ELECTROPHONE
An Inexpensive Condenser Microphone
for the Home Experimenter

Announcing the New UHF Miniature
MAGNETRON

SEE PAGE 5 . . . . .

Contents

Ectrophones (Inexpensive condenser microphones) .................................................. pages 3-4
Technical Information (Z-3081) ................................................................. page 5
Technical Notes (Using readouts on R-f heads) ............................................... pages 6-8
Many items around almost any ham shack are homemade by amateurs who make their own transmitters, some of their own receivers, but very few amateurs have ever made their own microphone. This has been due primarily to the fact that it is sufficiently expensive to make a microphone of good quality. The microphone about to be described is in the exception, as it is easy to make and is a good-quality microphone.

The Electrophone is a condenser microphone of novel construction which requires no external source of polarizing voltage. Very few parts are required to make the Electrophone, and almost any amateur can put one together in an evening. The output is higher than can be obtained from a regular condenser microphone, and if the Electrophone is made with great care it almost be equal to that from a crystal microphone.

**CONVENTIONAL MICROPHONES**

The regular type of condenser microphone consists of a small capacitance which may be varied by the presence of sound waves impinging on one of the condenser plates. If a source of direct current is placed in series with this condenser the current will vary as the capacitance changes. If this current is passed through a relatively high resistance a varying voltage drop will exist across this resistance. The variation of current will take place at an audio rate, and if the high resistance is placed in the grid circuit of a triode, the audio frequency voltage may be amplified in a normal manner.

The potential source which provides the direct current is called a polarizing voltage. This voltage serves, in a condenser microphone, in the same way as the voltage in a carbon microphone, although the action of the two types of microphones is quite different.

A direct polarizing voltage is necessary with the Electrophone, because it supplies its own internal source of voltage. This voltage is supplied with an electret.

**ELECTROPHONE ELECTRET**

An electret may be compared to a permanent magnet. That is, a permanent magnet is a continuous source of electromagnetic lines of force, whereas an electret is a continuous source of electrostatic lines of force. It is usually made in the form of a disk of insulating material which has permanently charged on its two flat surfaces electrical charges equal but opposite in sign. A charged diaphragm which is used for the purpose of converting sound waves into electrical energy is called an electret.

**Fig. 1. View of Electrophone showing alumi-**

**num felt diaphragm**

...above is the heart of the Electrophone, and should be made as carefully as possible. The general procedure is to take a piece of suitable insulating material and apply heat to it while a 5-volt voltage is applied across the two faces. Both the heat and the voltage necessary are critical, although not sufficiently critical to cause the constructor any trouble.

It is absolutely necessary to use the proper insulating material in preparing the electret. Those materials recommended are Lucite, Plexiglas or Kel-F. One material which will not work is polyethylene. If you are in doubt as to whether the material you have is polyethylene, Plexiglas or Lucite, a simple flame test may be made. Polyethylene will melt and burn with a blue flame, whereas Lucite and Plexiglas burn with a clear blue flame.

Once you have the proper material, select a piece about one-sixteenth inch thick and cut it to the shape of a circle. The exact diameter of the circle will depend upon the microphone case you use. These details will be discussed later. Next, procure a heavy plastic or thin piece of metal (see Fig. 3). The purpose of the large mass of metal is to maintain as uniform a temperature as possible on the electret.

The next item necessary is a power supply which will give a voltage of anywhere from 1000 volts to approximately 10,000 volts. The higher the voltage that is used, the better a microphone will be. This voltage may sound, from the standpoint of sensitivity, useless as high a voltage as possible without causing any harm to the electret. With the proper power supply a satisfactory microphone may be made which will do the job properly.

A satisfactory microphone may be made with 1000 volts, but for best results at least 2500 to 3000 volts, and if you want to do a superior job, use 10,000 volts. The job of providing a power supply is not as difficult as it may sound, because only a few microamperes of current are required.

In case you haven't already guessed it, the best place to obtain a high voltage which is capable of only a small amount of current is a television receiver.
An rf power supply of this type is ideally suited, not only because the voltage runs quite high, but also because there is much less danger involved in using such a power supply. However, regardless of the type of voltage supply used, remember that high voltages are dangerous and extreme caution must be exercised in their handling and operation.

If you are unable to obtain a high voltage supply, one may be put together by the method shown in Fig. 3. A circuit so designed is shown in Fig. 4. This type of supply may be used to test several types of electret microphones. However, remember that the electret will be destroyed if too high a voltage is applied to it.

Once everything is ready, we may proceed to make the Electrophone. Place the large pan or piece of metal on a source of heat. A burner in a gas or electric stove is quite suitable. Arrange the insulating material on top of the pan as shown in Fig. 3. Prove a top electrode (you may use the top of the microphone case as explained later) and place it on top of the insulating material, making sure that it is centered so as to prevent arc-over.

Next, connect the negative voltage supply to the bottom electrode, and also to the top, and connect the positive lead from the power supply to the top electrode. Now, leaving the voltage supply turned off, turn on the heat and bring the insulating material up to temperature. Plexiglas and Lucite should be brought to a temperature of 140 degrees Centigrade (385 degrees Fahrenheit) and Kel-F should be heated to 205 degrees Centigrade (400 degrees Fahrenheit).

These temperatures are not too critical and one may use the softening point of the plastic as a convenient guide instead of using a thermometer. Each of the temperatures listed is the point at which the insulating material begins to soften. If desired, a small piece of the material may be placed in the pan and used as a test piece. Examine it with a fork periodically and when it becomes soft the larger piece will be at about the proper temperature.

At the moment when the plastic has reached the softening point, you may put the positive voltage supply and leave it on for two hours. During this two-hour period the temperature of the plastic will be maintained at the temperatures previously mentioned. In general the heat will have to be turned down a bit in order that the temperature is not increased. Keeping the even temperature is not difficult if a large body of metal is used as indicated. After two hours, turn off the heat, but keep the high-voltage supply on. When the insulating material has cooled down to room temperature, disconnect the high voltage.

If you wish to check the actual temperature of the electret to ascertain if it is cool, remember to turn off the high voltage. Also, do not touch the face of the electret, either at this time or at any later time, as continuous handling of the electret will eventually ruin it. When you have finished with the electret, wrap it in metal foil until you are ready to mount it in the Electrophone. Any sharp edges you may have made should also be stored in this manner.

**COMPLETING THE MICROPHONE**

Amateurs with machine shop facilities will no doubt be able to make a very fancy housing for the microphone from metal pill boxes or valve cases, three inches in diameter and one inch thick are available at most drug stores or valve supply houses, and these make an ideal case for the Electrophone. The photographs show quite clearly how these valve cases are employed. The top of the valve can be used as the top electrode when making the electret, as it has a smooth inner and curved-up edge which helps prevent voltage flashover.

After the electret has been made in this manner, the center of it may be cut out as shown in Fig. 1. The hole should have a diameter of approximately 1/4 inches. A standard mmr patch may be used, or the area may be chiseled out.

The next step is to provide the main body of the valve case with a conductor of some sort. The type shown in Fig. 6 is a standard microphone connector.
electret, and eighth electret.

to right it firmly is metal this protective spacer solder should and wire spacer insulating material of this can (in our case 3 7/8 inch) and its thickness should be adjusted to leaves the outer surface of the electret just flush with the edge of the can, as shown in the sketch. Two holes may be drilled and tapped in the bottom of the insulating material to hold it to the bottom of the can.

A clearance hole for the output connector must be placed in this plastic, and also a hole must be drilled through the piece, in the center, in order to make contact with the foil on the bottom of the electret. To mount the insulating spacer, first solder a piece of bare wire to the output connector, then slip the insulating spacer into the can while feeding the wire through the center hole in the spacer. Next, fasten the spacer down with the machine screws and cut off the wire that protrudes above the spacer.

With a hot soldering iron a little depression about 1/4 inch in diameter is melted out around the wire and a ball of solder formed in this depression. The solder should protrude slightly above the surface of the spacer so that it may serve as a blunt contact point.

It is now time to take the electret out of its protective foil wrapping and mount it in the can. Before this is done, however, you must prepare a piece of metal foil-preferably aluminum foil of the sort that is sold in grocery stores—to use as the back electrode of the electret. Cut a circle of foil with a diameter one-fourth inch less than that of the can. Place this piece of foil on one side of the electret, and press it firmly in place. Make sure that you get it in the right position to start with, as you will not be able to move the foil within the can after soldering has been done on the electret. A suggested way to do this is to place the electret face down on a large piece of foil, then carefully place one edge of the circular piece about one-eighth of an inch from the side of the top face of the electret, and slowly lower the piece of foil, keeping hold of it until you are sure that it is centered. Once it is on, carefully, but firmly, press the foil against the electret.

Finally, cut a larger piece of foil to use as a diaphragm, and place it over the top of the can (before the electret is put in) and hold it around the edges, trimming the edges to make a neat job. Now, remove the large piece of foil, place the electret in position, place the large piece of foil over the electret, and put the top of the can in place. The Electrophone should now look as shown in Fig. 1. Finally the top piece of foil should remain as the protective spacer. Insulating material may be used, but not critical and many plastics will serve. The spacer, first soldered to the can, can be removed without serious difficulty, but it is probably permissible to leave the spacer. No attempt was made to protect them from humidity other than keeping them in their mounting cases.

Several Electrophones have been in use at WURKL for over a year and no decrease in the output voltage of 0.02 to 0.03 volts has been observed. Some experimenters have observed electrets for twelve years with no noticeable decrease in charge. No feedback troubles have been experienced and the Electrophone was merely plugged in to an existing crystal microphone input jack on the speech amplifier. No attempt was made to protect them from humidity other than keeping them in their mounting cases.

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The New UHF Miniature Magnetron

The new miniature magnetron tube recently announced by the General Electric Tube Divisions will undoubtedly find itself in many ham shacks in the near future. This tube is capable of operating continuously from 30 to 900 megacycles at a quarter-watt output.

Although designed primarily for television receivers operating in the proposed ultra-high-frequency television band, the Z-2061 will find wide use wherever a low power oscillator at these frequencies is required. The price of the Z-2061 will be comparable with other television receiver tube prices, which means that the amateur finally will be able to procure a low cost tube for operation on the ultra-highs.

Up to this time, magnetrons have been used to generate the high power required for radar equipment and counter-radar equipment used extensively during World War II. During this time the magnetron was not generally thought of as a practical device for TV home receivers, but through the combined efforts of the G.E. Laboratories and the Tube Divisions, the magnetron principal has now been successfully applied to make it a useful tube for the proposed UHF television band.

Generally speaking, a magnetron is a diode which, when operated in a magnetic field, can be made to generate radio frequency oscillations. In the case of the Z-2061, the magnetic field is supplied by a doughnut-shaped magnet, which fits over the tube. The magnetic field strength required is approximately 600 gauss. When the tube circuit is initially adjusted, it is necessary to rotate the magnet until the magnetic poles are in the proper position for operation.

A typical test oscillator for the miniature magnetron is pictured in Figs. 8 and 9. This oscillator in appearance is not unlike others with which the amateur is familiar. The circuit of the test oscillator is given in Fig. 10. It is not particularly intended to be duplicated by amateurs or experimenters but it does indicate how simple a circuit may be used.

Tuning, in the test oscillator pictured, is accomplished by changing the position of the shorting bar on the two anode lines. The oscillator pictured may be tuned over the range from 300 to 900 megacycles. Output may be obtained by coupling to the anode lines in a manner similar to the method used with other parallel line oscillators.

Internally, the Z-2061 consists of eight vanes arranged in a circle around the cathode. Alternate vanes are connected together, so that each anode consists of four vanes. The entire tube is therefore seen to consist of 8 vanes, a cathode and a filament. Dimensions internally are large enough so that no critical spacing is involved.

Tests indicate that the tube has good frequency stability, both for voltage changes and magnetic field variations. Further, the hum and noise level is down more than 60 db below carrier level.

An early issue of the Ham News will give constructional data on equipment designed for amateur services and employing the Z-2061.

—Lighthouse Larry

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Fig. 8. Experimental test arrangement for Z-2061 magnetron

Fig. 9. Underside view of Z-2061 test setup

Fig. 10. Circuit diagram of Z-2061 test set
The practice of testing an amateur transmitter while it is coupled to an antenna is quite common, despite the fact that the F.C.C. frowns on such doings. While testing an antenna system, of course, it is necessary to be on the air, but for most transmitter tests a dummy load is desirable. Use of a dummy antenna not only obviates unnecessary QRM but, if a known dummy load is employed, quantitative measurements of actual power output can be obtained.

The purpose of this article is to explain how to procure a good dummy load, and how to use it.

TIDBITS

A simple equivalent circuit of a composition resistor is shown in Fig. 12A, where R is the d-e resistance and C the total capacitance across the resistor. The equivalent circuit will not hold strictly true for all frequencies—unless a difficult tuning job is attempted.

At frequencies up to approximately 100 megacycles the inductance may be neglected (except for very low values of resistance). The series capacitance is also low, being less than one microf. (when considering composition resistors in the resistance range below 100 ohms). The effective capacitive reactance is high enough that it presents no serious problem.

In other words, composition resistors are good for use at radio frequencies. They will act as though they are a pure resistance—within limits. The main disadvantage of these units is that they are available only in low-wattage styles. This need not be too serious a drawback, as will be explained later.
DUCTANCE decreases as resistors are not as good for use at radio frequencies as composition resistors, but the wire units are capable of dissipating a great deal more power, and by the proper choice of unit satisfactory operation may be obtained.

POWER CONSIDERATIONS

Before discussing which resistor to use where, it might be well to consider power ratings. If you have a kilowatt transmitter, with an output of 160 watts, it might seem necessary to have a dummy load capable of dissipating this amount of power. However, this is not true, because it is possible to use resistors (both the composition type and wire and type) at several times their rating.

Tests have been made to determine the amount of overload which may be placed on resistors, and the following conclusions have been arrived at. If a group of composition resistors of the same resistance value as the sample under test are connected in parallel and if the overload is applied for not longer than one minute, and if a fifteen minute cooling off period is allowed between successive on periods.

Inasmuch as most tests can be conducted in a sixty second period, there is no need to use resistors which are capable of dissipating the full amount of power. As a matter of fact, if it is desirable to use resistors for long test periods, it may be necessary to have a safety factor involved unless adequate ventilation is provided for the resistors. That is, for long test periods, you should use resists capable of dissipating twice the power you apply to them.

Now that we have a general idea of the power rating we may need, let's see what resistors we can use for various power levels.

For measurement or antenna matching work, where you usually use your VFO or a grid-dip meter for a power source, half-watt composition resistors are adequate, power-wise. For impedance values of 50, 75 or 100 ohms, single unit 1/2 watt resistors are good up through 150 megacycles. For 300 ohm work, a single 300 ohm resistor is not satisfactory, as the effective capacitive reactance starts to show up at 100 megacycles. However, two 150 ohm 1/2 watt resistors in series are satisfactory up to 150 megacycles.

No tests were made on resistors of more than 300 ohms, but it may be assumed that at 100 ohms and above, the capacitive reactance will be a factor to be considered, so that higher and higher values of resistance will be "pure resistances" only for lower and lower frequencies.

Dummy loads capable of handling sixty watts (the output of a 1/2 watt input transmitter) can be made by employing 3 watt composition resistors. Ten 3 watt resistors will dissipate twenty watts, which, with our factor of three employed, allow their use as 6.3 loading. Obviously, these resistors can be placed either in series or in parallel, but tests indicate that it is desirable to make these loads as follows: For a 5 ohm load use ten 50 ohm resistors in parallel. For a 75 ohm load, use ten 750 ohm resistors in parallel. For a 300 ohm load, use ten 30 ohm resistors in series. All of these combinations give good results as dummy loads up to 150 megacycles.

The proper way to parallel resistors is indicated in Fig. 13. Make two circular disks of copper or brass, and drill ten holes, equally spaced, around the edge of each disk. Mount the resistors between the disks and solder each lead to the disk. If desired, a coaxial fitting may be mounted, as shown, or broad straps may be soldered to the two disks. If you use a 300 ohm load, the resistors should be in series. The best way to do this is to make two sets of

![Fig. 13. Examples of parallel-connected resistors](image)

![Fig. 14. Examples of high-power resistors](image)

![Fig. 15. Low-power resistor examples](image)
five resistors, each set in a straight line, then connect one end of the two sets together. This brings the two leads of the composite resistor adjacent to each other. All leads in the series string should be as short as possible.

Dummy loads capable of handling 300 watts can be made from ten 10 watt non-inductive resistors. For a 50 ohm load, use ten 300 ohm resistors in parallel. For a 75 ohm load, use ten 750 ohm resistors in parallel. For a 100 ohm load, use ten 900 ohm resistors in parallel. All three combinations are usable to 150 megacycles if the units are paralleled as described before.

Dummy loads for powers above 300 watts can be made in a variety of ways. The best load, as indicated by a series of tests, is a series-parallel combination of ten 100 ohm 10 watt resistors in parallel, connected in series with a similar unit, gives a 300 ohm load capable of handling 600 watts.

Higher wattage resistors can also be used, and tests have been run on all the resistors shown in the photographs. In general, it becomes increasingly difficult to make good dummy loads as the power requirements are raised. Non-inductive resistors with power ratings of 50, 100, 120 and 160 watt ratings have too much residual inductance to be used, singly, at frequencies higher than approximately ten megacycles, unless compensating capacitance is used in series with the resistors.

For example, a typical resistor with a residual inductance of two microhenrys requires a series capacitance of approximately 100 nuf at ten megacycles in order to be a “pure resistance.”

Placing these larger-wattage resistors in parallel will decrease the effective inductance, but not sufficiently, unless a large number of them are so connected. They can be used singly, or in pairs, if you wish to “dope out” the series inductance by means of a series capacitance.

**Dummy watt loads**

There are a few precautions to be observed when connecting a dummy load to a source of power. One, make as direct a connection as possible, and use low inductance leads, such as copper straps.

Two, keep the dummy load away from metallic objects, in order to avoid an unbalance to ground. Third, keep the dummy load well in the clear so that adequate air circulation is assured.

**Dummy resistors**

The information just given on non-inductive resistors is intended as a general guide to the selection of such resistors. Rigorous and complete tests are quite difficult to make, especially when a large variety of resistors is considered. Most of the data given was determined by the test arrangement shown in Fig. 11, which consists of a Millen grid-dip meter and an Elidio Antennoscope. This sort of test permits a practical answer to be obtained quite easily.

The wire-wound resistors tested were made by Westinghouse, and by the Eastman-Kodak and the National Electric. These three companies have standard lines of non-inductive resistors which are readily available.

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**Lighthouse Larry**

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