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Impedance Comparators
Stability of Standards

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COVER

VITRAMON,® Inc., uses the Impedance Comparator for comprehensive measurements on statistical samples from each production lot of capacitors.

IMPEDANCE COMPARATOR ADAPTABLE TO MANY KINDS OF MEASUREMENTS AND TESTS

"Double-duty" instruments that provide laboratory accuracy in production-line testing, as well as production-test speed in laboratory measurements, are universally welcomed. The General Radio TYPE 1605-A Impedance Comparator has proved to be just this type of instrument and it has, time and again, proved its versatility and adaptability in a variety of applications throughout the electronics industry.

The Impedance Comparator indicates directly the impedance difference between a standard and an unknown and eliminates the tediousness of manual bridge balancing. Many of the limit-bridge predecessors of the Impedance Comparator operated at a fixed low frequency, which limited their sphere of application. The G-R Impedance Comparator not only has a built-in oscillator providing 100-c, 1-kc, 10-kc, and 100-kc operation but, in addition, incorporates features which allow a much greater degree of precision and considerably more versatility than do previously available instruments.

Basically, this instrument[1] is a self-contained impedance measuring system comprising a signal source, a bridge, and a detecting circuit (Figure 1). The bridge circuit consists of the standard and unknown external impedances, which are to be compared, and two highly precise transformer-type unity ratio arms. The voltages across these ratio arms are equal within one part in a million. Hence the accuracy of the impedance measurement depends primarily upon the accuracy of the external standard used. Detector sensitivity permits impedance-difference measurements to a precision of 0.01% and phase-angle difference measurements to 0.0001 radian. The meters, which indicate impedance difference and phase-angle difference, can be read at a glance.[2]

[1] Holtje, M. C., and Hall, H. P., "A High Precision Impedance Comparator," *General Radio Experimenter*, Vol. 30, No. 11, 1956.

[2] See page 6 for a panel view of the Comparator.

Laboratory Accuracy, Production Speed From One Instrument

The many applications of the G-R Impedance Comparator in industry well illustrate the instrument's versatility. A typical use is that at VITRAMON,® Inc., of Bridgeport, Connecticut, manufacturers of porcelain-dielectric capacitors. VITRAMON uses the Comparator to determine the temperature coefficients of their capacitors. The temperature of a sample capacitor is varied from −55°C. to 200°C. while bridge readings are taken periodically at a number of temperatures. From these data, a plot of percent deviation of capacitance versus temperature is obtained, the slope of which is the temperature coefficient. The inherent ability of the Impedance Comparator to make measurements without manual balancing or readjustment and the built-in guard circuit, which eliminates the effect of lead capacitance, enable VITRAMON to obtain the desired laboratory accuracy at a speed heretofore unattainable by conventional test methods.

Figure 1. Block diagram of the Type 1605-A Impedance Comparator.

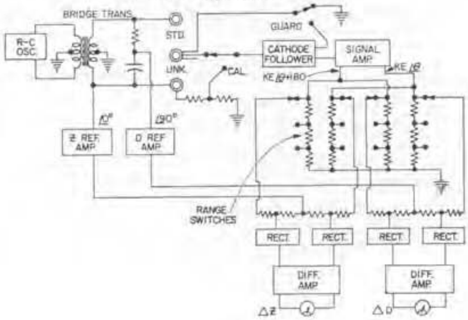


Figure 2. Semi-Automatic Tester at Bendix Radio Division, Bendix Aviation Corporation.

On the production line where speed is essential, the Impedance Comparator has become a VITRAMON workhorse. Used in conjunction with a standard capacitor, the bridge permits 100% checks of capacitor production lots, as opposed to the spot testing, without increase in labor costs. This go-no-go type of test is made with an accuracy of the order of 0.1% for both capacitance and phase angle.

Semi-Automatic Sorting

When engineers of Bendix Radio Division of Bendix Aviation Corporation, Baltimore, Maryland, needed a "brain" for their Semi-Automatic Tester (Figure 2), they chose a TYPE 1605-A Impedance Comparator. The Semi-Automatic Tester, which can check all components on a printed-circuit subassembly and thus verify adequacy, is manufactured under subcontract for IBM and the United States Air Force.

Here is how Bendix put the Comparator to work: the Impedance Comparator panel meters were disconnected. The metering voltages, proportional to impedance-magnitude difference (in percent) and phase-angle difference (in radians), are amplified by the tester and compared to allowable tolerances. Printed-circuit components which produce voltages in excess of pre-set tolerances are automatically rejected. Built-in relays permit automatic switching of Comparator impedance ranges by a remote punched-card programmer. With automatic programming, testing rate is one measurement per second!

Here are a few reasons why Bendix uses the Impedance Comparator: it indicates *both* impedance magnitude and phase angle without knob twiddling; it provides d-c voltages proportional to percentage deviation from a standard; it has excellent guard circuitry which permits the long cable runs usually necessary in automatic equipment; and it combines a wide impedance range with high measurement accuracy.

Environmental Testing

An interesting application evolved from Inland Testing Laboratories' need to make environmental reliability tests on a large number of capacitors. The automated instrumentation system (Figure 3), built at their Morton Grove, Illinois, plant to accomplish this measurement, incorporates the TYPE 1605-A Impedance Comparator. The system measures and records, in sequence, insulation resistance, capacitance, and phase angle of many thousands of capacitors of several types, each operating at a different voltage level and temperature. These capacitors are housed in two large compartmentalized environmental test chambers. The instrumentation system is remote with respect to the components in the chamber.

The TYPE 1605-A Impedance Comparator, which is the heart of this intricate test apparatus, serves as the measuring device for capacitance and loss measurements. Comparator meter-

Figure 3. Inland Testing Laboratories use the Impedance Comparator in an automated instrumentation system for environmental reliability tests on capacitors.

ing voltages are fed into a digital voltmeter and are converted to digital form for punched-card recordings. The data so recorded will provide detailed statistical information concerning reliability and life cycles of capacitors operating under various voltage and environmental conditions.

A Research Tool

Measurement of small dielectric changes of gases requires a precision that taxes the resources of even the most sensitive impedance-measuring device. Professor R. H. Cole[3] of Brown University asked the General Radio Company to modify a Type 1605-A Impedance Comparator so that it would have an impedance-difference sensitivity several times that of the catalog model. He wished to make measurements of small dielectric constant changes of gases and of dilute solutions. Although these measurements are usually made by heterodyne resonant circuit or resonant-cavity methods, the Impedance Comparator won out because of its advantages of simplicity of operation, its freedom from lead capacitance and other stray effects, and its ability to operate at frequencies below 100 kc.

The phase-sensitive detector circuits are stable and quiet enough to permit further modification of the instrument, so that, with an external detector, the usable sensitivity is one part per million!

In order to accomplish these measurements, Professor Cole constructed the circuit shown in Figure 4. The comparison method used for gases consists of two identical cells which are 80-pf three-terminal parallel-plate capacitors. Differences in capacitance, when cell I is filled with the gas of interest, and cell II with a reference gas or vacuum, are balanced by the capacitance wye network $C_A C_B C_C$. The variable capacitors C_A and C_B are ganged in opposition, so that rotation gives a linear shift of reference capacitor C_C from the electrical midpoint. Values of C_C are chosen to give 0.5-, 5-, and 50-pf full-scale deflection. Data obtained for such gases as nitrogen, argon, and carbon dioxide are consistent to ten parts per million or better.

These are but a few of the many applications in which the Impedance Comparator has demonstrated its usefulness. It is truly a universal instrument; one which meets both the laboratory criterion of accuracy and the production criterion of speed.

— Howard Painter

[3] Cole, R. H., "Methods for Dielectric Measurement of Fluids," National Academy of Sciences — National Research Council Conference on Electrical Insulation, 1958 Annual Report.

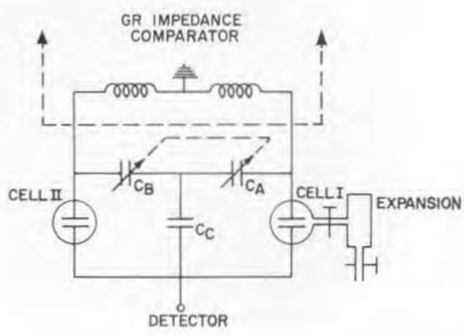


Figure 4. Circuit used for measurement of small changes in dielectric constant.

THE TYPE 1605-AS2 IMPEDANCE COMPARATOR

In the preceding article, mention was made of a modification of the Impedance Comparator to give a higher degree of resolution than the standard model. While the full-scale standard ranges of 10%, 3%, 1%, and 0.3%, with corresponding ranges for phase angle, are adequate for most uses, there are always applications where increased sensitivity is desirable.

In our own laboratory, for instance, it soon became apparent that, while a sensitivity of 0.003 full scale for dissipation factor is useful, an increase in sensitivity by a factor of 3 to 0.001 would vastly enhance the usefulness of the instrument. For example, with a sensitivity of 0.003 full scale, the dissipation factor of good capacitors made of low-loss materials such as mica, teflon, or polystyrene, although detectable, represents extremely small-scale deflections. With 0.001 full-scale reading on the other hand, sufficient deflection is obtained so that the instrument can be used for the sorting of high-quality silvered mica films. Selection for capacitance value and rejection for high dissipation factor can both be accomplished rapidly. A number of such instruments of increased full-scale sensitivity have been supplied and are now being manufactured in limited production quantities.

Since any well-designed instrument represents a compromise between numerous economic and technical factors, it is rarely possible to increase performance in one respect without sacrificing in some other characteristic. In the Impedance Comparator the increased sensitivity is obtained by an increase in the low-resistance limit of measurement and by elimination of the 10% deviation ranges. Neither compromise is necessary on a technical basis, but is arrived at rather on an economic basis. The impedance limitation comes about from the fact that the increased sensitivity is most readily obtained by a change in the turns ratio of the bridge transformer. Since the available power from the internal oscillator is not changed, the increase in the measurable impedance naturally follows. Similarly, the elimination of one range to make room for the new range is dictated by the mechanical considerations of switch design, available space, and panel layout.

— I. G. Easton

Panel view of the Type 1605-AS2 Impedance Comparator.

SPECIFICATIONS

Impedance Ranges: Resistance or impedance magnitude: 20 Ω to 20 MΩ. Capacitance: 40 μμf to 80 μf; to 0.1 μμf with reduced sensitivity. Inductance: 200 μh to 10,000 h.

Internal Oscillator Frequencies: 100 c, 1 kc, 10 kc, 100 kc; all ±3%.

Meter Ranges: Impedance Magnitude Difference: ±0.1%, ±0.3%, ±1%, ±3% full scale. (Can be adjusted for maximum of 50%.) Phase Angle Difference: ±0.001, ±0.003, ±0.01, ±0.03 radian full scale (equal to dissipation factor on lowest ranges).

Accuracy of Difference Readings: 3% of full scale; i.e., for the ±0.3% impedance-difference scale, accuracy is 0.009% of the impedance magnitude being measured.

Voltage Across Standard and Unknown: Approx. 1 volt.

Accessories Supplied: Type CAP-35 Power Cord, telephone plug, external-meter plug, adaptor plate assembly (fits panel terminals) and spare fuses.

Tube Complement: 1-5651, 1-5751, 3-12AX7, 4-6AL5, 5-12AT7, 3-6U8, 1-6AS7G, 1-3A10, 1-VE65A-1

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles; about 100 watts input at 115 volts. Instrument will operate satisfactorily on power-supply frequencies up to 400 cycles, provided that the supply voltage is at least 115 volts.

Power input receptacle will accept either 2-wire (Type CAP-35) or 3-wire (Type CAP-15) power cord. Two-wire cord is supplied.

Mounting: Relay-rack panel with cabinet; Type 1605-AR has fittings to permit either instrument or cabinet to be removed from rack without disturbing the other; Type 1605-AM has end supports for table or bench use.

Dimensions: Panel, 19 x 8¾ inches; depth behind panel, 12 inches.

Net Weight: 29½ pounds.

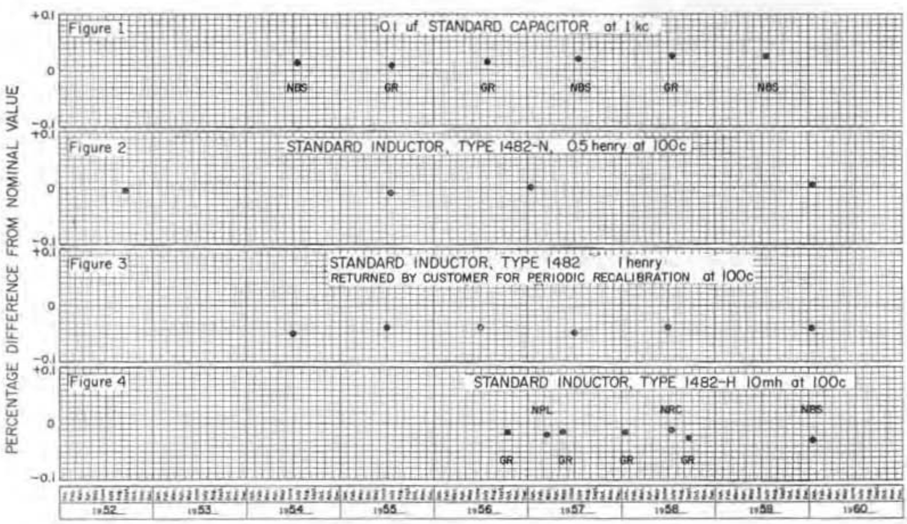
Type		*Price*
1605-ARS2	Impedance Comparator (relay-rack mounting)	$925.00
1605-AMS2	Impedance Comparator (bench mounting)	925.00

U. S. Patent No. 2,548,457.

STABILITY RECORDS OF STANDARDS OF INDUCTANCE AND CAPACITANCE

The data shown in the accompanying plots will be of considerable interest to all who use General Radio standards of inductance and capacitance.

Figure 1 shows a six-year record of measurements on a capacitor of the 1409-type, having a nominal capacitance of 0.1 μf. In this period, three measure-



ments of the capacitor were made by the National Bureau of Standards, and three were made in the General Radio Laboratories in terms of NBS-calibrated standards. The total spread of 0.0075% for all measurements in this six-year period is indicative of the stability of the capacitor.

Figure 2 is a record of NBS measurements over a nine-year period of one of General Radio's 0.5-henry reference standards of inductance. The total spread is ±0.0075%.

Figure 3 is the record of General Radio's measurements of a 1-henry standard inductor Type 1482-P, returned to us each year for recalibration. The total spread over a six-year period is ±0.005%.

Figure 4, a record of measurements on a 10-mh Type 1482-H Standard Inductor, is of particular interest because it includes measurements made by national laboratories in three countries, the National Physical Laboratory in England, the National Research Council in Canada, and the National Bureau of Standards in the United States. Three measurements by General Radio are also included. The total spread in these measurements is ±0.01%, a remarkable agreement when we consider that the measurements include any drift which might occur over a 4 to 5-year period, plus a round trip across the Atlantic, another to Canada, and a third to Washington.

All measurements in these plots have been corrected to a temperature of 20.5°C.

LOS ANGELES OFFICE

— CORRECTION —

The editor offers his apologies to Mr. Kenneth Castle, sales engineer at our Los Angeles office, whose name and photo were omitted from the list in the March issue of the Experimenter. Mr. Castle, whose photo is shown herewith, is very much a part of our Los Angeles staff.

MINIMUM BILLING AND INSPECTION CHARGE

We find it necessary to put into effect as of May 2, 1960, a minimum billing amount of $10.00 applicable to all orders except those for repair parts or for cash sales.

Should Government or other Source Inspection be required, there is a surcharge of 1% with a minimum of $2.50 per shipment.

General Radio Company

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