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The AEROVOX Research Worker

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How To Test Condenser Capacities

PART 2

By the Engineering Department, Aerovox Wireless Corp.

WHERE relatively small capacities of the order of .00005 mfd. (50 micro-microfarads) to .01 mfd. (10,000 micro-microfarads) are to be measured, the method described in the last issue of the Research Worker is not practical. These small capacities can be measured accurately by means of direct-reading microfarad meters, but since these meters cost several hundred dollars each, they are obviously out of the question for the average experimenter.

It is a relatively simple proposition however, to make up an accurate instrument to measure small capacities. This instrument while not of the direct reading type such as the expensive microfarad meters, requires only a few seconds to take a reading and is therefore exceptionally well suited to the needs of the experimenter, especially since it can be used for a wide variety of other purposes.

The wiring diagram of this instrument is shown in Fig. 1.

It consists simply of a standard R. F. oscillator with an external absorption circuit consisting of coil "L3" and means of connecting a condenser, to tune the circuit, across the coil.

Coils "L1" and "L2" may consist of a single coil of 76 turns of No. 24 or 26 wire, wound on a two-inch bakelite or hard rubber tube and tapped in the center. Coil "L3" should consist of the same type of winding also with 76 turns, and means for mounting it at about right angles to coil "L1" and about two inches away from "L1." It is desirable to mount it in such a way that the coupling between "L3" and "L1" can be varied.

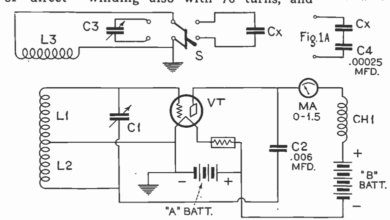

Fig. 1

Either a CX-301A or a CX-299 tube may be used as the oscillator. The use of a CX-299 is preferable in that a small 4½-volt battery such as is usually used as a 4½-volt "C" battery can be used as the "A" battery and a small 45-volt "B" battery may be used as a "B" battery.

A .00035 mfd. variable condenser may be used in position "C1" to tune the oscillator to any desired frequency within the range of the coils and condenser, about 1500 to 500 kilocycles (200 to 600 meters). Another .00035 mfd. variable condenser can be used at "C3." It is desirable that this condenser be of the straight capacity line type so that capacity changes will be proportional to degree changes in dial movements. The dial of this condenser should be calibrated in micro-microfarads.

A 0-1.5 milliampere milliammeter is used in the plate circuit of the oscillator tube. An 85-millihenry R. F. choke coil is used in the plate circuit to prevent damping of the R. F. currents which would otherwise have to pass through the high resistance of the "B" battery. A type 1450, .006 mfd. Aerovox mica condenser is used at "C2" to bypass the R. F. current in the plate circuit across the choke coil and battery and to connect the plate of the tube with the tickler coil "L2" to produce the "feedback" action which causes the tube to oscillate.

(Continued on page 4)

The operation of the circuit to test an unknown capacity is very simple.

The unknown capacity, "Cx" is connected across the set of switch-points of the double pole, double throw switch as shown and the switch, whose blades connect to the terminals of coil "L3" is thrown to the right so as to connect the unknown capacity across coil "L3." With the oscillator in operation condenser "C1" is adjusted until the reading on the milliammeter is brought down to a minimum which indicates that the absorption circuit in which the coil "L3" and the condenser "Cx" is connected is tuned into resonance with the frequency to which the oscillator is tuned. In making these adjustments and observations, it will be noted that the sharpest dip of the needle is obtained when the coupling between "L3" and "L1" is very "loose."

The switch should then be thrown to the left so as to connect the calibrated condenser "C3" across coil "L3." The next step is to adjust "C3" until the needle of the milliammeter again dips sharply, indicating that the absorption circuit is again tuned into resonance with the oscillator and is drawing maximum energy from the oscillator circuit.

When this occurs, it indicates that condenser "C3" is set to the same capacity as "Cx" and the capacity of "Cx" can then be determined by reading the value from the calibrated dial of condenser "C3."

Best results are obtained by calibrating the .00035 mfd. condenser "C3" from the 10 degree marking on the dial to the 90 degree marking.

By using this range of the condenser, capacities of from 35 to 315 micro-microfarads (.000035 to .000315 mfd.) can be measured directly.

For higher capacities up to .001 mfd. it is possible to shunt mica condensers across condensers "C1" and "C3" so as to raise the wavelength of the oscillator and absorption circuits. A .00025 mfd. mica condenser across "C1" will increase the maximum capacity of "C1" within the working range already mentioned up to .000565 mfd. A similar condenser will have to be used across condenser "C3." In taking readings on condenser "C3" with the extra capacities connected across the two variable condensers, all that is necessary is to add the additional capacity used across the condenser to the capacity reading obtained from the dial of condenser "C3."

Readings up to about .001 can easily be taken in this manner. For high capacities of from .001 to .01

$$Cx = \frac{1}{\left(\frac{1}{C3} - \frac{1}{C4}\right)}$$

Fig. 2

mfd. readings should be taken on a series combination consisting of the unknown capacity, "Cx" and a .00025 mfd. fixed condenser "C4" as shown in Fig. 1A.

The readings for capacity are taken in exactly the same way as before on condenser "C3." Then the capacity of "Cx" can be found by using the formula for the resultant capacity of two condensers connected in series. In its simple terms, as it applies to this particular case "Cx" and "C4" the formula is resolved into the form shown in Fig. 2. "Cx" is the unknown capacity which is connected in series with the .00025 mfd. condenser "C4," while "C3" is the capacity reading of "C3," equivalent to the capacity of the two series condensers "Cx" and "C4." The values should all be either in microfarads or in micro-microfarads.

Besides its use in measuring

$$L = \frac{1{,}000{,}000{,}000{,}000}{39.44\, f^2 C}$$

Fig. 3

condenser capacities, the oscillator can be used in numerous other ways. If the dial of the oscillator condenser "C1" is calibrated in terms of frequency, while the condenser "C3" is calibrated in microfarads or micro-microfarads, the oscillator can be used to measure the inductance of coils by using the formula for resonance shown in Fig. 3. In this formula "L" is the unknown inductance in microhenries, "f" is the frequency in kilocycles and "C" is the capacity reading in micro-microfarads obtained from "C3" at resonance.

By using the oscillator as an R. F. oscillator which can be adjusted for the whole wavelength range it is possible to calibrate variable condensers or see how closely several different condensers match by comparing them at different dial settings at various frequencies. To do this, start at the zero point of the oscillator tuning condenser "C1." Connect one condenser across the switch points in place of condenser "C3" and connect the other condenser across the switch points in place of condenser "Cx" of Fig. 1. At every frequency setting of condenser "C1" adjust first one and then the other of the variable condensers connected to the opposite switch points of switch "S." If they are accurately matched at every point, the dial readings of both condensers should be the same.

The same idea can be used to match tuning coils or transformers except that in this case, a variable condenser is connected across the blades of the switch in place of coil "L3." Then for every setting of the oscillator the setting of the variable condenser connected across the switch blades should read the same for resonance with each coil that is connected across the condenser.

The oscillator can also be used as a beat note wavemeter if it is calibrated in kilocycles or wavelength. When the oscillator is placed close to the coils of a receiver which is tuned to an incoming signal, an audible beat note will be produced in the loudspeaker which is connected to the receiver output when the oscillator is tuned slightly off the wavelength being received so as to cause a beat note to be produced. As the oscillator is adjusted to the frequency being received however, the note will fade out.

These are some of the more common uses of this simple instrument. Others will occur to the experimenter as he becomes acquainted with its possibilities.

The Elimination of Dynamic Speaker Hum

SO overwhelming has been the acceptance of the dynamic speaker by the radio public that little discussion is necessary to show that this type of speaker will be by far the most popular type of speaker on the market for some time to come.

The most outstanding advantages of the dynamic speaker are first its ability to handle, without appreciable distortion, volume that would ordinarily overload the average magnetic type of speaker, whether cone or air column, and second its faithful reproduction of the entire range of audible frequencies which give realism to radio reproduction. To obtain these desirable characteristics it is necessary to use a very powerful magnetic field which is beyond the capabilities of a permanent magnet such as is used in the magnetic speakers.

In the dynamic speaker the p erful magnetic field required is se. up by an electro-magnet.

In the electrodynamic speaker whose field winding is excited by means of a storage battery we have what may be considered as the most perfect reproducer now available.

The use of a storage battery for exciting the field of a dynamic, with its attendant troublesome charging of the battery at regular intervals is not practical, except where lighting current is not available.

By far the majority of such speakers are now constructed to permit operation from the 110-volt, 60 cycle, A. C. lines. This is accomplished by employing the equiva lent of an "A" battery eliminator as shown in the diagram of Fig. 1.

As shown in this diagram, the 110-volt current is fed into the primary winding of the exciting transformer and is stepped down to approximately 12 volts A. C. by the transformer. This 12-volt A. C. current is applied across the full wave rectifier and comes through as a rectified or pulsating direct current. The pulsating direct current is passed through the field winding of the electromagnet and creates a powerful magnetic field. The voice coil is suspended in this powerful field. When currents, such as the voice currents obtained from the output of a receiver, are passed through the voice coil, forces are generated which cause the floating voice coil, and the cone diaphragm to which the voice coil is attached, to move in unison with the voice current.

If the rectified current fed to the field of the electromagnet were pure D. C. such as is obtained by using a storage battery, exceptionally fine results could be obtained without any trace of hum, since the magnetic field set up by the magnet would be constant. The current which is fed to the electromagnet however, while rectified, is pulsating and this variation in the value of the current causes a variation in the intensity of the magnetic flux resulting in a hum that is usually the only objectionable feature of A. C. dynamic speakers.

Various means have been used to reduce this hum to a minimum. While these systems reduce the hum to a point which is not very objectionable while a program is being received with some volume, the hum obtained on low volume, or during lulls in the program, is sufficient to be audible at a considerable distance from the speaker.

One of the methods used to eliminate the hum is to design the speaker field coil and core in such a way that the current flowing through the coil is sufficiently high to produce a highly saturated field. This reduces the effect of any slight change in the magnetizing current due to the fluctuations of the current to practical limits.

This method while effective to a certain extent, does not solve the problem of obtaining really hum-free operation.

Aside from the fact that the hum still remaining is loud enough to be heard at some distance from the speaker, this type of construction has the disadvantage of requiring a heavy duty rectifier working at heavy load, the use of a large core and field winding and the comparatively large bulk and heavy weight which such construction involves.

A somewhat better system of hum elimination is obtained by connecting, in series with the voice coil, another coil wound in opposite phase to that of the voice coil, and fastening this neutralizing coil on the end of the field magnet core close to the voice coil. Any variation caused by the fluctuations of current in the field winding will then be impressed almost equally on both the moving voice coil and the stationary neutralizing coil, but in opposite phase. The disturbing hum currents will then tend to neutralize each other, but the moving coil is affected only by the current supplied to the voice coil circuit by the receiver output.

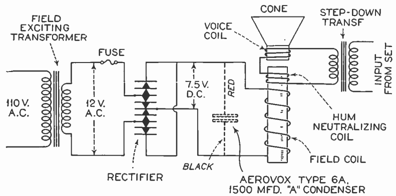

Fig. 1

While this method is effective to a certain extent and is a considerable improvement over the use of a dynamic speaker without any hum balancing arrangement the hum coil system is not an absolute cure and leaves much to be desired in approaching the ideal of humless operation such as can be obtained by using pure direct current to excite the field.

The difficulties met with in attempting to use the hum coil alone as a means of eliminating hums are due to the fact that while the coupling between the field winding and the neutralizing coil are fixed, the coupling between the field coil and the moving coil varies because of the movement of the voice coil in the field. Further, the coupling is not relatively the same between the two coils at all frequencies. It is therefore impossible to completely eliminate the harmonics created by the ripple voltage source, that is, the A. C. line.

The most effective cure for hum in a dynamic speaker of any type, whether it uses the saturated field principle to reduce hum or whether it uses the hum coil idea, is to connect an Aerovox Type 6A, 1500 mfd. "A" condenser across the rectifier-field coil circuit as shown in Fig. 1.

A good idea of the effectiveness of the "A" condenser in eliminating hum may be obtained by con sulting the graph shown in Fig. 2. This graph was taken on one of the best dynamic speakers available which uses the hum coil system to eliminate hum. As will be noted the much better results obtained by using the "A" condenser is brought out forcibly by the graph. The observations from which these curves were plotted were taken by the Conner-Crouse Corporation of New York City, a well-known firm of consulting engineers specializing on the development of audio amplifiers, power units and loud speakers for receiver manufacturers.

In the graph shown in Fig. 2, readings of hum voltages were taken at line voltages ranging from 90 to 130 volts. It will be noted that without the use of a hum coil or "A" condenser, the hum level or ripple voltage rises from 2 at 90 volts line voltage to 2.75 at 130 volts.

The use of the hum coil reduces the variation of hum at differen voltages but the hum present in the speaker is still more than it should be for really quiet operation.

It will be noted that the used of a hum coil in this case reduced the hum to approximately 25 per cent of the original value when no neutralizing system was used. The use of the 1500 mfd. "A" condenser across the field coil, with the hum coil disconnected so that none of the reduced hum could be attributed to any aid from the hum coil, reduced the hum to less than eight per cent of its original value and shows conclusively how much more efficient the "A" condenser is in reducing hum. The use of a 4000 mfd. "A" condenser reduced the hum still more, that is to less than five per cent of its original value. While the use of the higher capacity is somewhat more efficient, it is hardly worth while to go tc the extra expense unless exceptionally quiet operation is desired or a particularly noisy dynamic speaker must be cured of its hum.

When the 1500 mfd. condenser was connected across the rectifier field coil circuit, as shown in Fig. 1 so that both the hum coil and the condenser were acting to balance and smooth out the ripple, the rip ple voltage was so low that it could not be read on the sensitive laboratory voltmeter used in the test. The use of an "A" condenser therefore with the average hum coil dynamic speaker results in practically the ideal condition obtained when exciting the field of a dynamic by means of a storage battery.

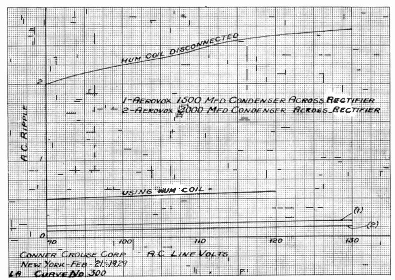

Fig. 2

An Aerovox "A" condenser suitable for this purpose is shown in Fig. 3. The terminals of the condenser can be connected directly across the output terminals of the rectifier or across the winding of the field coil of the dynamic speaker. They may either be soldered to the terminals of the rectifier or coil or clips may be attached to the ends of the condenser leads and these clips connected to the rectifier terminals.

In connecting the condenser across the circuit, it is important to make sure that the negative (black) lead of the condenser is connected to the negative side of the circuit and that the positive (red) lead of the condenser is connected to the positive side of the circuit. The polarity of the circuit

Fig. 3

can be determined very easily by testing across the circuit with an ordinary battery voltmeter. When the voltmeter shows a reading, it indicates that the positive terminal of the voltmeter is connected with the positive lead of the circuit, the lead to which the positive (red) lead to the condenser should be connected. The negative (black) lead should then be connected to the lead to which the negative terminal of the voltmeter is connected.

Another simple way to determine the proper leads to which to connect the condenser is to connect the positive (red) lead of the condenser to the outside terminals of the rectifier and the negative terminal of the condenser to the center terminal of the rectifier as shown in Fig. 1.

Aside from the greatly improved operation which results due to the elimination of hum, the use of the condenser increases the sensitivity of the speaker by increasing the voltage and consequently the strength of the field of the electromagnet. This increase in signal strength is so noticeable that a listening test will easily bring out the difference in volume, especially if a weak signal is being received.

The advantages to be gained by the use of an "A" condenser are so obvious that they fully justify the slight additional expense necessary to add this piece of equipment to a standard dynamic speaker.