Wayne Kerr CORPORATION
22 Frink Street, Montclair, New Jersey 07042 • (201) 746-2438

Innovations in Instrumentation ■ Measurement ■ Analysis ■ Synthesis ■ Control

B221A Universal Bridge

with Type Q221 Low-Impedance Adaptor

- **Exceptional Range: C: 0.0002 μμF to 100,000 μF; R: 50 μ ohms to 50,000 megohms; L: 5 mμH to 10⁹H**
- **Discrimination to 0.01% of Full Scale**
- **Accuracy to 0.1% of Reading**
- **Flexible: Transformer-Ratio-Arm Circuit Provides Two, Three, and Four-Terminal Measurements; has "Kelvin Configuration" for Low-Impedance Measurements Without Lead Errors**
- **Simultaneous Display of Real and Imaginary Components of an Impedance, with Equally-High Accuracy and Resolution**
- **Automatic Balancing, Instant Readings, Remote Recording, with Type AA221 AUTOBALANCE® Adaptor**

The Wayne Kerr Type B221A Universal Bridge is an instrument of advanced design employing the transformer-ratio-arm technique and offering the choice of two-terminal, three-terminal (for high impedances), and four-terminal (for low impedances) measurements.

The B221A will measure even high-impedance components wired into a circuit, eliminating the effects of undesired shunt impedances by means of the three-terminal ratio-arm configuration. Since shunt effects of long cables are also thus automatically "guarded out", the instrument is particularly suited for remote measurements.

Very *low* impedances are measured by an "AC Kelvin" method, so that the series impedance of the measuring leads or the contact resistance of the connections to the impedance under test do not affect accuracy.

The instrument will also measure the transfer admittances of 3- or 4-terminal networks — e.g., transistor parameters or transformer voltage ratios. Components with superimposed DC, such as chokes and polarized capacitors, may be measured directly, without the need for zero adjustments or time-consuming substitution techniques.

The B221A Bridge is extremely easy to operate and read accurately. A novel mechanism provides direct readings of digits, decimals, and units of measurement for each setting of the centrally-placed range switch (see Figure 1). Thus any errors that might be caused by the use of incorrect multiplying factors are obviated.

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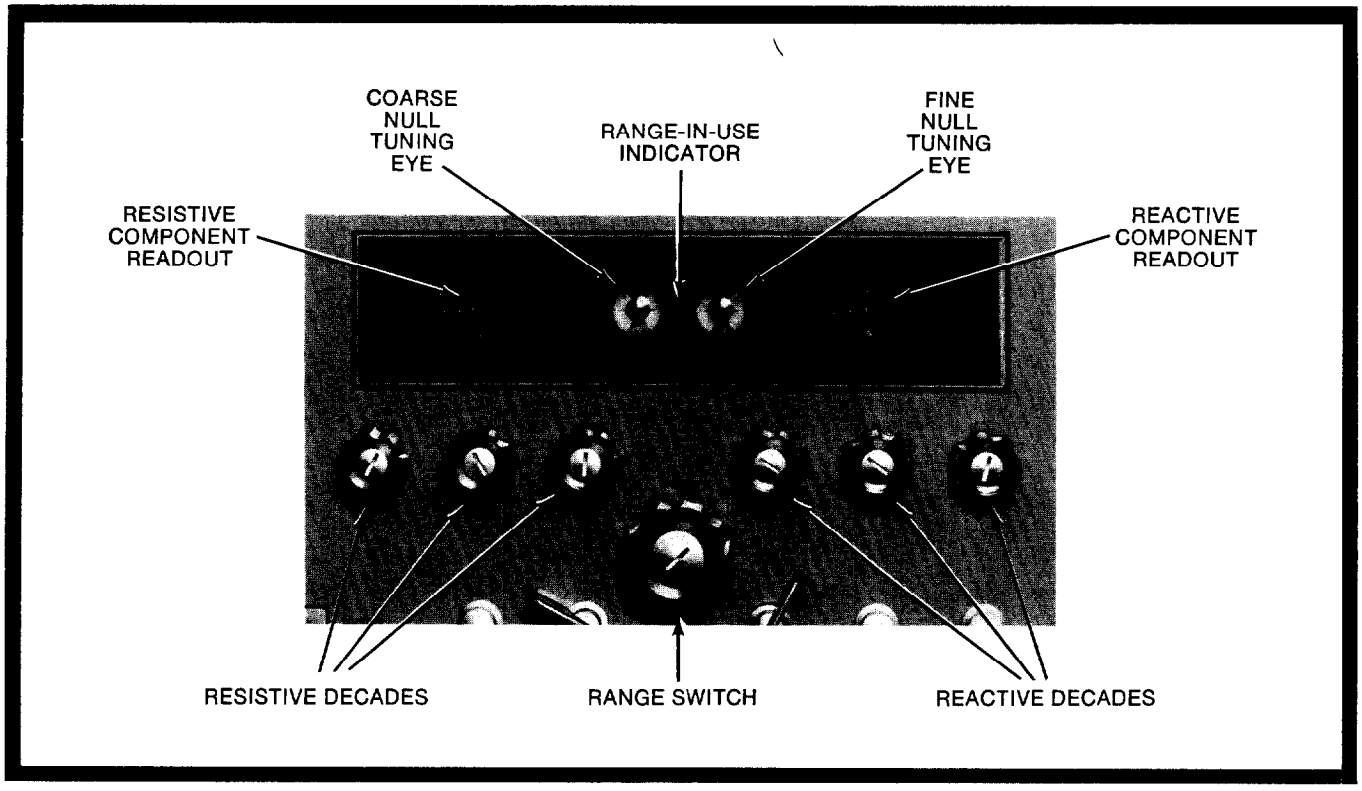

Figure 1

Three decades, two switched and one continuously variable, are provided for both resistive and reactive measurements; when these contols are operated, the values are automatically displayed in the appropriate dial windows. No rezeroing is required for range changes.

Operation is made even simpler with the AUTO-BALANCE® ADAPTOR AA221, which provides the final two-digit "trim" of a four-digit measurement automatically in the form of a meter reading. Connection of the unknown impedance to the Bridge terminals produces an immediate reading of the resistive and capacitive components simultaneously. Separate recorder outputs permit continuous tracking of variations (with temperature, etc.) of both components by remote recorders or digital voltmeters. No manual balancing of the bridge is required, enabling precision batch-testing of components at extremely rapid rates; a scale-offset feature permits GO-NO-GO testing to be performed without switching operations.

Theory of Operation

Figure 2 is a simplified diagram of the B221A circuit arrangement. T_1 is the voltage transformer with two windings having turns N_u and N_s. T_2 is the current transformer, the primary of which is tapped at turns n_s and n_u. If it is assumed that the transformers are essentially ideal (entirely reasonable for 4-digit measurement), the relation between the unknown and standard impedances is, at Balance:

$$Z_u = \frac{N_u \bullet n_u}{N_s \quad n_s} \quad Z_s.$$

Both the standard and the unknown impedances can now be connected between appropriate taps of the voltage and current transformers, and with one set of standards a range of impedance measurement of 1,000,000 to 1 can be obtained. The transformers are so designed that very heavy shunt loading is possible without affecting accuracy of measurement. For full description of the technique, see Wayne Kerr Monograph No. 1, "The Transformer-Ratio-Arm Bridge", available on request.

The standards employed are capacitive and resistive, and by reversing the sense of their connection to the current transformer, inductance and negative resistance can be measured; i.e., the bridge will make measurements in any quadrant of the complex plane.

The built-in source consists of a stable LC oscillator and buffer amplifier tuned to 1592 cps (10^4 radians/sec) to simplify calculations involving $2\pi f$, although other frequencies may be furnished on special order, and provision is made on the standard instrument for use of an external source and detector from 20-20,000 cps.

The detector circuit consists of a two-stage tuned amplifier using ferrite-core inductors and silvered-mica capacitors. Null indication is given by two magic eyes

placed at points of different gain in the amplifier, each having 2 sections (one three times as sensitive as the other) to yield a total of 4 stages of sensitivity. This means that range finding is achieved without recourse to adjustment of the sensitivity control, and subsequent coarse and fine balancing is achieved with progressively more-sensitive detectors.

ADAPTORS

Autobalance Adaptor AA221

The fundamental circuit of the "AUTOBALANCED" bridge, employing AUTOBALANCE ADAPTOR AA221, is shown in Figure 3. T1 and T2 are the voltage and current transformers of the B221 Bridge. As before, when the impedance of the unknown satisfies the equation

$$Z_u = Z_s \bullet \frac{a}{b} \bullet \frac{c}{d}$$

where a, b, c, and d are the turns of the indicated windings, the bridge is balanced. The voltage induced in the secondary of T2 is zero, and the meter reads zero. Such a condition occurs at cardinal values of unknowns, such as 32.00, 33.00, etc., with the appropriate decade settings. When, however, the value lies between two cardinal values (e.g., 32.43), an unbalance would normally be induced in the secondary of T2. The feedback amplifier A, however, has very high gain, and its output is connected to winding "e" in such phase as to cancel the unbalance. This feedback signal is read on a phase-sensitive detector, and indicated on a meter (m). It would, in our example, read "43", which would be added to the "32" set on the bridge dials, to yield the exact value, 32.43. The design is such that the residual error is negligible, and the full accuracy and sensitivity of the B221 Bridge are retained over its original range (or the range with Adaptor Q221, when used).

Low Impedance Adaptor Q221

The Low-Impedance Adaptor Model Q221 extends the range of the B221 Bridge to capacitances as high as 100,000 μF, and to correspondingly minute values of resistance and inductance, down to 50 micro-ohms and 25 mμH. Serving as an "impedance inverter" between the bridge and the unknown, it permits comparison of component values, detection of small parameter changes as in measuring temperature coefficients, "dry" electrical connections, switch contact resistance, etc. Lead resistance or contact resistance of connections to the unknown do not affect the accuracy of the measurement.

Also available for use with the B221 are a series of chemical adaptors for measurement of conductivity and dielectric constants, and the Model TA221 Transistor Adaptor, for measurement of semiconductor small-signal AC parameters. Separate bulletins on these accessories are available on request.

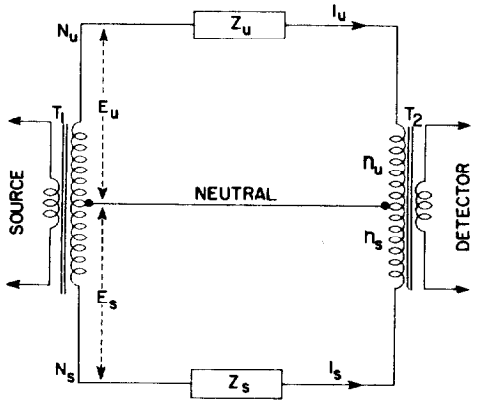

Figure 2. Simplified Diagram of the Transformer-Ratio-Arm Bridge.

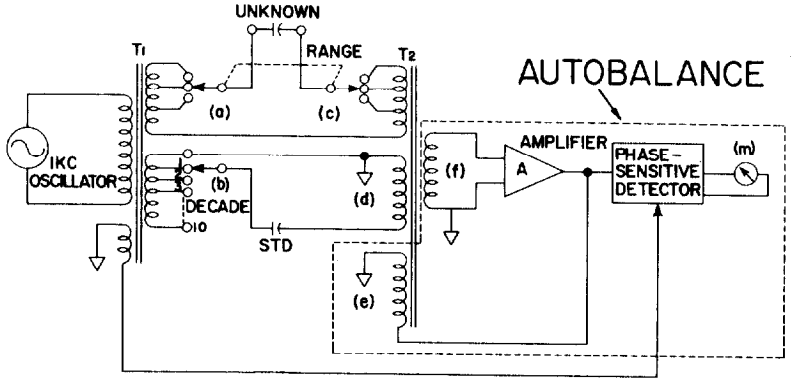

Figure 3. Simplified Diagram of the B221A Bridge with AA221 Autobalance Adaptor.

SPECIFICATIONS

Overall Coverage (Bridge with Low-Impedance Adaptor)

Resistance:

R: 50 μ ohms to 50,000 megohms

Capacitance:

C: 0.0002 $\mu\mu$F to 100,000 μF

Inductance:

L: 5mμH to 10^8H

Universal Bridge B221A

Source Frequency:

1,592 cps $\pm$1% ($\omega = 10^4$) (other frequencies, 1000 cps, etc., are available)

Conductance:

0.01μMho — 11mMho (9Ω — 100MΩ) to an accuracy of $\pm$0.1% To 0.00002μMho (50,000MΩ) with reducing accuracy dependent on discrimination

Capacitance:

0.1$\mu\mu$F — 11.1μF to an accuracy of $\pm$0.1%. To 0.0002$\mu\mu$F with reducing accuracy dependent on discrimination

Inductance:

0.9mH — 1,000H to an accuracy of $\pm$0.1% when source frequency is measured: otherwise to $\pm$2%. To 10^8H with reducing accuracy dependent on discrimination

Power Supply:

100-125 and 200-250V, 40-60 c/s. Power consumption, approximately 25W

Dimensions:

Width: 17 inches (43 cm)
Height: 11½ inches (29 cm)
Depth: 7½ inches (19 cm)

Weight:

Approximately 25 pounds (11.4 kg)

Low Impedance Adaptor Q221

Resistance Ranges:

50$\mu\Omega$ to 10Ω in four ranges. Accuracy: $\pm$1% + 25$\mu\Omega$

Impedance Ranges:

As above

Inductance Ranges:

0.005μH to 1mH in four ranges. Accuracy: $\pm$1% $\pm$0.005μH

Discrimination:

0.2% of maximum in both above ranges

Capacitance Ranges:

10μF to 5 farads in four ranges. Accuracy depends on precise knowledge of frequency. Approaches 1% for 0.1% frequency accuracy.

Dimensions:

Base diameter: 5 inches (12.7 cm)
Height: 3¼ inches (8.28 cm)

Weight:

Approximately 5½ pounds (2.5 kg)

Autobalance Adaptor AA221

Range:

Same as above

Recorder Outputs:

0-100μA into 10 ohms. From G or C meter circuits

Voltmeter Outputs:

0-100 mV. Approximately 200K ohms impedance (balanced). From G or C meter circuits

Power Supply:

Power Unit 110V or 200-250V, 50-60 cps operation

Dimensions:

17" (43 cm) wide, 11½" (29 cm) high, 7½" (19 cm) deep

Weight:

19¼ pounds (8.7 kg)

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