The GENERAL RADIO EXPERIMENTER

L. I NO. 3 AUGUST, 1926

The Design and Use of the Speaker Filter

By H. W. LAMSON, Engineering Department

In the earlier days of radio broadcasting the chief aim of the average enthusiast was for DX, distance at any price. Thus the crystal detector, for many years an old standby, became superseded by the regenerative vacuum tube detector with its truly marvelous sensitivity. Before long the ever increasing number of broadcasting stations raised the demand for another important feature of a radio receiver—selectivity. This was accomplished by placing a tuned radio frequency amplifier between the antenna system and the detector element, as exemplified in the neutrodyne, superheterodyne and other familiar circuits.

In recent times a new demand has been made upon the radio art. Nowadays, when a considerable number of the major broadcasting stations are frequently tied together to transmit, in unison, programs of exceptional merit and wide popular interest, programs available literally to an audience of millions, the cry for DX has become more and more subjugated to the demand for quality, for faithful and realistic reproduction and sufficient intensity to produce a volume of speech or music customarily associated with grand stand and orchestra seats. Thus, attention is turned to the audio amplifier and interest has become centered upon power amplification.

For this purpose several new designs of vacuum tubes have been placed upon the market to be used in the last stage of the audio amplifier. Chief among these are the UX-120, a dry cell tube; the UX-112 and the UX-171, storage battery tubes; and finally the UX-210, a "high power" amplifier. Of this list the UX-171 and UX-210 are undoubtedly the best in their respective ratings. Each operates with a large plate voltage and, when properly biased, has a long straight-line operating characteristic which permits a wide range in volume while maintaining quality.

The Type 387 Speaker Filter

These power amplifier tubes, however, draw a noticeably larger plate current than such tubes as the UX-201A or UX-199, and this feature has necessitated, or at least made quite desirable, an additional piece of equipment in the power amplifier, whose chief function is to keep this direct current from passing through the speaker. Why is this desirable? Perhaps the two principal reasons are as follows:

1—If a steady direct current is passed through the loudspeaker the armature or diaphragm is deflected one way or the other so that an unsymmetrical strain is placed upon the vibrating system. Then, when a pulsating ripple of current (speech or music) is passed through the instrument, the restoring forces are unbalanced, the moving parts do not vibrate in strict accordance with the wave form of the current ripple, and distortion results. This effect is comparable to pushing against a piano string with the finger while striking the corresponding key.

2—If a direct current is passed through the loudspeaker certain parts of the magnetic system may become more or less saturated with magnetism, so that when a ripple of current is passed through the instrument the variations in the magnetic pull may not correspond in magnitude to the amplitudes of the current ripples. That is, a small ripple of current may produce a relatively large change in the magnetic force on the driving mechanism, again giving rise to distortion.

Either one of two different instruments may be employed for removing this undesirable direct current from the loudspeaker. These are known as the **output transformer** and the **speaker-filter.** The former is self-explanatory; the latter consists of an inductance choke which passes the DC plate current, but which offers a high impedance to the audio frequency currents, forcing them to pass through a condenser into the loudspeaker.

Figure 1 illustrates the use of the output transformer "T" between the amplifier tube "A" and the speaker "S." Figures 2 and 3 show the corresponding circuits of the speaker-

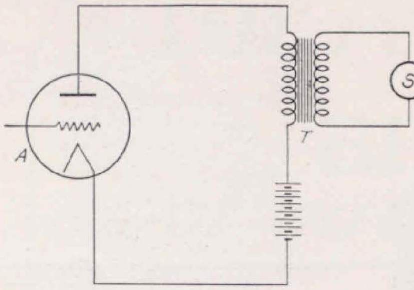


Fig. 1

filter, composed of the choke "L" and the condenser "C." The arrangement indicated in Figure 3 is preferable since, with the circuits as shown in Figure 2, the loudspeaker is at high potential with respect to ground, which is usually connected to the minus terminal of the "B" battery.

An investigation was recently undertaken in the General Radio laboratories to ascertain the best practical design for the elements of the speaker-filter. When it is recalled that the impedance or opposition to flow of alternating currents in a choke inductance increases with the frequency, while the impedance of a condenser decreases as the frequency rises, it will be apparent that the speaker-filter must be relatively more efficient for the higher pitched notes. Thus, if the inductance of the choke and the capacity of the condenser were both made too small a perceptible amount of low frequency current might pass through the choke and be lost to the loudspeaker.

At first glance the solution would appear to consist of making both "L" and "C" very large. Increasing the capacity of the condenser, of course, increases costs and at the same time increases the possibility of an accidental puncture or breakdown. Increasing the value of "L," while maintaining reasonable dimensions to the instrument, means more turns of finer wire. This, of course, introduces more resistance to the passage of the direct current so that less "B" voltage will be available at the plate of the amplifier tube. Then again, too many ampere turns on a given size core might tend to saturate the iron and reduce the efficiency of the choke. To ascertain the practical limits of design, three speaker-filters were constructed. Each contained a condenser of two microfarads capacity and each had an individual choke coil described as follows:

Speaker-filter "A"—Inductance 22 henrys, resistance 385 ohms.

Speaker-filter "B"—Inductance 50 henrys, resistance 745 ohms.

Speaker-filter "C"—Inductance 100 henrys, resistance 1,940 ohms.

For purpose of comparison, a standard design of output transformer "D" having a primary inductance of 0.9 henry (320 ohm resistance) and a secondary inductance of 0.6 henry (385 ohm resistance) was also used. The technique of the measurements is described below. Various pieces of equipment used in the study of loudspeakers were employed.

The audio frequency output from a "heterodyne beat oscillator" was amplified once by a small vacuum tube amplifier and then passed into

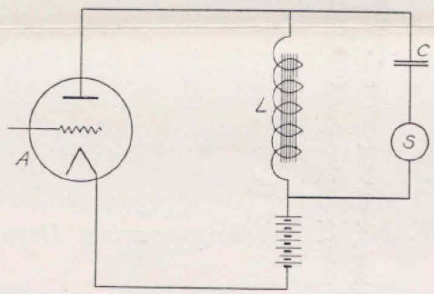


Fig. 2

a combination "B" battery eliminator and power amplifier. The output from the plate of the power amplifier tube could be passed at will through any one of the four instruments described above and then into a loudspeaker. This speaker was placed in a large sound-proof box, which contained also a pair of microphones used to pick up the sound emitted from the speaker. The pulsating currents from the microphones were then passed through a suitable transformer and rectified by a crystal so that their relative intensity could be measured on a millivoltmeter. Thus **comparative** measurements of the sound output of the loudspeaker could be made, using the different types of speaker-filter, etc.

To attempt to make measurements at a single pitch or frequency is difficult for several reasons. These objections were overcome by "wabbling" the pitch, that is, by varying the frequency repeatedly and regularly over a small range, perhaps twice a second. This was done by means of a small motor driven rotary condenser attached to the oscillator. This "wabble" produced a slight pulsating motion on the needle of the meter, but a mean reading could easily be obtained.

The first set of data were taken with a power amplifier employing the UX-171 tube and using as low a pitched "wabble" as would give a

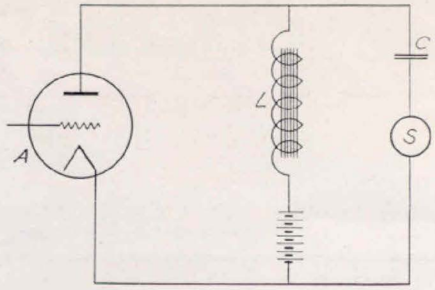


Fig. 3

reasonable response to the loudspeaker. Readings were taken in succession on instruments "A," "B," "C" and "D," and then repeated in the same order perhaps a dozen times. This repetition was deemed necessary owing to the variability of certain elements in the circuit, noticeably the microphones. The readings on a particular instrument were then averaged to give a mean value which could legitimately be compared with corresponding values obtained with the other instruments. For purpose of comparison these values were expressed as ratios to the value obtained with the output transformer "D," which in every case proved to be the least efficient. The data given in Table I show the average ratios thus obtained with several makes of loudspeakers, all being of the cone type.

TABLE I.

Type of Loudspeaker	Speaker Filters A	B	C	Output Trans. D
Erla	1.42	1.44	1.40	1.00
Musicone	1.27	1.28	1.32	1.00
West. Elec.	1.23	1.22	1.30	1.00
Acme	1.66	1.59	1.52	1.00

UX-171 with Low Pitched Wabble

In a similar manner comparative data were taken using the UX-171 tube by employing a high pitched "wabble." These ratios are given in Table II.

TABLE II.

Type of Loudspeaker	Speaker Filters A	B	C	Output Trans. D
Acme	1.28	1.26	1.28	1.00
West. Elec.	2.03	1.94	1.75	1.00
Musicone	1.32	1.31	1.31	1.00

UX-171 with High Pitched Wabble

A high power "B" eliminator and amplifier employing a UX-210 tube was then substituted for the UX-171 amplifier, and the data given in Table III. were obtained using a low pitched "wabble."

TABLE III.

Type of Loudspeaker	Speaker Filters A	B	C	Output Trans. D
West. Elec.	1.23	1.29	1.41	1.00
Acme	1.24	1.30	1.34	1.00
Erla	1.34	1.40	1.51	1.00
Musicone	1.38	1.55	1.76	1.00

UX-210 with Low Pitched Wabble

Lastly, the UX-210 amplifier was used with a high pitched "wabble," giving the data of Table IV.

TABLE IV.

Type of Loudspeaker	Speaker Filters A	B	C	Output Trans. D
Musicone	1.08	1.09	1.09	1.00
West. Elec.	1.04	1.05	1.05	1.00
Acme	1.20	1.21	1.23	1.00

UX-210 with High Pitched Wabble

Let us now examine these results which may, perhaps, be a bit surprising. It must be borne in mind that the figures give no indication of the relative merits of the cone speakers, but indicate merely a comparison between the various types of speaker-filters when used with a particular loudspeaker.

Table I shows that, with the low pitched "wabble," any one of the speaker-filters might be chosen as the best, depending upon the type of cone employed. The maximum variation (1.66 to 1.52) or 9 per cent. represents so small a difference that it could not easily be detected by ear. The relative efficiency of the filters and the output transformer, on the other hand, varies appreciably with the type of loudspeaker used.

Table II shows that, except in the case of the Western Electric cone, there is no appreciable difference between the speaker-filters when passing a high pitched note. As stated previously, this is to be expected on theoretical grounds.

With the UX-210 amplifier and a low pitched "wabble" the data of Table III shows a consistent improvement, favoring the Type C filter in each case. This improvement, however, is by no means pronounced, the greatest difference noted, 27 per cent. in the case of the Musicone, being an amount barely perceptible to the human ear.

Operating with the high pitched "wabble," the data of Table IV again offer no choice between the behavior of the filters.

It appears, therefore, that for all practical purposes the same intensity is obtained with all three types of speaker-filters. This being the case, it would then be desirable to use the Type A, which has the lowest resistance and hence leaves the highest voltage available at the plate of the amplifier tube and is, at the same time, least liable to core saturation.

A series of comparative measurements were then made between the A type of speaker-filter as described above and the A type of filter with the condenser increased to 6 MF. by the addition of a 4 MF. unit. Using various cone speakers with both high and low frequency "wabbles," it was found that the difference between the two capacities was less than the error of measurements, an entirely negligible amount, so that a condenser of 2 MF. proves to be quite large enough for the purpose.

Quartz Plates Available to Amateurs

After many disappointments, due to failures of sources of supply, the General Radio Company is now able to supply quartz plates for amateurs. These plates will be supplied for frequencies between 1750 and 2000 K. C. (171.4 and 150 meters). This will permit the use of the plates on any of the amateur bands by tuning to the proper harmonic.

Plates will be supplied as close as possible to specified frequencies in the above band. The frequency of each plate, measured to 0.25% accuracy, will be supplied with the plate.

The plates are somewhat irregular in shape from ½ to 1" in diameter. Faces are ground smooth and parallel, and the edges are bevelled. These plates are guaranteed to oscillate when used in a properly built holder, and kept clean. The plate voltage of the oscillator tube should be from 40 to 200. Puncture of the quartz plate due to excessive voltage is a characteristic of the material which cannot be prevented.

The plates as above described are supplied at $15.00 each, unmounted, post paid.

Notice

The expense of printing and mailing "The Experimenter" each month is too great to permit promiscuous circulation.

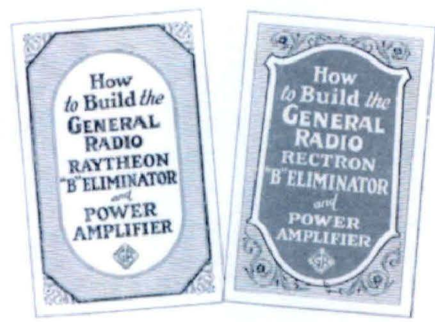
If you wish to continue to receive copies regularly and have not returned your post-card requesting that your name be placed on our mailing list, please write and have your name put on our permanent list.

Our permanent mailing list to receive all future copies of "The Experimenter" will be made up from returned post-cards and letters from experimenters who are anxious to avail themselves of the information contained in our new publication.

There is absolutely no charge attached to this service and we are very glad to extend all of our experimenter friends a permanent subscription for "The Experimenter" with our compliments.

Assure yourself of receiving all future copies by mailing us your card or writing us a letter today.

New Construction Literature on the Rectron and Raytheon Plate Supply and Power Amplifier Units Now Ready



In addition to building and improving their sets the amateur builders this year will also turn their ingenuity to the construction of plate supply units and power amplifiers.

In order that the amateur builders may carry on this constructional activity without unnecessary bother in collecting the required material and information the General Radio Company has brought out both Raytheon and Rectron Plate Supply and Power Amplifier units in kit form, and has published construction booklets containing all instructions for building plate supply and power amplifiers using either rectifier tube.

In addition to schematic diagrams they contain full scale pictorial diagrams showing exact arrangement of parts and actual connections.

In general characteristics and operation these power kits are similar to the completely assembled Type 400, Plate Supply and Power Amplifier which uses a rectifier, the UX-213, and as an amplifier tube the UX-171 power tube.

Dealers will be able to obtain a quantity of the construction booklets for free distribution to their set-building customers on request to their jobbers or to the General Radio Company.

For All Popular Makes and Circuits

of radio receiving sets

A Constant "B" Voltage Supply Unit with Power Amplification

TYPE 400

***Price* $68.**

The New GENERAL RADIO "B" Eliminator and Power Amplifier

Broadcast listeners everywhere are now demanding above all else "B" battery elimination and reception that is NATURAL.

The answer to this demand is the new General Radio Type 400 "B" eliminator and Power Amplifier which is designed to operate with all popular makes and circuits of radio receivers, regardless of whether they may be operated by storage battery or dry cell tubes.

Where A. C. 110-volt (60 cycle) lighting current is available the use of the Type 400 Unit is the most practical and satisfactory method of supplying all necessary "B" voltages. The Power Amplifier in conjunction with the "B" eliminator permits the convenient use of a high power tube in the last audio stage. This overcomes the tendency toward tube overloading and removes the most common cause of distortion in loudspeaker operation. An outstanding feature of the General Radio Type 400 "B" Power Unit is that it has no variable resistance voltage controls to get out of order and cause noisy reception.

Voltages in this unit are controlled by fixed resistances which are properly designed to make the Type 400 readily adaptable to all average receivers.

Once installed it requires no further alteration and is ready for years of unfailing service.

The Type 400 Unit is designed to use the UX-213 Rectron rectifier tube and UX-171 power tube in the amplifier.

Dealers, show this unit to your set owning customers, and you will interest them, demonstrate it and it will sell itself. Why not include a Type 400 Unit in every new installation?

Place your initial order with your jobber now and be ready for the big popular demand for plate supply and power amplifier units.

GENERAL RADIO COMPANY CAMBRIDGE, MASS.

GENERAL RADIO INSTRUMENTS

Behind the Panels of Better Built Sets