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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

TYPE 1612-AL R-F CAPACITANCE METER

Also IN THIS ISSUE

● **IT IS PROBABLE** that not many readers of the *General Radio Experimenter* are very keenly aware of the standardization activities of the RTMA (Radio-Television Manufacturers Association), nor of the many problems which are posed to the active committeemen as they develop these standards.

A good example of the unexpected ramifications of the standardization process can be found in the electron-tube-socket standardization work which has so far produced Standard TR-111 in the Transmitter Section and will, in the near future, produce a Receiver Section Socket Standard. Even before TR-111 actually was issued, and while it was going through the successive steps required for standardization, committee work was going forward on extensions and revisions of TR-111 to keep the standard alive and abreast of the times.

Figure 1. Panel view of the Type 1612-AL R-F Capacitance Meter, showing open capacitance scale at low end of range.

TEST EQUIPMENT NEEDED

Oftentimes in the development of a standard it will be, by common consent, deemed essential to make a certain type of test on the item being standardized. Frequently, the specification may require testing equipment which is not presently available. This was the case with the capacitance tests required by Paragraph 4.32 of TR-111. Paragraph 4.32 provides for two types of measurements: (1) direct capacitance between two specific socket contacts, all other contacts and metal parts being grounded; and (2) capacitance between a specific contact and all others (tied to all metal parts). The actual individual specification sheets for the various sockets, however, call for only the latter type of measurement.

The simple measurement was adopted because it is highly desirable that the capacitances be measurable on equipment which is inexpensive to buy and simple to operate, so that all concerned, manufacturers and users, can afford to own the testing equipment and can all have identical equipment so as to eliminate the measuring gear as a possible source of controversy in inspection. Direct-capacitance measurements are tricky to make and require expensive equipment. A simple capacitance measurement from one contact to all other metal parts, of the order of 1 $\mu\mu$f, is easily made with simple and inexpensive equipment. For this reason, therefore, the individual specification sheets of TR-111 contain only capacitance requirements from one contact to "all", and standardization now in process will reduce the number of these measurements from two to one.

TEST EQUIPMENT SELECTED

The capacitance values for various sockets are all of the order of 1 $\mu\mu$f. The search for the simple inexpensive equipment with which to measure, at a frequency of 1 Mc, a capacitance of the order of 1 $\mu\mu$f to an accuracy of 0.1 $\mu\mu$f or better was delegated to a small task group by the TR 9.8 Socket Subcommittee. Eventually it was decided to employ a modification of General Radio's Type 1612-A R-F Capacitance Meter[1]. The Type 1612-A has ranges of 80 $\mu\mu$f and 1200 $\mu\mu$f. The capacitance network in the instrument is designed to give a considerably expanded scale at the low-capacitance end of the low range. It was hoped, and later borne out by making a sample, that the expanded or quasi-logarithmic scale of a 10-$\mu\mu$f range would give sufficient accuracy at the 1-$\mu\mu$f measurement level. Experiments with the first sample carried out by several different engineers, who had had no previous experience with the instrument, indicated that it would be readily possible to repeat settings within 0.02 $\mu\mu$f by simply observing the maximum on the resonance-indicating meter.

As soon as these engineers had had a chance to use the experimental model of the capacitance meter at a TR 9.8 committee meeting, they immediately sensed the usefulness of the device and inquired whether a 100-$\mu\mu$f range could not be incorporated into the instrument. In effect, they were asking that the modified capacitance meter have roughly one-tenth the maximum ranges of the original Type 1612-A. This was not at all difficult to do, and a second experimental model was prepared, embodying this added feature. As in the case of the Type 1612-A, the shifting from one range to the other is accomplished automatically as the dial is rotated from one half of its scale over to the other, with

[1] W. F. Byers, "A Compact Radio-Frequency, Capacitance-Measuring Instrument," *General Radio Experimenter*, November, 1948.

no extra panel switching operations. On the 10-$\mu\mu$f range, the first 1 $\mu\mu$f occupies almost one-half of the scale length, and settings can be made to 0.02 $\mu\mu$f.

METHOD OF MEASUREMENT

In use the capacitance meter is prepared for a series of measurements by (1) setting the main dial to one or the other of the two zero points, (2) setting the meter for maximum by use of the zero adjust (front-right-hand) dial, and (3) by setting the meter to full scale by the oscillator output (lower-left-hand) dial. If now a capacitance is to be measured, it should be attached to the unknown or X terminals. The main dial is retuned for maximum meter reading and the capacitance is indicated directly by the dial setting.

SOCKET MEASUREMENT METHOD

How do we go about measuring the capacitance of a *socket?* The socket, by Paragraph 4.32 of TR-111, shall be mounted on a round metal plate 1/16″ thick and 4″ in diameter. Obviously there must be some sort of an adaptor interposed between the binding posts of the TYPE 1612-AL instrument and the socket. This adaptor must simulate in its projecting connecting parts a tube base with which the socket is to be used. Unless adequate shielding is provided by the adaptor, two undesirable conditions will exist: (1) mainly one of inconvenience, in which hand capacity between main or zero-adjust tuning controls and the high unknown binding post will either make measurement difficult or vitiate its accuracy; and (2), the stray capacitance between the large grounded metal plate and the high unknown binding post, of an unknown magnitude, will impair the accuracy of measurement. For these reasons each adaptor is made using an aluminum shield can as a chassis, which, incidentally, provides a ready means for hiding, as well as containing, the mounting and wiring gear associated with the tube base.

An adaptor is attached to the instrument by screwing it on to the stud of the ground unknown binding post after removing the binding-post top, through the means of a female-threaded part driven from the top by a screwdriver slot. Currently there are three adaptors available, as follows:

1. 1612-P1, for 7-pin miniature sockets, to measure "No. 4 contact to all."
2. 1612-P2, for octal socket, to measure "No. 4 contact to all."
3. 1612-P3, for 9-pin miniature noval socket, to measure "No. 5 contact to all."

REDUCTION OF ERRORS

If you have been concerned, as many others working on the project were, with

Figure 2. View showing the three socket adaptors, one attached to the X terminals of the capacitance meter. Internal view of adaptor at top right shows terminals, one of which is a lead for clamping in a binding post and the other a captive nut which replaces the binding-post cap.

the smallness of the capacitance being measured and the consequent importance of probable errors in measurement due to strays or other causes, you are probably by now ready to ask a question. How can we measure accurately the capacitance of a socket this way? The adaptor has an air capacitance between, in the case of the noval, say, pin five and all of the other eight, which capacitance is eliminated when the socket is plugged on. The socket capacitance indicated by the instrument will be less than the true socket capacitance by the amount of this air capacitance between adaptor pins. In order to measure this capacitance value experimentally, pins were progressively shortened until they just made contact with the socket springs, thus reducing as far as possible the air capacitance between pins. The difference in measurements turned out to be only one or two hundredths of a micromicrofarad, which could appropriately be neglected. Since the capacitance values listed on the individual specification sheets were determined with this factor taken into account, only variations in this correction are pertinent.

RTMA standardization will not, for obvious reasons, require the use of one particular proprietary testing device. Amendments to TR-111 now in the RTMA mill, however, state that the Type 1612-AL R-F Capacitance Meter with appropriate adaptors has been found to be a satisfactory means for making the capacitance measurements required by TR-111. And the advantages are obvious in having all inspectors, manufacturers' or users', employ the identical testing equipment.

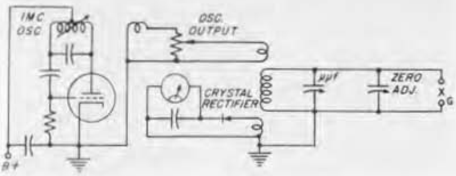

Figure 3. Simplified schematic circuit diagram of the R-F Capacitance Meter.

LOSS INDICATION

The Type 1612-AL provides an additional feature not required by TR-111, namely, a rough indication of the losses in the socket dielectric.

In general, the maximum meter reading will come somewhat below full scale. The amount by which the reading fails to attain full scale depends upon the losses in the capacitance being measured. In the case of tube sockets, for instance, a little experience would indicate what deflections would be appropriate for sockets using various dielectrics. No visible departure would be observed for polyethylene-insulated sockets, only a very small amount for a ceramic socket or a glass-bonded mica one, somewhat more for a mica-filled phenolic, and several divisions for a socket of ordinary black cellulose-filled phenolic.

DIRECT CAPACITANCE MEASUREMENTS

It should be mentioned that, while direct or three-terminal capacitance measurements can be made with the capacitance meter, such measurements are not very convenient nor accurate. Three two-terminal measurements must be made and the unknown calculated from the resulting three equations.

OTHER USES

The Type 1612-AL R-F Capacitance Meter is by no means limited to measurements on sockets. Numberless other capacitance measurements can easily be made, for which the features of measurement at 1 Mc and convenience of operation, including capacitance reading on one dial, are important.

1. Many ceramic capacitors are to be found in the range of 0 to 100 μμf (or in

the range of 0 to 1000 $\mu\mu f$, if a TYPE 1612-A is available as well as a TYPE 1612-AL). These would include separate tubular ceramics, both insulated and uninsulated, disc-type ceramics, and the tubular ceramics included in electron-tube sockets.

2. Small molded mica fixed capacitors, of either foil-mica or silver-mica construction, can be measured at a frequency much nearer that of use than 1 kc or 60 cycles would be.

3. Small variable trimmer capacitors can be accurately measured for maximum and minimum value, or even for curve of capacitance versus rotation. This would apply to variable mica trimmers, variable plate-type air trimmers, variable multiple-cup-type air trimmers, variable ceramic trimmers, and the various piston-type variable trimmers having glass dielectric.

Precautions must be taken, of course, in providing a production-type measuring jig, to make sure that no errors in measurement are introduced by the jig itself, or as a result of its construction or shielding deficiencies. These stray capacitance errors become more important percentagewise as smaller capacitances are being measured.

Another convenient use for these instruments is in the assessment or identification of insulating materials. Samples can be measured between flat plates, and an approximate value of dielectric constant can be calculated from the measured capacitance and dimensions of the plates and the sample. The departure of the maximum reading of the resonance meter from full-scale deflection (after, of course, proper initial setting) is a good indication of the losses in the dielectric.

PROCESS SAMPLING

The R-F Capacitance Meter has also been used in sampling, for control purposes, the concentration of ingredients in chemical processing. Where dielectric properties, particularly dielectric constant, can be used as indicators of concentration, periodic comparisons of process samples with a standard sample can be made on the capacitance meter. For this application a suitable test cell can be devised by the user to meet his particular requirements.

CONCLUSION

In short, the TYPES 1612-A and -AL R-F Capacitance Meters are versatile and useful devices, and are extendable in their utility, almost without limit, by the imagination of their owners and users.

— P. K. McELROY

SPECIFICATIONS

Capacitance Range: TYPE 1612-A, 0 to 1200 $\mu\mu f$ in two bands — 0 to 80 $\mu\mu f$ and 0 to 1200 $\mu\mu f$; TYPE 1612-AL, 0 to 100 $\mu\mu f$ in two bands — 0 to 10 $\mu\mu f$ and 0 to 100 $\mu\mu f$. Ranges are switched automatically as capacitance dial is rotated.

Capacitance Accuracy:

Type 1612-A

Low Range — ± 0.5 $\mu\mu f$ below 10 $\mu\mu f$
$\pm 5\%$ between 10 and 80 $\mu\mu f$

High Range — ± 5 $\mu\mu f$ below 100 $\mu\mu f$
$\pm 5\%$ between 100 and 1200 $\mu\mu f$

Type 1612-AL

Low Range — ± 0.05 $\mu\mu f$ below 1 $\mu\mu f$
$\pm 5\%$ between 1 and 10 $\mu\mu f$

High Range — ± 0.5 $\mu\mu f$ below 10 $\mu\mu f$
$\pm 5\%$ between 10 and 100 $\mu\mu f$

Capacitance Scale: Scale is spread out at low end of dial and nearly linear at high end. For TYPE 1612-A, smallest division is 1 $\mu\mu f$ for the low range and 10 $\mu\mu f$ for the high range. For TYPE 1612-AL, smallest scale divisions are one-tenth these values. Minimum measurable capacitance is influenced by sharpness of resonance as well as scale distribution, and is about one-half the smallest division.

Dielectric Losses: Relative meter indications with different dielectric samples give a comparative measure of dielectric loss.

Oscillator Frequency: 1 megacycle ±1% adjusted at factory. Frequency can be readjusted if necessary by means of a movable dust core.

Resonance Indicator: A 1N34 crystal rectifier is used with a microammeter to indicate resonance.

Tube: A 117N7-GT tube is used in the oscillator circuit, and is supplied.

Power Supply: 115 volts, 50 to 60 cycles ac, or dc.

Power Input: 12 watts at 115 volts ac; 11 watts at 115 volts dc.

Dimensions: (Length) 12 x (height) 6⅝ x (depth) 7½ inches, overall.

Net Weight: 11 pounds, 10 ounces.

Type		*Code Word*	*Price*
1612-A	**R-F Capacitance Meter**	AFTER	**$170.00**
1612-AL	**R-F Capacitance Meter**	AGAIN	**170.00**

Licensed under patents of the Radio Corporation of America.

SOCKET ADAPTORS FOR USE WITH TYPE 1612-AL

Type		*Code Word*	*Price*
1612-P1	**Adaptor for 7-pin miniature**	HEPTA	**$9.00**
1612-P2	**Adaptor for octal**	OCTAL	**9.00**
1612-P3	**Adaptor for 9-pin miniature noval**	NOVAL	**9.00**

ROBERT F. FIELD RETIRES

On December 29, Robert F. Field formally retired from the Engineering Department of the General Radio Company after 21 years of service. Actually, he will be in and out of our laboratories for some time working on various personal investigations he has started.

Robert F. Field

To any regular reader of the *Experimenter*, Mr. Field's name is certainly a familiar one. His contacts with the engineering profession began long before his association with General Radio because, after graduating from Brown University in 1906 and receiving a Master's degree there the following year, he taught physics and electrical engineering at Brown for a number of years. Then in 1915 he left to take advanced work at Harvard University, receiving a Master's degree in 1916. From 1918 until he joined the General Radio staff, he was Assistant Professor of Applied Physics at Harvard, teaching courses in communications engineering, and specializing in electrical measurements.

Mr. Field had been with General Radio only three months when the January, 1930, *Experimenter* carried the first of a long line of his articles on bridges and associated subjects. This article, entitled "An Equal-Arm Capacitance Bridge," analyzed substitution measurements with the now venerable Type 216. During the next few years several bridges were designed by Mr. Field and put into production including the bridge-type frequency meter, Type 434, the Type 716 Capacitance Bridge, the Type 544 Megohm Bridge, and probably the most famous of them all — the first model of the Type 650-A Impedance Bridge — which was soon to become a laboratory fixture along with the soldering iron and slide rule.

Work with bridge circuits soon brought him to the study of impedance standards, the measurement of all types of impedances, and the problems caused by residual impedances in standards and components. One important contribution to the art made as a result of some of this work was the paper presented jointly with D. B. Sinclair at the IRE-URSI meeting in April, 1935. It was entitled "A Method for Determining the Residual Inductance and Resistance of a Variable Air Condenser at Radio Frequencies" and was published in the "Proceedings of the I.R.E." the following year.

It is not necessary to mention all of the instruments developed by Mr. Field to indicate his versatility and ever-present desire to improve measuring techniques, our knowledge of impedances, and the materials from which they are constructed. Furthermore, the investigation of such details as "Connection Errors in Capacitance Measurements" (January, 1938, *Experimenter*) kept pace with his interest in circuits and instrument design. Before long anyone who didn't know about the importance of interfacial polarization to the electrical engineer just hadn't come close to Mr. Field. The results of some of his work concerning polarization and its effect on the properties of dielectrics appeared in his paper, "The Basis for the Non-Destructive Testing of Insulation," which was presented to the AIEE convention in Toronto, June, 1941, and published in the AIEE Transactions in September, 1941.

The study of insulation and dielectric materials in general subsequently occupied much of Mr. Field's time. His paper, "The Behavior of Dielectrics over Wide Ranges of Frequency, Temperature, and Humidity" (published by General Radio), was presented to many groups anxious to learn more about the mechanism of dielectrics and its relation to the testing of various existing types of insulation. The problem of humidity and its effects also was the subject of several *Experimenter* articles of much interest to those working in humid summer climates. And in the May, 1946, *Journal of Applied Physics* he presented his paper on "The Formation of Ionized Water Films on Dielectrics Under Conditions of High Humidity."

Although many of these studies indicated Mr. Field's interest in capacitors and capacitance measurements, inductors were not left out completely, and they came under his scrutiny. In March, 1942, with P. K. McElroy, Mr. Field asked in the *Experimenter*, "How Good is an Iron-Cored Coil?" His latest contribution was presented to the Symposium on Improved Quality Electronic Components at Washington, D. C., in May, 1950, on "Reduction of Losses in Air-Cored Coils."

No summary, however brief, of Mr. Field's contributions to technical literature, should omit reference to his classic paper, "An Engineering Approach to Trout Fishing," which appeared in the *Experimenter* for January, 1946.

Several of Mr. Field's colleagues are now arranging to carry on various aspects of his active engineering program. Mr. Ivan G. Easton will continue work he has done with Mr. Field in the study of electrical insulating materials and bridge measurements and will assume the over-all direction of the program, and Mr. Horatio W. Lamson, who has also done considerable work in the field of inductor design, will carry on research and development projects which Mr. Field has started, especially on air-cored inductors.

Horatio W. Lamson

Ivan G. Easton

SEE US AT THE I. R. E. SHOW

Radio Engineering Show
Grand Central Palace
New York City
BOOTHS 92 AND 93
March 19-22 1951

Plan to visit the General Radio booth at the forthcoming Radio Engineering Show, March 19-22, at Grand Central Palace, New York.

Many of the new instruments announced in the *Experimenter* during the past year will be on display—u-h-f measuring equipment, oscillators, bridges, signal generators, v-t voltmeters, decade impedance units, many others.

A complete working display of TYPE 874 Coaxial Elements will be set up. You can see how measurements of impedance, voltage, and power can be made accurately and easily with this completely integrated line of elements.

Many instruments will have their cabinets removed, to demonstrate the high-quality components and construction methods used in General Radio equipment — the features that give long life and dependable service.

Representatives of our engineering department will be on hand to answer your questions and to discuss with you the performance and applications of General Radio precision-built test equipment.

Plan now to see this display of the most complete line of high-quality test equipment available today.

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