AEROVOX BUILT BETTER CONDENSERS AND RESISTORS

The Aerovox Hi-Farad Condenser

Gives greater filtering efficiency per microfarad of capacity

The filtering efficiency of any condenser depends both on the capacity of the condenser and its power factor. The filtering action of a number of condensers of any given capacity but having different power factor characteristics may, therefore, vary widely, the condenser having low power factor characteristics (low equivalent series resistance and consequent low power factor losses) providing much better filtering action than a condenser of equal capacity having high power factor characteristics (high equivalent series resistance and consequent high power factor losses).

High power factor or high equivalent series resistance in a condenser produces waste of energy in the condenser. This results in lowering its filtering efficiency and producing heating which further reduces the efficiency and life of the condenser.

Power factor measurements, made on a number of Aerovox and competitive electrolytic condensers, reveal some interesting facts on the importance of low power factor characteristics.

The results of a number of tests on a representative number of electrolytic condensers of each manufacturer are shown in Table I.

The much better, lower power factor characteristics of Aerovox condensers are obvious.

To show, in a practical form, the effect of poor (high) power factor characteristics on filtering efficiency, a representative condenser of each manufacturer was put on voltage for three hours till the leakage current of all the condensers reached a low, normal value. The condensers were then connected, one after the other, by a suitable switching arrangement, across the first section of the filter circuit of a standard power supply unit. The peak A.C. ripple voltage across the first section was measured for each type of condenser by means of an oscillograph. In this way it was possible to obtain a definite record of the effect of each condenser in filtering, or reducing the ripple across the first section of the filter, with the results shown in Table II.

Table I.

Power Factor Characteristics

Aerovox Hi-Farad DRY Electrolytic Condensers	8.2%
Liquid Electrolytic Condensers of Competitor No. 1	16.1%
Liquid Electrolytic Condensers of Competitor No. 2	33.0%

Table II.

Peak Value of Ripple Voltage Across Filter Section

Using an Aerovox Hi-Farad DRY Electrolytic 8 Mfd. Condenser	29.7 Volts
Using an 8 mfd. wet electrolytic condenser of Competitor No. 1	39.6 Volts
Using an 8 mfd. wet electrolytic condenser of Competitor No. 2	46.5 Volts

This practical test shows conclusively the much better filtering action obtained with Aerovox low power factor, DRY Electrolytic Condensers, per microfarad of capacity.

It is therefore possible to obtain filtering results equivalent to those obtainable with 8-mfd. units of other manufacturers by using lower-capacity Aerovox DRY Electrolytic Condensers at a worthwhile savings in price, or to obtain considerably better filtering with an Aerovox 8-mfd. unit than can be obtained with 8-mfd. units of other manufacturers.

From either standpoint, the advantages of using Aerovox DRY Electrolytic Condensers which are not only superior from the standpoint of filtering action, but have the IMPORTANT additional advantage of being DRY, are evident.

A considerable amount of additional information on Aerovox DRY Electrolytic Condensers is contained in the booklet featured below. Write for a copy without delay.

THIS BOOK GIVES THE LATEST AND MOST COMPLETE INFORMATION ON ELECTROLYTIC CONDENSERS

FREE! A copy of this 32-page book, containing a wealth of information on all types of electrolytic condensers will be sent free of charge on request. Just mail the coupon below. The book treats in detail the very important factors that affect the operation and life of electrolytic condensers of various types; the characteristics necessary in filter and bypass condensers to perform their functions satisfactorily and many other subjects of vital importance in the proper use of such condensers.

If you want to know whether leakage is a reliable indicator of filtering efficiency; what electrolyte characteristics are necessary for efficient electrolytic condenser action; how the filtering efficiency of various types of electrolytic condensers compares with paper condensers; in short everything you should know about electrolytic condensers you will find the information in this book. A copy is yours for the asking.

Aerovox Wireless Corporation,
70 Washington Street,
Brooklyn, N. Y.

Please send me, without charge or obligation, a copy of your book, "The Hi-Farad DRY Electrolytic Condenser."

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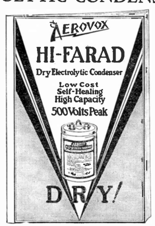

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The AEROVOX Research Worker

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The Essential Factors in the Design of Receiver and Amplifier Systems

Part III*

By the Engineering Department, Aerovox Wireless Corporation

HOW to calculate the amplification required in an audio amplifier, how to plan an amplifier to give this required gain, and finally how to determine the voltages at which the tubes must be operated to obtain best results, were discussed in detail in the previous article in this series which appeared in Vol. 3 No. 6 issue of the Aerovox Research Worker. The gain of an amplifier is one of its most important characteristics, but the frequency characteristic is certainly of equal and possibly even greater importance. In this issue we consider the factors that affect the frequency characteristics of audio amplifiers, confining our discussion to resistance coupled circuits. Much of the information that follows applies with but slight modification, however, to other types of amplifiers such as impedance coupled circuits containing combinations of resistance, transformer or impedance coupling.

When we refer to the frequency response of an amplifier we mean that characteristic which indicates how uniformly the unit amplifies various frequencies throughout the desired range of audio frequencies. In analyzing this quality of an amplifier we must therefore know what range in frequency is desirable (the lowest frequency and the highest frequency it is necesary to amplify uniformly). In this connection the chart of Fig. 3 is of considerable interest. It is taken from an article by B. S. Cohen, published in the March, 1928, issue of the Proceedings of the Institute of Electrical Engineers, London. It should be noted that the ideal limit for perfect reproduction of speech and music is considered to extend from 30 cycles up to 10,000 cycles per second. Exhaustive tests have shown that all frequencies below 50 cycles per second can be eliminated without any effect on the quality. For all practical purposes, therefore, we can consider 50 cycles per second as the desirable lower limit and about 6,000 to 7,000 cycles per second as a satisfactory upper limit.

Range of Audio Frequencies

Cycles per Second	REMARKS
32,768	Beyond limit of audibility for average person.
16,384	Telephone silent with 40 volts on receiver terminals.
10,000	Considered ideal upper limit for perfect transmission of speech and music.
8,192	Highest note on fifteenth stop.
5,000	Considered as satisfactory upper limit for high quality transmission of speech and music.
4,096	Highest note on pianoforte.
2,560	Approximate resonant point of ear cavity.
3.072	
3,000	Considered as satisfactory upper limit for good quality transmission of speech.
2,048	
2,000	Maximum sensitivity of ear.
1,500	Mean speech frequency from articulation standpoint.
850	
800	Representative frequency telephone currents.
600	
426.66	Orchestra tuning.
256	
200	Considered as satisfactory lower limit for good quality transmission of speech.
128	
100	Considered as satisfactory lower limit of high quality transmission of speech and music.
80	Lower note of man's average voice.
64	Lowest note of 'cello.
60	
32	Lowest note of average church organ.
30	Considered ideal lower limit for perfect transmission of speech and music.
27	Lowest note of pianoforte.
25	
16	Lowest audible sound. Longest pipe in largest organ.

Fig. 3

In the following discussion we will consider the desirable limits to be from 50 to 6,000 cycles per second.

Now let us consider the resistance coupled amplifier and determine how the constants of the circuit affect the frequency characteristic. The fundamental circuit of a stage of resistance coupled amplification is shown in Fig. 4. In this figure Rl is the plate resistor; Rg is the grid leak, and Cl is the coupling condenser.

The voltage gain of such a circuit is the signal voltage on the grid of tube V2 divided by

NOTE*: The first and second instalments of this article appeared in Vol. 3, Nos. 5 and 6 of the Research Worker.
Readers whose subscription begins with this issue (October-November) and who, therefore, missed the first two instalments of this article, may obtain Parts I and II on request. There is no charge or obligation. Merely write to the Research Worker, Aerovox Wireless Corporation. 70 Washington St., Brooklyn, N. Y.

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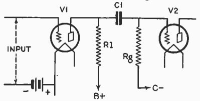
the signal voltage on the grid of tube V1.

If we impress a 2-volt signal on the grid of the first tube and 20 volts appears across the grid of the next tube, then the gain is 20



C1—Aerovox Type 1450 Mica Condenser
Rg—Aerovox Type 1092 Grid Leak
Rl—Aerovox Type 1094 Carbon Resistor
Fig. 4

divided by 2 which gives 10. If the amplifier is to have a uniform frequency response, a gain of 10 must be obtained at all frequencies between 50 and 6000 cycles, the limits we have choosen. Actually, we do not need an absolutely uniform characteristic, for the ear cannot distinguish a decrease in voltage amplification of less than about 10 per cent—this is equivalent to saying that the amplification at 50 and 6000 cycles shall not be less than 90 per cent of the gain at medium frequencies. This means that the overall characteristic of the amplifier must be uniform to within 90 per cent. If two stages are used, each stage must be uniform to within the square root of 90 per cent (.90) or approximately 95 per cent and if three stages are used, each stage must be uniform to within the cube root of .90 or approximately 97 per cent. Arranged in table form, we have the following figures for one, two or three stage resistance coupled amplifiers that are to have an overall frequency response that does not fall below 90 per cent.

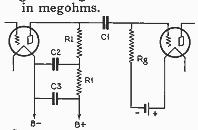
TABLE 1.

Number of Stages	Uniformity required per stage
1	90 per cent
2	95 per cent
3	97 per cent

If we take as an example, a resistance coupled amplifier of three stages, using type 340 tubes, then the recommended value for the plate resistor, Rl of Fig. 4, is 250,000 ohms. A table of tube characteristics indicates that the a. c. plate resistance of the 340 tube is 150,000 ohms. Knowing these values we can calculate the capacity of the coupling condenser required to produce the desired frequency response. The required capacity of the coupling condenser necessary to give a certain response at the lowest desired frequency can be calculated from the following formula, taken from an article by Sylvan Harris, published in the December, 1926, issue of the Proceedings of the Institute of Radio Engineers.

$$C = \frac{Rl+Rp}{6.28\times fo\,[Rg\,(Rl+Rp)+(Rl\times Rp)]\sqrt{\frac{1}{k^2}-1}}$$

where Rl is the resistance of the plate resistor in megohms.
Rp is the a. c. plate resistance of the tube in megohms.
fo is the lower cutoff frequency.
Rg is the grid leak resistance in megohms.



C1—Aerovox Type 1450 Mica Condenser Required Value.
C2, C3—Any Standard Aerovox 1 to 2 mfd. Paper Condensers.
Rg—Aerovox Type 1092 Grid Leak
Rl, R1—Aerovox Type 1094 Carbon Resistors.
Fig. 5

k is the per cent uniformity of response required (97 per cent for a three stage amplifier).
C is the capacity of the condenser required, in microfarads.

For given values of plate resistance, load resistance uniformity of amplification and frequency this formula can be simplified. If the tube resistance is 150,000 ohms (.15 megohms) and the load resistance is 250,000 ohms (.25 megohms) the formula becomes that given below for a cutoff frequency of 50 cycles per second and a uniformity of 97 per cent (.97).

$$C = \frac{1}{80\times Rg+7.5}$$

If the grid leak resistance is to be 0.5 megohm, then the required capacity of the coupling condenser can be determined by substituting this value in the above simplified formula.

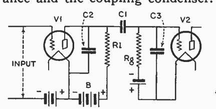
$$C = \frac{1}{80\times 0.5+7.5}$$
$$= .021 \text{ microfarads}$$

If the grid leak resistance is one megohm

$$C = \frac{1}{80\times 1+7.5}$$
$$= .0115 \text{ microfarads}$$

These two examples serve to indicate the important fact that the larger the value of the grid leak resistance, the smaller is the coupling capacity required to produce a certain frequency characteristic at the lower cutoff frequency. It is not advisable, however, to use coupling condensers larger than necessary, for as the response of the amplifier is extended to lower frequencies, the possibility of oscillations — so-called motorboating—is increased. In connection with this problem, the circuit of Fig. 5 will be found useful in preventing a resistance coupled amplifier from "putputting." This circuit was originally suggested by Roger Wise, at that time chief engineer of E. T. Cunningham, Inc. The anti-motorboating circuit consists of R1, C2 and C3, Fig. 5., connected in the plate circuit of the detector tube. R1 should have a value of about 0.1 megohm and the two condensers, C2 and C3, should each have a capacity of 1 or 2 mfds.

The preceding discussion has indicated that the low frequency response of a resistance coupled amplifier depends largely upon the values of the grid leak resistance and the coupling condenser.



C1—Aerovox Type 1450 Mica Condenser
C2, C3—Tube Capacities.
Rg—Aerovox Type 1092 Grid Leak
Rl—Aerovox Type 1094 Carbon Resistor
Fig. 6

Now let us examine the factors that affect the high frequency response

At high frequencies the simple circuit of Fig. 4 becomes that shown in Fig. 6. Note the addition of two new capacities, C2 and

C3. C2 is the output capacity of tube V1 and is usually of the order of 5 to 10 mmfd. C3 is the input capacity of tube V2 and its value depends upon the amount of amplification obtained in V2. For amplifications of the order of 20 with a type 340 tube, the input capacity is about 200 mmfd. In the following discussion we will assume that C3 is the only capacity, since it is much larger than C2.

The reactance of a condenser is equal to

$$Xc = \frac{1}{6.28fC}$$

where
Xc is the reactance in ohms.
f is the frequency in cycles per second.
C is the capacity in farads.

Since the highest frequency we desire to amplify is 6000 cycles, the reactance of C3, if its capacity is 200 mmfd., is calculated to be approximately 133,000 ohms at 6,000 cycles. At 6000 cycles, the reactance of the coupling condenser, C1, will be very small—about 2500 ohms, if the capacity is .01 mfd. In effect, therefore, the capacity, C3, is a shunt across the plate and grid coupling resistors. Since the grid leak resistance is much larger than the plate resistance and has little effect in reducing the effective resistance of Rl when connected across Rl, it is essential that the combination of C3 in parallel with Rl does not decrease the high frequency response an excessive amount by reducing the effective impedance of Rl by its connection across Rl. The effect of C3 on the frequency character-

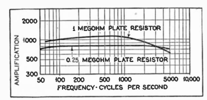
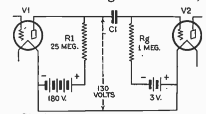


Fig. 7

istic will be most severe with high values of resistance for Rl, since the greater Rl, the greater the variation in impedance produced by C3. As a corollary, it follows that for good quality it is advisable to use the smallest value of plate coupling resistance that will give sufficient amplification. As indicated previously the capacity, C3, depends upon the amplification obtained and is, in fact, approximately proportional to the amplification. Therefore, as we reduce the value of the plate coupling resistance to lower the gain we automatically decrease C3 and thereby increase its reactance. As a result, there is a very rapid improvement in quality as the plate resistance is reduced. It is for this reason that many resistance coupled amplifiers use 100,000 ohm plate resistors rather than 250,000 ohm units.

In concluding this discussion on the resistance coupled amplifier, we can say that this type of circuit is capable of giving exceedingly uniform response, if it is carefully designed. In such an amplifier, high gain per stage and good quality go in opposite directions (a characteristic that is true of all types of amplifiers) and if good frequency response is to be had, one must be content with only a reasonable stage gain. This point is indicated by the two curves of Fig. 7, taken from an article by A. V. Loughren, presented before the Radio Club of America. Note the improvement in uniformity of frequency response obtained by the use of the lower value of plate resistor. Even greater improvement would be obtained with 100,000 ohm plate coupling resistors.

With any amplifier the results obtained depend largely upon the quality of the apparatus used in its construction. In the case of the resistance coupled amplifier, it is especially important that high grade condensers, such as Aerovox Mica Condensers, be used. The d. c. resistance of the condenser must be of the order of 400 megohms or more. The insulation resistance required to obtain satisfactory operation can be figured very easily. Fig. 8 shows a typical stage of resistance coupled amplification using 340 type tubes with plate and grid resistors as indicated. These tubes draw approximately 0.2 milliamperes of plate current with 180 volts of B battery. The IR drop in the plate resistor, Rl, is, therefore, 50 volts, so the effective voltage between plate and filament is 130 volts as indicated. This d. c. voltage is impressed across the coupling condenser, C1, and the grid leak, Rg, in series. If any d. c. current flows through this circuit, a



C1—Aerovox Type 1450 Mica Condenser
Rg—Aerovox Type 1092 Grid Leak
Rl—Aerovox Type 1094 Carbon Resistor
Fig. 8

voltage drop will be produced across the grid resistor which will change the bias on V2. Let us assume that the bias on V2 is 3 volts and that leakage current through the condenser should not be permitted to change the bias by more than 10 per cent, corresponding to .3 volts. A .3 volt drop will be produced across Rg by a current of 0.3 microamperes. Since the voltage acting on the circuit is 130 volts, the total circuit resistance necessary is 130 divided by .0000003 ampere (.3 microampere) or 433 megohms.

Since the grid leak resistance is one megohm, the condenser d. c. resistance must be at least 432 megohms.

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