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RADIO SERVICING INSTRUMENTS†

From the Engineering Viewpoint

By J. H. MILLER*

THE problem of adequate service on broadcast receivers is demanding increasing attention from the radio engineer. There are now in the hands of the public entirely too many receivers functioning well below par because of minor faults. Such sets do not result in new sales, but tend to convey the impression, in each individual case, that broadcasting as a whole is not advancing.

It is believed that equipment to enable the servicemen to resuscitate such sets easily, quickly and economically is a real requirement of the industry. If the old set can be brought to at least its normal condition, confidence can be restored and the way paved for modern equipment.

While the method of analysis of current and voltage in the tube socket is well known, it merely serves to point out the stage in trouble and give a general picture of what may be the specific difficulty. Modern radio sets, however, are becoming increasingly complex as to circuits and abnormal voltage or current readings may frequently be caused by a number of defects which can not be analyzed from such readings only.

In a single receiver we may have several times as many resistors as we have tubes; potentials, both direct current and radio frequency, are broken up into sections by resistance networks, and direct and intermediate and radio frequency currents are segregated by means of capacitors. The requirement for devices to more accurately measure these resistance and capacity units is, therefore, a growing one.

In the endeavor to reduce obsolescence in test equipment of various kinds, unit panels have been made available. Fig. 1 shows five such panels in a carrying case intended for the serviceman. This gives him sufficient equipment to run down even major troubles in most any instance.

The three lower units are an analyzer of conventional type, a self-modulated oscillator covering the broadcast and intermediate bands and a tube checking device.

Because of the rather bulky assembly of the several units, they have been made removable as individual testing devices and are enclosed in small steel boxes as shown in Fig. 2. This allows for the removal of any of these units where it may be particularly required and also allows for the transportation of only such test units as are needed in a particular call.

The Volt-Ohmmeter

The upper two units in Fig. 1 are the recently developed volt-ohmmeter at the left and capacity meter at the right. The volt-ohmmeter panel is shown in greater

Fig. 1.

† Presented before the Radio Club of America, May 10, 1933.

* In charge of Radio Engineering Division, Weston Electrical Instrument Corporation, Newark, N. J.

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detail in Fig. 3. The scale on the instrument is shown in Fig. 4. The switch positions are such that the scale reads directly in ohms on the next to the right hand switch position. In the right hand position the indications are divided by 5 and the first division to the right is 0.2 ohm.

Decimal multipliers are used for the higher values and the highest is R × 10,000; the last division at the left is marked 1,000 on the scale so that this becomes 10 megohms, directly readable with a truly portable device.

The details of the circuit have been worked out so that this rather wide range is obtainable through the use of a maximum of 15 volts of battery. A single No. 2 unit cell is used for all but the highest resistance. To this is added three of the smallest 3-cell "C" batteries for the highest range.

In order to obtain this wide range in values it has been necessary to use the very latest developments in instrument construction and a discussion of the ohmmeter theory will indicate the general angle of attack on the problem.

The series type ohmmeter, of which this is an example, may be analyzed directly by Ohm's Law. Consider first the current flowing through the instrument

$$I = \frac{E}{R}.$$

In this case E is the open circuit voltage of the battery being used and R the total resistance of the circuit including that of the instrument, the battery and connecting leads.

Taking the second case where an external resistance is connected in series, we have for the new value of current,

$$I' = \frac{E}{R + X},$$

where X is the external resistance which has been added to the circuit.

In order to get the reading on the instrument scale, let us consider the deflection in terms of full scale deflection; that is, let us arrange matters so that the result will be in per cent of full scale. We then have

$$\frac{I'}{I} = \frac{\frac{E}{R + X}}{\frac{E}{R}}.$$

The first member is per cent of full scale deflection and the second member may be reduced to

$$\frac{R}{R + X}.$$

This shows that the series type of ohmmeter is essentially a resistance comparator and if the resistance of the instrument circuit is known, the voltage of the battery and the current which flows may be completely dropped out of the picture. To be sure, there must be a sufficient amount of current to get a good readable indication on the instrument and in order that the scale may be of good length the potential and internal resistance must be so proportioned as to give sufficient current for full scale deflection with zero external resistance. But once these have been satisfied, they completely drop out of the picture and the readings in per cent of full scale are purely a matter of resistance proportion.

However, if we fix the resistance, the battery voltage will vary as the battery gets old and accordingly we must compensate the instrument sensitivity so that with a definite and fixed internal resistance full scale is always indicated. This may be done in any one of several ways.

Battery Compensation

A magnetic shunt is perhaps one of the most satisfactory methods of compensating for battery variation, but requires special construction in the instrument itself. A certain amount of scale distortion will also be present with different positions of the magnetic shunt simply because the flux distribution in the air-gap will change with the position of the shunt itself. While not of great importance in a small instrument it is definitely a factor, although the mechanical difficulties perhaps are of greater importance.

Another method of adjustment for battery voltage is to provide a variable shunt for the instrument movement itself. Since the resistance of the instrument movement is rarely more than 6 or 7 per cent of the total circuit resistance, shunting it down a matter of another 10 per cent will change the total circuit resistance by the order of considerably less than 1 per cent. The method is very simple to apply, simply requiring a small rheostat of suitable value. Practical ratios seem to indicate that the rheostat should have a maximum resistance of from ten to twenty times that of the instrument. In series with the rheostat is a fixed resistance to prevent the instrument from being completely short-circuited and this is usually from two and one-half to three times the resistance of the instrument movement.

This method, therefore, allows for the adjustment of the current sensitivity of the instrument to match the variation in the applied voltage and at the same time maintains the circuit resistance constant to within better than 1 per cent. If adjustments have been made at the center of the resistance variation, then the adjustment is good to considerably better than ½ of 1 per cent.

Making the analysis in this way, and considering the instrument as a resistance comparator, it will be seen that methods of adjustment using series resistance are inherently wrong in that they change the value R in the foregoing equations. It has been assumed by some that the change in effective battery voltage was not a change in open circuit potential, but rather a change in the internal battery resistance and that a series external resistance would compensate. This is not the case, however. The battery voltage drops even on absolute open circuit, as measured on a potentiometer, and the resistance increase is in general a very great deal smaller in terms of the circuit as a whole than the true drop in voltage.

Ranges

The resistance ranges supplied are largely the result of a study of the requirements. Ten (10) megohms seems to be the maximum which it would be necessary to measure; 5 megohm units are fairly common, but very few units of over 10 megohms in value are found in commercial receivers. In the design of a series type ohmmeter the left end

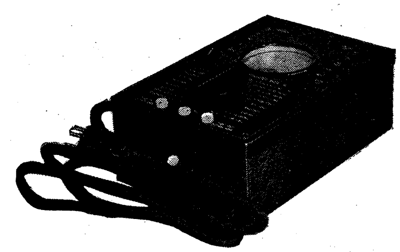

Fig. 2.

Fig. 3. Model 663.

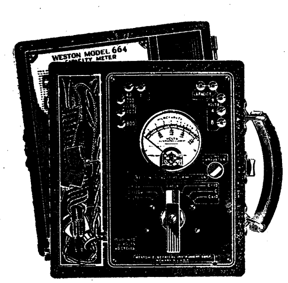

Fig. 7. Model 664.

of the scale is always infinity on any range. The practical top of the scale, however, is considered arbitrarily after the first division and this is 2½ per cent of the scale length. We may then allocate 10 megohms at this point.

In a series type ohmmeter, where the pointer indicates full scale on zero external resistance, the center scale point is equal to the resistance of the instrument circuit including all necessary series resistance. If, therefore, we consider the maximum reading as 2½ per cent of full scale, center scale is 1/40 of this value or 250,000 ohms. If the instrument resistance on the highest range is to be 250,000 ohms, we must get an instrument of sufficient sensitivity so that it will give full scale deflection with this resistance as a part of its circuit on whatever battery used.

Microammeters

Recent developments in the design and construction of direct-current instruments have made available microammeters with ranges very considerably lower than have been heretofore available and in the present instance an instrument with a full scale sensitivity of 50 microamperes has been used. It is not very many years since 1 milliampere was considered as maximum full scale sensitivity on a small instrument and it will be seen that the present sensitivity of twenty times the older value is a very marked gain and has been made over the last decade. Magnets of special alloy steels of large cross section, coils wound from wire considerably finer than the human hair have both contributed to the increased sensitivity now available. Incidentally this sensitivity is by no means the maximum since in the present instance an instrument with a reasonably high torque was required; by reducing the torque as may be done for laboratory work, full scale currents of considerably less than 50 microamperes can be had.

With a sensitivity of 50 microamperes and a resistance of 250,000 ohms the battery voltage works out to be 12.5. It seemed in order to use a lower voltage for the lower resistance measurements and of course the lowest battery voltage is a nominal 1.5. A decimal ratio would, therefore, indicate 15 volts

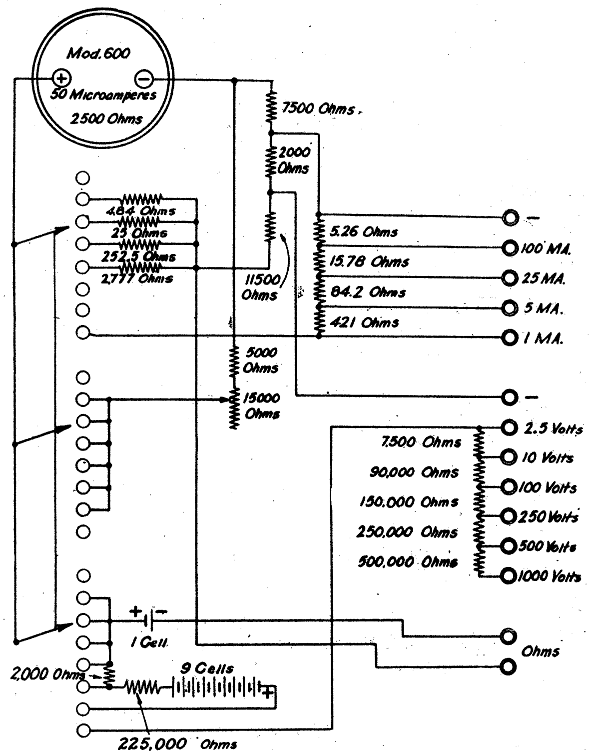

Fig. 5. Connections of volt-ohmmeter.

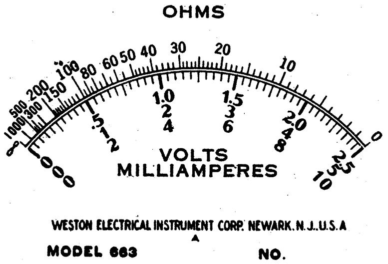

Fig. 4. Model 663 scale.

as the higher voltage. This fits very nicely and will allow for the 15-volt battery dropping in voltage a reasonable amount and will also allow for a slight increase in current due to that shunted by the rheostat for adjusting purposes.

For the next lower range in resistance the same current sensitivity is maintained with a single dry cell of 1.5 volts, the next lower range is obtained by shunting to 500 microamperes, the next by shunting to 5 milliamperes, then 50 milliamperes and for the lowest range the instrument is shunted to 250 milliamperes. This last value is considered as the maximum which can be taken from one of the larger unit cells and as a matter of fact the battery resistance is a very definite factor in this range and must be considered in setting up the network. It is probable that the accuracy over the full scale is somewhat reduced on this low range because of the change in battery resistance over its useful life. This range, however, is used only for the very low resistances which are read at the extreme right of the scale adjacent to the point where the initial adjustment is made and the error is, therefore, small. For readings of over a few ohms the next range is selected.

This completes the electrical design with the selection of the instrument, its current and voltage values and the type of adjustment. The wiring diagram is shown in Fig. 5 in schematic form and it will be noted that a 3-pole 8-position switch is used, one blade of which selects the shunts to change the current drain of the instrument. Another blade throws in the battery adjusting rheostat and a third blade throws in the extra battery and resistance on the high range.

The center blade would not have been necessary except for the fact that the instrument is also supplied with four current ranges and six voltage ranges to increase its utilitarian value and it is necessary to remove the adjusting rheostat where absolute values are to be taken. As a voltmeter the instrument is shunted to 1 milliampere full scale; as a milliammeter its drop is several hundred millivolts because of the rather high resistance coil, but this is usually quite satisfactory where plate currents are to be measured.

While originally developed for radio servicing, the wide range of usefulness of this assembly has made it one of the most popular instruments in the plant. Wherever a department must determine possible troubles in an assembly, this particular combination volt-ohmmeter seems to be the best single unit. While not possessing the accuracy of a bridge in the measurement of resistance, it will nevertheless segregate resistance errors and will even read leakage values where these exist to spoil the functioning of an assembly. It is believed, therefore, that with its multiplicity of ranges, this instrument will find an increasing range of usefulness.

The Capacity Meter

A capacity measuring device can be built along the same general lines as the ohmmeter, using alternating current of a definite frequency and a sensitive alternating current instrument. The equations are somewhat more complex because the reactance of the condenser must be considered as such and instead of the somewhat simple equation we get,

$$\% \text{ deflection} = \frac{R}{\sqrt{R^2 + X_c^2}}$$

Converting this into a form wherein the capacity is shown directly in microfarads we have,

$$\% \text{ deflection} = \frac{R}{\sqrt{R^2 + \frac{10^{12}}{4\pi^2 f^2 c^2}}}$$

This may be further simplified to bring it into the form,

$$\% \text{ deflection} = \frac{R \times 2\pi f c}{\sqrt{R^2 (4\pi^2 f^2 c^2) + 10^{12}}}$$

Again it will be noted that voltage and current are not in the picture, but that the per cent deflection is purely a function of the resistance of the circuit, the capacity in series and the frequency. But most lines are today carefully controlled and we must thank the makers of electric clocks that we now have a sufficiently constant frequency to make reliable capacity measurements simply and directly.

The instrument used is adjusted to 250 microamperes full scale and is of the rectifier type. Adjustments for variation in line voltage are made by a variable shunt across the instrument movement itself where the resistance is relatively low and this in turn keeps the change of total circuit resistance to a small value.

The instrument is first connected in series with suitable resistance to bring it to 4 volts full scale; it is then shunted as required for the higher ranges. For measuring electrolytic condensers up to 200 microfarads, the instrument is adjusted to 100 milliamperes and functions at 4 volts tapped from a small transformer. This low value of voltage does not seem to do any damage to electrolytic condensers and no polarizing voltage is apparently needed. The scale is shown in Fig. 6 and will be seen to be remarkably uniform over a good portion of its length. The high range to 200 microfarads is obtained by switching as shown in Fig. 7 to a position marked × 10; the direct position adjusts the instrument to 10 milliamperes full scale. The position marked ÷ 10 calibrates the instrument to 1 milliampere still maintaining the 4 volts. The position marked ÷ 100 removes the shunts so that the instrument functions at ¼ milliampere sensitivity and the 10-volt transformer tap is brought into play. The position ÷ 1,000 is the highest sensitivity of ¼ milliampere and 100 volts. This is used only for small fixed condensers and no difficulty has been had with breakdown. With this range it will be noted that the center point on the scale is 0.004 mf. The first main division is 0.001 mf. or 1,000 micromicrofarads. This is divided into 10 parts so that the first small division is 100 micromicrofarads. An ordinary 23-plate tuning condenser gives a nice indication. It is somewhat surprising to many engineers to see a sufficient amount of 60-cycle energy pass across the air-gap of an ordinary tuning condenser to give a readable indication on a commercially obtainable instrument.

The diagram, Fig. 8, is somewhat similar to the ohmmeter in that a multiple blade switch is used which picks up the shunts, the series resistance and transformer taps and throws in the adjusting shunt. A position is arranged for a series of voltage readings to extend the usefulness of the instrument.

While the rectifier type of instrument somewhat limits the accuracy of a device of this sort, its very wide range of usefulness from air dielectric tuning condensers up to larger electrolytics makes it a most desirable unit for checking capacities. It is being used not only in the radio laboratory, but in many plants manufacturing other equipment where condensers constitute a part of the apparatus.

The radio serviceman, as represented by the requirements of all trouble shooting organizations, is really responsible for these two instruments. The development of combinations of this sort is largely a matter of replying to field pressure for equipment which is needed for a specific purpose. Now that the instruments are available, the instrument manufacturer finds that they have an appeal considerably beyond the field of servicing receivers. They are being used by assemblers of electrical equipment and even the telephone and telegraph companies are finding the versatility of these combinations makes them valuable in all sorts of work, particularly with long lines.

We might, therefore, credit the radio field as a whole with being responsible for another small contribution to the field of measurements and measuring equipment.

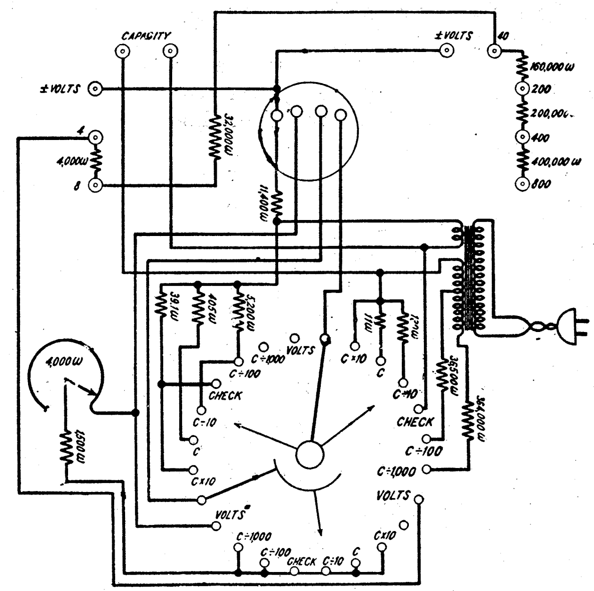

Fig. 8. Connections of capacity meter.

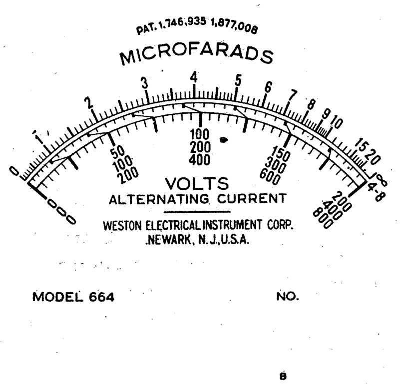

Fig. 6. Model 664 scale.

BOOK REVIEW

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RADIO ENGINEERING HANDBOOK. Edited by Keith Henney. Published by McGraw-Hill Co., Inc., New York City, 1933. *Price,* $5.00 (583 *pages*—482 *illustrations—flexible*).

As the allied industries have their handbook of engineering principles, practices, and standards we may now thank Keith Henney for a handbook prepared expressly for radio engineers. Henney's work in radio literature is of the highest order and his editorial efforts in this new conception make the text one of the most authoritative collections of engineering data ever compiled for the radio engineer in a single volume.

Essentially, the *"Handbook"* is a technical symposium prepared by a select staff of twenty-two specialists, each of whom are authorities on the particular subject they have submitted. Its primary purpose is to serve as a handbook for those engaged in engineering practices; however, much of the text can readily be assimilated by the average radio man. The use of mathematics in elucidating many of the compound problems is employed in abundance throughout the book. Although the first section is composed of arithmetical and allied electrical tables, there is a wealth of such information interposed throughout the entire book. The inclusion of schematics of new circuits and other hook-ups not common to everyday routine makes the text particularly useful as a reference guide.

The subject treatment may be regarded as divided into two parts: The first half of the book considers the theoretical study of the primary components constituting the tuned circuits as well as the fundamental applications and inherent properties of individual arrangements such as regards the vacuum tube in particular. The second half of the Handbook comprises a distinct study of a particular branch of the science, dealing with the more specialized ramifications of radio communication.

Section six on "Combined Circuits of L, C, and R" is worthy of mention since a similar treatment of the varied applications of this subject has not heretofore been completely incorporated in any radio text and was generally confined to special assignments in technical magazine articles. The following section seven on "Measuring Instruments" brings at hand a general and readily digested review of a wide variety of electrical instruments common to the engineer's laboratory. A sectional chapter is devoted to theoretical discussion of "Detection and Modulation" and their applications to engineering design.

C. W. Horn is well prepared to consider the broadcasting practices effectively in a very instructive, although too brief account of this art. R. C. Hitchcock in a section on "Rectifiers and Power Supply Systems" combines both theory and practice to render a practicable and useful treatment of a subject usually given inconsiderable thought in common discussions. In the posterior section on "Loud Speakers and Acoustics," the idiosyncrasies and performance inherent to electro-acoustic motors are further exposed.

R. H. Ranger discusses "Facsimile Transmission" and in his lucid contribution relates the methods of this system. Harry Diamond is the contributor of section twenty-one wherein the significant aids to aircraft radio communication and navigation are mentioned. In conclusion Dr. Irby briefly describes the principal methods employed in recording and reproducing sound motion pictures.

This comprehensive reference manual is perhaps the most valuable technical book that has come to the writer's attention in several years and it is unhesitantly recommended to every engineer and technician desiring an authoritative cyclopedia of modern radio tendencies in general.—*Reviewed by Louis F. B. Carini.*

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SUGGESTIONS TO CONTRIBUTORS

CONTRIBUTORS to the Proceedings, by bearing in mind the points below, will avoid delay and needless expense to the Club.

1. Manuscripts should be submitted typewritten, double-spaced, to the Chairman of the Papers Committee.* In case of acceptance, the final draft of the article should be in the hands of the Chairman on or before the date of delivery of the paper before the Club.

2. Illustrations should invariably be in black ink on white paper or tracing cloth. Blueprints are unacceptable.

3. Corrected galley proofs should be returned within twelve hours to the office of publication. Additions or major corrections cannot be made in an article at this time.

4. A brief summary of the paper, embodying the major conclusions, is desirable.

5. The club reserves the right of decision on the publication of any paper which may be read before the Club.

*For 1933 the Chairman of the Papers Committee is C. E. Brigham, 200 Mt. Pleasant Avenue, Newark, N. J.