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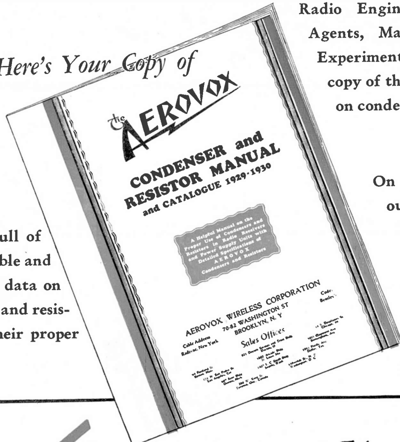

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1930 — 5

The AEROVOX Research Worker

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The Essential Factors in the Design of Receiver and Amplifier Systems

PART I

By the Engineering Department, Aerovox Wireless Corporation

THE modern radio receiver has become a precision product, built under the most exacting conditions prescribed by skilled engineers. It is no longer a heterogeneous combination of parts, wired together to conform to some trick circuit. A desired overall performance is obtained by combining a number of elements, each of which contributes its quota to the final result or overall performance. The complete design represents the results of intensive laboratory investigations.

In the logical design of a receiver there are several interesting and instructive investigations of the fundamentals of receiver design which one may explore without a laboratory full of expensive instruments. All that is required is a pencil, some paper and an understanding of how radio receivers operate. With these simple tools it is possible to work out the general design of receivers. Considerable interest has been expressed by readers of the Research Worker, in this particular subject and we have therefore prepared a series of articles which will discuss in detail the fundamental design of radio receivers. This article is the first of the series.

Surprising as it may seem, in working out the design of a receiver we must put the cart before the horse. The place to start the design is at the loud speaker, the tail end of the set, and work towards the antenna. A moments consideration will indicate why this is so. The loud speaker represents the direct point of contact between the listener and the broadcasting studio. The final function of every radio receiver is to supply the listener with music of good quality and of proper volume. Quality is a characteristic that depends largely on the use of good apparatus in the receiver and operating the tubes under conditions to produce the least possible distortion. Volume depends upon the overall amplification of the receiver and the power handling capacity of the power tubes and loud speaker. In working out a receiver circuit we start with the one definite thing—the output from the loud speaker. The output from the loud speaker and its sensitivity determine how much power is required to drive it and knowing this we can decide the kind and number of power tubes we must use. Having determined this point we then proceed to figure how much audio frequency voltage must be supplied to the power tubes to obtain maximum output. We then work back through the audio amplifier gradually increasing the overall amplification until the input voltage to the amplifier is about equal to the audio frequency output voltage we can expect to get from the detector. Knowing the audio frequency voltage required from the detector we can calculate the modulated radio frequency voltage we must apply to the detector input to get the required audio frequency output. The r. f. input to the detector determines how much r. f. voltage must be supplied by the last tube of the r. f. amplifier. We then work back through the r. f. amplifier until the input voltage required is sufficiently small to give the receiver the desired sensitivity. This very briefly is the manner in which the design should progress. In order to work out a design by such a method the following major facts must be determined:

Unit	Data Required
Loud Speaker:	Efficiency Impedance Power Handling Capacity
Power Tubes:	Type, number and method of connection; Maximum Undistorted output; A.C. input required for maximum output; A. C. plate resistance.
Audio Amplifier:	Maximum A.C. output required; Audio voltage available at input; Gain required; Type of amplifier—transformer, resistance or impe-

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	dance coupled;
	Plate voltage available;
	Type of tubes.
Detector:	Sensitivity;
	Maximum audio output;
	R.F. input required;
	Type of tube
Amplifier: Radio Frequency	Required R.F. output voltage;
	Sensitivity required;
	Available input voltage;
	Selectivity required.
Antenna Circuit:	Effective height of antenna;
	Type — indoor, outdoor or loop.

The preceding tabulation serves to indicate once again that the design of one section of a receiver depends to some extent upon the characteristics of the other parts of the set. For example, the audio amplifier design cannot be completed without a knowledge of the characteristics of the power tubes and the audio output voltage from the detector. The r. f. amplifier design hinges around the voltage required to operate the detector and the voltage available from the antenna circuit. It will also depend upon the selectivity requirements for this will determine the number of tuned circuits required.

We can state in the form of a problem the material which will be covered in the remainder of this article and the other articles to follow in this series.

Problem

A receiver is to be able to supply sufficient output from a loud speaker for good reproduction, without any danger of overloading. The loud speaker is 2 per cent efficient. The overall sensitivity of the set is to be 10 micro-volts per meter. Determine the following data:

1. Type and number of power tubes required.
2. Overall audio frequency gain and number of stages required, using either transformer or resistance coupling.
3. Output voltage from different types of detectors and modulated r. f. input to the detector required to give this output.
4. Output voltage required from r. f. amplifier and overall gain required to give a sensitivity of 10 micro-volts per meter. Number of r. f. stages and gain per stage required if four tuned circuits are to be used. Same data for three tuned circuits.
5. Plate voltage and plate current required for the operation of the various tubes. Tabulation of all voltages and currents required from the B power unit.
6. Calculation of all resistance values for filtering and C bias.
7. Drawing of complete circuit of receiver.

The above problem and the list of data which we will determine by working through the design will give readers a clear idea of the scope of the articles to follow in this series. It is a series which, we are sure, will be read with interest by experimenters and engineers alike. For the data on which to base our discussion we will make use of the laboratory work on detectors and amplifiers which has been described in technical publications by various engineers. The remainder of this sheet will be devoted to a determination of the first point, the amount of power required from the power tubes.

The amount of power required will depend upon the efficiency of the loud speaker and the amount of acoustical (sound) energy the loud speaker must create in the room in which it is being operated. This power must be produced without overloading the power tubes, for if this occurs serious distortion will result. In determining the characteristics necessary to prevent overloading we must assume certain values, but we can get a good idea of what the requirements are. We must base our calculations on the most difficult conditions. The most trying test is given to a receiver when it is required to reproduce an orchestra program, for here the range in volume is very great and the fortissimo passages very loud.

Suppose, to take an average case, an orchestra is being broadcast and that the ratio of power between the pianissimo and fortissimo passages is a million to one, corresponding to a range of 60 db. Because of the characteristics of the lines used to pick up broadcast programs it is necessary to cut down this range to about 40 db. ten thousand to one, so as to keep the weak passages above the line noise and to prevent the loud passages from overloading the amplifiers. Let us assume that this ratio of ten thousand to one is maintained throughout the broadcast and receiving systems, which would be true if there was no overloading at any point.

Now we have to decide how much power is required to satisfactorily reproduce the softest passages. A relative idea of the amount of acoustical power required can be obtained from the fact that the average power of normal speech is about ten microwatts (0.000010 watts). We can therefore assume that the minimum power required from the loud speaker can be about three microwatts.

If we assume that the energy associated with the pianissimo is to be three microwatts, then the energy during the fortissimo passages will be ten thousand times as great, or 30,000 microwatts, which is the same as 0.03 watts. To have a factor of safety we will double this so that maximum acoustical power required from the loud speaker will be 0.06 watts. Now the problem states that the loud speaker efficiency is 2 per cent. Therefore, the power input to the loud speaker during the loudest passages will be

$$\text{Power into loud speaker} = \frac{\text{Output power}}{\text{Efficiency}} = \frac{0.06}{0.02} = 3 \text{ watts}$$

Therefore the power tube must be able to supply three watts of undistorted power. Now let us list the various types of tubes and determine which type should be used. The list is given below:

Type of Tube	*Plate Voltage*	*Grid Voltage*	*Undistorted Output in Watts*
112-A	135	9	0.12
371-A	180	40	0.7
345	250	32	1.6
310	400	31	1.3
350	450	84	4.5

From this table it is evident that no single tube except the 350 will supply sufficient power and it hardly seems advisable to use this tube for the high plate voltage it requires would make the receiver very expensive to construct. We will therefore have to use two tubes in push-pull to obtain the required power. A single 345 tube delivers 1.6 watts and two of them in push-pull will supply at least 3.2 watts. A single 371-A is rated at 0.7 watts, so two in push-pull give about 1.4 watts. It appears therefore that the arrangement which will most satisfactorily supply the required power consists of two type 345 tubes in push-pull and this is the arrangement we should use. We have therefore determined the first important point in this process of designing a receiver. We have learned how to calculate how much power is required assuming a certain loud speaker efficiency and how to pick and choose from several possible tube combinations the arrangement meeting the requirements most satisfactorily.

This treatment of the problem cannot be considered exact, but it has served our purpose. It was necessary to assume an average value for the power associated with the pianissimo passages and this assumption determines the maximum power required. But the preceding discussion has shown how to calculate such things and has served also to indicate why power tubes must be used.

The next part of this series will discuss the design of the audio amplifier determining the gain required, the plate voltages, etc., for both a transformer coupled affair and for a resistance coupled amplifier.

Aerovox Products Employed in Unique Amplifier Installations

The Aerovox Wireless Corporation is always interested in hearing of unique radio installations in the construction of which Aerovox products have been used to insure satisfactory operation and long life.

Bludworth, Inc., a firm of electro-acoustical engineers specializing in the design and installation of the highest grade of amplifiers and public address systems for public and private use, have recently completed several interesting voice amplifier systems.

The apparatus built by this firm is designed regardless of cost to perform a definite service, that of giving not merely intelligible but absolutely faithful reproduction.

One of the outstanding systems designed and installed by Bludworth, Inc., is the $125,000 equipment now in service in the New Yorker Hotel in New York City, one of the largest and most modern hotels in the world. The system provides for radio, phonograph and public address throughout the entire hotel.

The Aerovox Wireless Corporation is justly proud of the part which Aerovox condensers and resistors are playing in this remarkable installation.

Perhaps the most unique system worked out and put into service by this concern is one which they recently installed in the home of one of the most prominent men in America.

This installation consists of remote controlled radio, phonograph and microphone pickup systems so designed that any event happening in the United States can be reproduced in his mansion by means of direct wire connections with the scene of the event.

The equipment necessary for this complete system was installed at a cost of $75,000 and is probably the finest private installation in the world. Aerovox condensers and resistors were used exclusively in this installation.

These are but two of the most outstanding installation of this concern. Among others, the Riverside Church installation, Boston Madison Square Garden and that of the Princeton University Chapel are examples of installations designed specifically for those buildings by Bludworth, Inc. In all of these installations, Aerovox condensers and resistors were used exclusively.

Mr. T. F. Bludworth, head of the organization that bears his name is one of the pioneer engineers specializing in the installation of high quality amplifiers and public address systems. His system of remote control, developed six years ago is one of the most perfect of its kind in existence today.

Mr. Bludworth pays Aerovox a high tribute when he says that in the many installations in which he has specified Aerovox condensers and resistors exclusively, not a single Aerovox unit has ever failed in service.

Charles Golenpaul Now With Aerovox

The Aerovox Wireless Corporation is pleased to announce the appointment of Charles Golenpaul, formerly with the Clarostat Mfg. Co., to the sales staff of the Aerovox Wireless Corporation.