The GENERAL RADIO EXPERIMENTER

L. I NO. 3 AUGUST, 1926

The Design and Use of the Speaker Filter

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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 Thus the crystal detector, for many years an old standby, became superseded by the regenerative vacuum tube detector with its truly marvelous sensitivity.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-

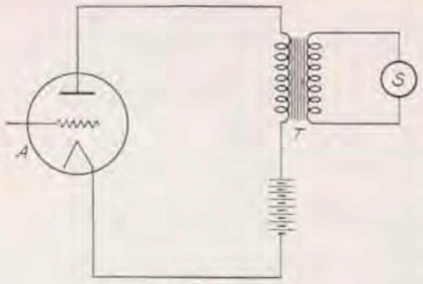


Fig. 1

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

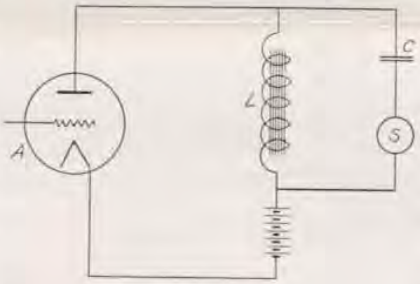


Fig. 2

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

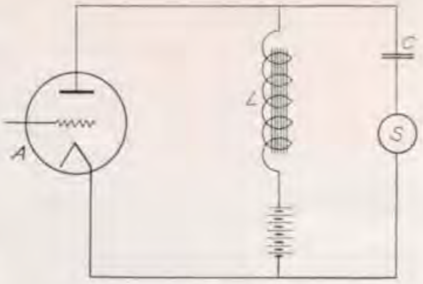


Fig. 3

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

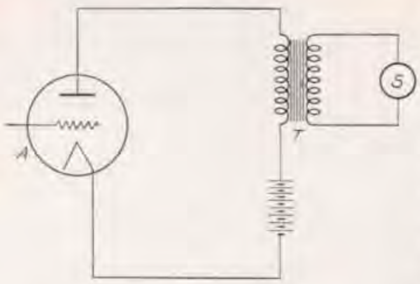
In a similar manner comparative data were taken using the UX-171 tube by employing a high pitched "wabble." These ratios are given in Table II.

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."



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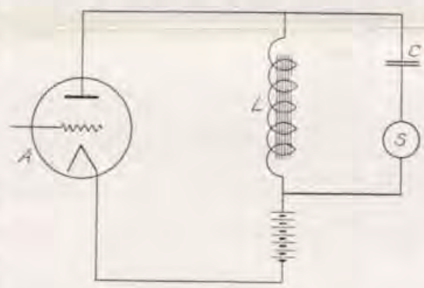

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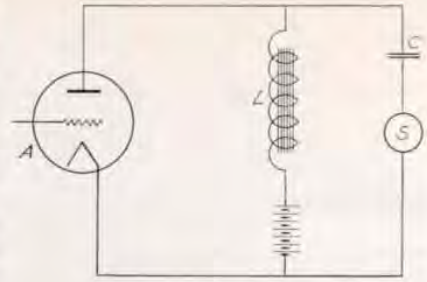

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