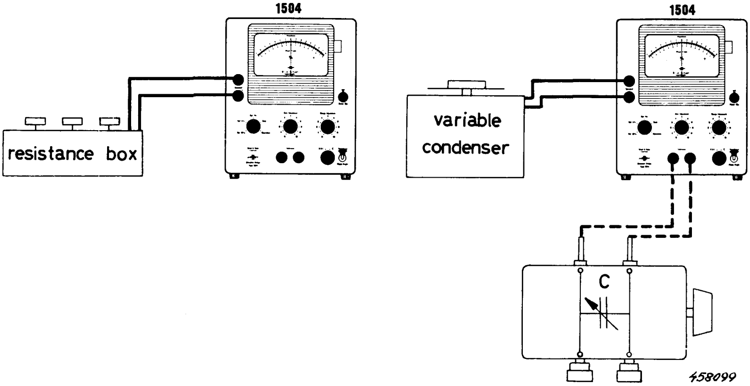


Fig. 5.8. Resistance box and variable condenser connected to Deviation Bridge type 1504.

value on the resistance box. This form of resistance measurement is much quicker in practice than adjusting a Wheatstone Bridge, because the meter of 1504 responds much quicker than the usual light-spot galvanometer.

Capacitors may also be measured on the 1504 in exactly the same way. In order to compensate for the connections to the variable condenser and its minimum capacity, the unknown capacitor should be connected via a small extra measuring box, containing a balancing capacity. In this way, a quick and very exact measurement of small capacitors can be carried out.

Checking a Tube's Transconductance and Internal Resistance.

For many applications, for example d.c. amplifier, scaling units for calculating machines, and so on, it is important that those tubes which are employed in the construction have definite values with narrow tolerances for both transconductance and internal resistance. The Deviation Bridge Type 1504 will also here give complete satisfaction in the control and choice of suitable tubes.

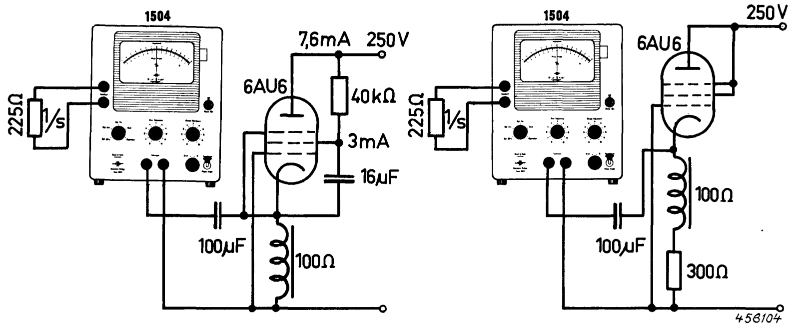


Fig. 5.9. Measuring transconductance of 6AU6 tube connected respectively as pentode and triode.

Fig. 5.9 shows a typical set-up for measuring a tube's transconductance, the tube being connected respectively as pentode and triode. The indicated resistance values are applicable for tube type 6AU6.

If other tube types have to be measured, the components as shown in the diagram must naturally be changed in value to suit. It is important that the choke coil shown in the cathode lead of the diagram has an impedance which is great in relation to the tube's reciprocal transconductance at the measuring

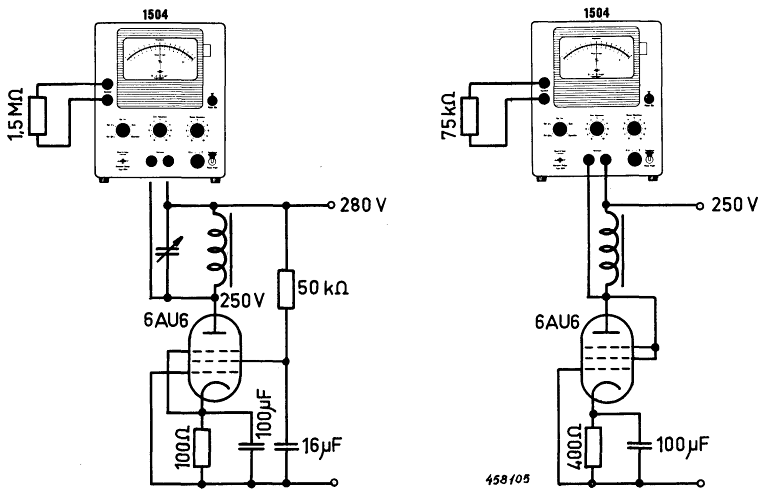


Fig. 5.10. Measuring internal resistance of 6AU6 tube connected respectively as pentode and triode.

frequency of 1000 c/s. In the same way, the impedance of the coupling condenser which connects the tube set-up to the bridge (the 100 μF condenser in the diagram) should have a value which is small in relation to the reciprocal transconductance. By choosing as standard resistor a value of 225 Ω, the bridge pointer will indicate 0 if the 6AU6 tube has the transconductance given in the catalogue.

Fig. 5.10 shows the corresponding set-up for measuring a tube's internal resistance, and here it is important that the impedance in the tube's anode circuit should be much greater than the tube's internal resistance. Therefore, when the tube is connected up as a pentode, it is expedient to produce resonance in the anode impedance.

6. Appendix

Phase-Shift due to Capacitive Loading.

The output stage which feeds the oscillator signal to the bridge is tuned so as to introduce no unwanted phase-shift. However, when large capacitors are being measured, the capacitive loading will cause some phase-shift between the oscillator signal and the bridge signal.

The phase-discriminating system uses the original oscillator signal as a datum, and therefore the measured voltage will be partly composed of a signal which **should** be in quadrature and therefore rejected. This means that impedance and phase angle measurements will be slightly dependent on each other.

Suppose the impedance deviation is a % to the left side and the phase angle deviation b % to the right side.

The introduced error on impedance scale is then some fraction of b to the right side (same side as phase angle indication). The introduced error on phase angle is some fraction of a to the right side. (Opposite side as impedance deviation indication). The relevant fractions are tabulated below.

20 %	Impedance accuracy	0.01 b	for capacities up to	1 μF
		0.02 b	at	10 μF
	Phase angle accuracy	0.01 a	for capacities up to	10 μF
5 %	Impedance accuracy	0.02 b	for capacitites up to	0.5 μF
		0.05 b	at	3 μF
		0.12 b	at	10 μF
	Phase angle accuracy	0.02 a	for capacities up to	3 μF
		0.05 a	at	7 μF
		0.07 a	at	10 μF
1 %	Impedance accuracy	0.07 b	for capacitites up to	0.5 μF
		0.12 b	at	5 μF
		0.16 b	at	10 μF
	Phase angle accuracy	0.04 a	for capacitites up to	0.5 μF
		0.07 a	at	5 μF
		0.14 a	at	10 μF

Table A1. The maximum extra inaccuracy which is introduced when measurements are carried out on capacitors. With an impedance deviation reading of a % and a phase angle deviation reading of b % the inaccuracy on the 3 different % ranges are directly found.

Effect of tan δ (Dissipation Factor) upon Capacitance Deviation Measurements.

Example:

Actual capacitance deviation = 0.
Angle of loss of unknown capacitor = δ.

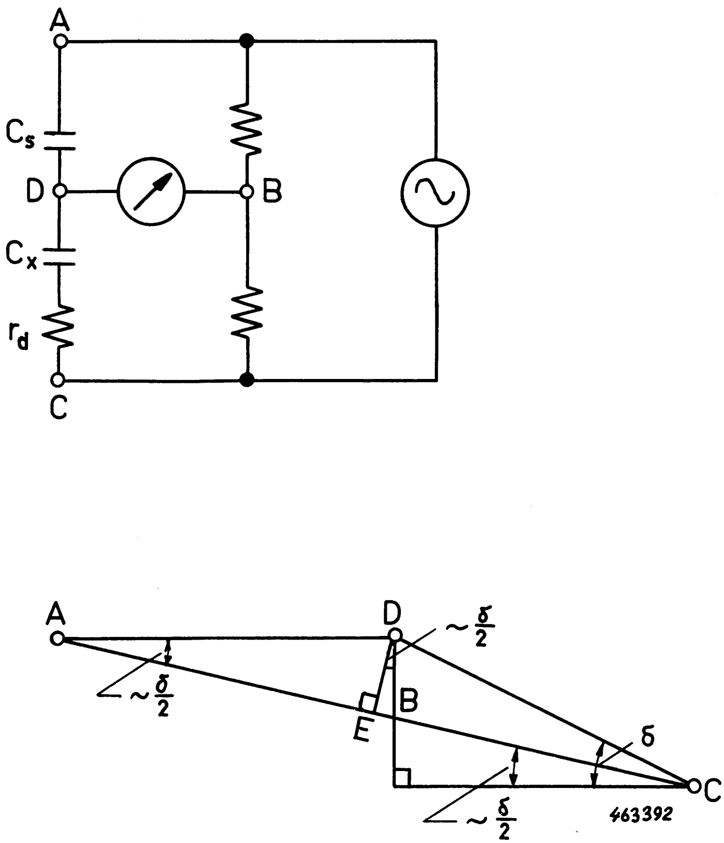


Fig. A1. Circuit diagram of a Wheatstone Bridge and the vector diagram.

For the sake of simplicity the C_x-dissipation is represented by a series resistance r_d.

The voltage B-D is fed through the amplifier to the phase sensitive detector, where it is analysed into the voltage E-D representing the phase angle deviation and the voltage B-E representing an impedance deviation.

B-E is closely equal to A-B $\tan^2 \frac{\delta}{2}$ if A-E ~ A-B.

If $\tan \delta = 0.2$, $\tan \frac{\delta}{2} \cong 0.1$ and $\tan^2 \frac{\delta}{2} = 0.01$ then B-E = A-B × 0.01 which corresponds to an impedance difference of 2 %.

This holds true with the fact, that the instrument indicates impedance deviation, and since the impedance of C_x is

$$\sqrt{X_{cx}{}^2 + (X_{cx} \tan \delta)^2}$$

and of C_s is X_s the percentage impedance deviation is

$$\frac{X_{cx} \sqrt{1 + \tan^2 \delta} - X_{cs}}{X_{cs}} 100$$

and by setting $X_{cx} = X_{cs}$

$$(\sqrt{1 + \tan^2 \delta} - 1)\ 100\ \%$$

and if $\tan \delta = 0.2$

$$(\sqrt{1 + 0.04} - 1)\ 100 = 2\ \%$$

Effect of Capacitance Deviation upon the Measurement of tan δ.

1. Assume that the impedance deviation is zero. This gives the vector diagram ADC, and the phase angle of C_x being δ represented by B-D = A-B $\tan \frac{\delta}{2}$
2. Another value of C_x is chosen, but the dissipation factor is kept constant. A new vector diagram comes out, namely AD_1C.

If the difference between C_s and C_x is for instance 20 %, B-E will be 10 % of B-C, and hence E-D_1 10 % smaller than B-D.

Example: C_x 20 % larger than C_s. $C_x = C_s + 20\ \%$ and the actual phase angle 0.3 (or "30 %").

The phase angle indicated on the instrument will be 0.3 — 10 % = 0.27 (or "27 %"). If C_x had been 20 % smaller than C_s, $C_x = C_s - 20\ \%$, the phase angle indication would have been 0.3 + 10 % = 0.33 ("33 %"). This error can be reduced considerably, by introducing a dissipation factor to C_s (parallel and/or series resistor) equal to the average dissipation factor measured.

If the measured average dissipation factor is 0.26 and the max. allowable dissipation factor is 0.3, the limit for rejection will now be 0.04, and the absolute uncertainty in the example above is reduced from 0.03 to 0.004 for a capacitance deviation of 20 %.

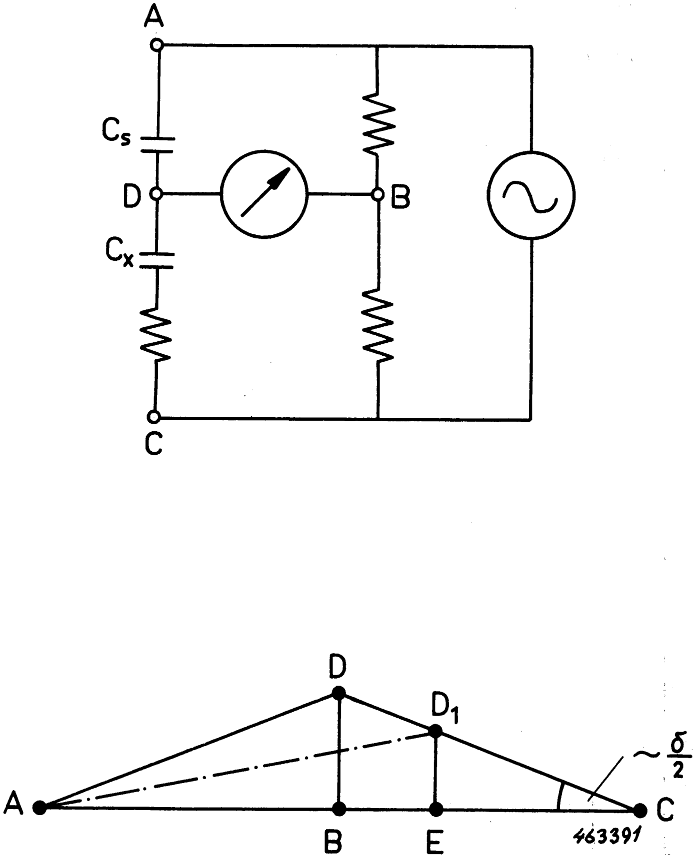
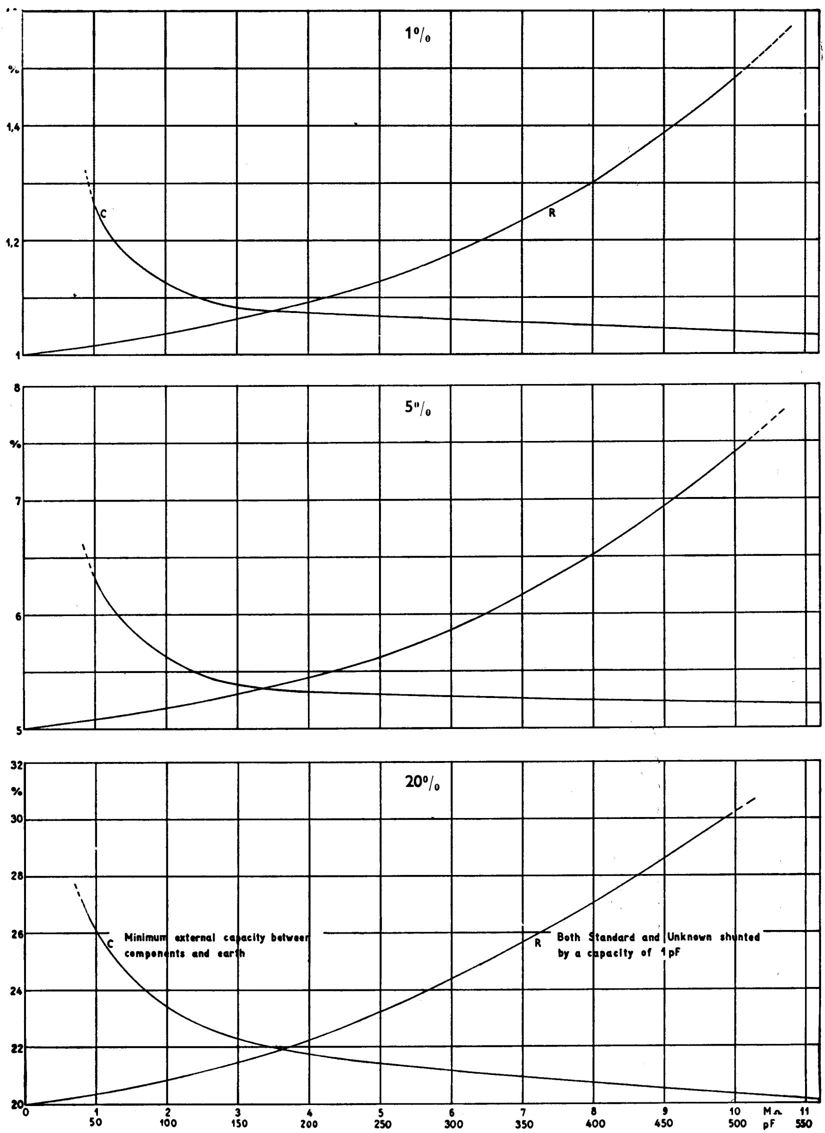


Fig. A2. Circuit diagram of a Wheatstone Bridge and the vector diagram.

Corrections Curves for Reference Point Adjustment

Valid for instruments with serial number 15100 and upwards

Type 1504



Specification.

Ranges of Test Components for Deviation Measurements:

Resistance: 10 Ω—10 MΩ

Capacitance: 50 pF—10 μF

Inductance: 2 mH—100 H

Ranges of Test Components with Two External Standards and Direct Reading:

Resistance Range from 0—0.15 Ω to 0—3.5 MΩ

Capacitance Range from 0—1.5 pF to 0—3.5 μF

Measurement Frequency: 1000 c/s.

Meter: Large moving-coil instrument in which removeable scales can be inserted (see figure). Illuminated scale with zero point in the centre. The instrument is safeguarded against overloads. Ranges for impedance deviations from — 1.5 % to + 1.5 %, — 7 % to + 8 %, — 25 % to + 35 % and — 50 % to + 100 % and for phase angle deviations from — 1.5 to + 1.5 × 10^{-2}, — 7 to + 7 × 10^{-2}, — 30 to + 30 × 10^{-2} and — 80 to + 80 × 10^{-2} radians.

Accuracy of impedance measurements: Better han 0.03 % for deviations close to zero. With zero phase angle difference of standard and unknown: Better than 3 % of indicated deviation at full-scale deflection.

Stability: The zero point is independent of the line voltage. Deflections from the zero point will change 3 % for a 10 % variation of line voltage.

AC-Hum: The bridge is not sensitive to hum voltages.

Impedance — Phase Angle Switch: A special microswitch is included to allow speedy switching from impedance to phase angle measurements.

Tubes: 3×6AU6 (EF94), 6AQ5 (EL90), OA2 (150C2).

Power Supply: 100—115—127—150—220—240 Volts AC. 50—400 c/s. 40 Watts.

Dimensions: 33 (height) × 28 (width) × 20.5 (depth) excl. dials cm.
13 (height) × 11 (width) × 8 (depth) excl. dials inch.

Weight: 10 kg (22 lbs.)