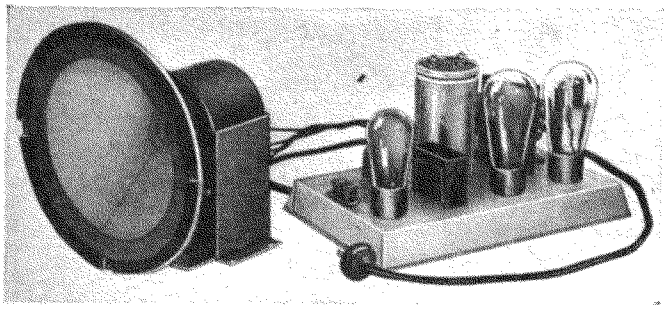
DESIGNING AND CONSTRUCTING DIRECT-COUPLED A. F. AMPLIFIERS



Photograph of an A.F. direct-coupled amplifier built by the author which uses the circuit of Fig. I.

The first of a series of two articles designed to give the reader a number of practical direct-coupled circuits with sufficient design data to explain "what's what."

L. B. BARCUS

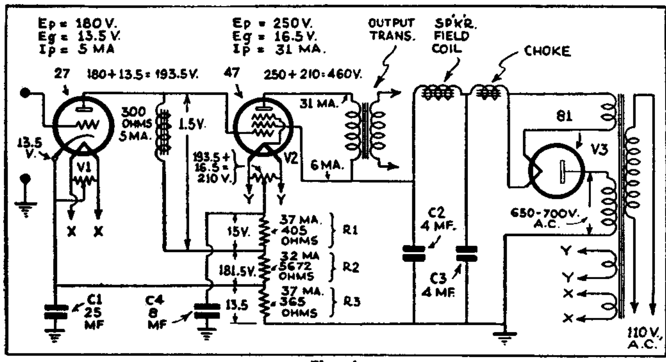


Fig. 1
Circuit of a direct-coupled amplifier using a 27 (or 56) feeding a 47.

OF LATE the attention of the radio fraternity has been turned more and more to the audio characteristics of radio apparatus. Urged on by the better class of radio receivers, the public has become critical of tone quality wherever audio amplification is employed. In an attempt to stimulate the sale of radio sets, engineers have made tremendous strides in the perfection and development of existing circuits. The past year has seen a number of elaborations in audio circuits, giving, in the aggregate, more power, better control and greater fidelity.

Unfortunately, however, practically every application of audio amplification in use today makes use of circuits almost impossible of complete perfection. Even the best amplifiers, in use today, show considerable distortion, regardless of the care and expense involved in their construction. For this reason, the amplifiers to be discussed in these articles were developed to give every constructor the opportunity to build an amplifier which will fulfill his every expectation and to give results noticeably superior to the most expensive conventional circuits.

The direct-coupled amplifiers, to be described, are all alike in that they are uniformly free of drummy, muffled, or blaring output. Their frequency response is uniform from the lowest bass to the highest note broadcasted. The limitations of these circuits are not in themselves, but in the speakers and the input systems in use today.

Each of these amplifiers is constructed upon one basic system, and a clear understanding of the principles will enable anyone to devise an instrument to exactly fit his own needs. A close study of Fig. 1 will reveal the underlying facts encountered in the system. Since the plate of one tube is directly connected to the grid of the next, the first problem, naturally, is that of arranging the voltages to give each of the tubes its normal operating potentials.

Theory of Direct-Coupled Circuits

If V1 and V2 have the same plate-current drain, and the plate of V1 is connected to the filament circuit of V2 by the choke, it follows that the two tubes will form an electrical circuit similar to two resistors in series, and any plate voltage applied to V2 will be divided between the two tubes. Thus, by giving the plate of V2 a potential equal to the sum needed by both tubes, we have a method of giving both stages the proper differences of voltages while gaining, at the same time, the highly desirable direct-coupling. Let us consider the facts in greater detail.

It is seldom that the first stage, V1, draws as much current as the succeeding tube. Therefore, we must rely on resistors R1, R2, and R3 (Fig. 1) to apportion the currents properly. The determination of the values of these resistors is the chief calculation encountered in designing an amplifier.

If any value of "B" voltage is available, the voltage requirements of each tube are noted. Then, beginning with the grid of V1 which is effectively at ground potential, the required tube voltages are jotted down on the diagram and added, progressively, throughout the circuit as shown. In Fig. 1 there are four voltage levels in the circuit, the cathode of V1 being the first. With the operating potentials given, the voltage applied to the plate of V2 amounts to 460 volts. This high voltage can be best obtained by using a type 81 rectifier tube, as shown. The usual power transformer with a 650- or 700-volt center-tapped secondary winding may be used. When used with a choke input to the filter, the well regulated output of the filter is approximately the correct voltage needed. In case only a *limited* "B" voltage is obtainable, it must be apportioned to the tubes in a manner best calculated for their satisfactory operation.

The first step is to determine the voltage drop across the coupling choke by the formula, E equals IR, where I is the plate current of V1 and R is the resistance of this choke. This voltage drop is seldom enough to furnish the bias for V2, it being only 1.5 volts with the choke shown in Fig. 1, so that the balance of the bias must be obtained otherwise. It is feasible to place a resistor in series with the choke, but the author prefers to use R1 to maintain a more stable bias. The entire plate current of V2 flows through R1. Thus, the rest of the needed bias is calculated in the usual manner. Tube V2 normally has a bias of 16.5 volts, 1.5 volts of which results from the voltage drop across the choke, leaving 15 volts as the potential across R1. Therefore, by Ohm's law, R1 equals E/I or 15 divided by .037 ampere, which gives R1 as 405 ohms. It should be observed that the screen of the 47 tube draws 6 ma. which must be added to the plate current in the calculations.

The bias of V1 is derived from R3, which is seldom over 500 ohms due to the large current flowing through it. While the plate of V1 draws 5 ma. from the resistance strip, this entire amount is returned to it through the cathode of the

tube resulting in the same current flowing through R3 as through R1. The 13.5 volt bias divided by 37 ma. thus gives us a value of 365 ohms for R3.

It falls upon R2 to bear the greatest load in maintaining the filament of V2 at the proper potential. The voltage drop across R2 is always equal to the desired plate voltage of V1 plus the voltage drop across the choke, or 181.5 volts in Fig. 1. Since the 5 ma. consumed by V1 does not flow through R2, that amount is subtracted from the total current flow through R1 in calculating the correct value of R2. In Fig. 1, therefore, R2 equals 181.5 volts divided by .032 amp which results in 5,672 ohms.

Regardless of the complexity of the circuit to be used, it is necessary to rely on no more than arithmetic in calculating the values of the components. No difficulty will be encountered if, first of all, the required voltages at all points are noted and the various divisions of currents traced, as was done above. In each of the diagrams illustrating this article, each step is shown. A study of them should give enough pointers to enable the average technician to design any type of amplifier, desirable, from two stages to a multi-stage P.A. system with 500 watts output.

Volume Controls

In order not to disturb the voltages and currents flowing in an amplifier, a different type of volume control is necessary. A potentiometer shunted across the choke would remove the grid bias of the following tube in some cases and alter it in others when the arm of the potentiometer, to which the grid of the tube is connected, is turned to the low potential side. In Fig. 3, where the voltage drop of the choke is only 1.5 volts and the total bias 50 volts, the use of the potentiometer shunt could scarcely be called objectionable since the bias would not be thrown off over 3%. In Fig. 2, however, the bias would be altered over 10%. It is wise, therefore, to insert a large bypass condenser on the lower side of the potentiometer or to run the lead to a tap on R2 at the same voltage level as that of the plate of V1.

Considering that these systems were designed solely for their superior tonal characteristics, care should be taken in choosing the components with which an amplifier of this type is to be built. For example, C1 and C4 shown in Fig. 1 should have a high capacity, with C1 one of the low-voltage, high capacity bias type. The audio chokes are most important, too; although the action of this type of amplifier tends somewhat, it seems, to improve the frequency characteristics of audio chokes so that one having only a fairly straight line choking effect will be found to give good account of itself when used in this connection. Naturally, however, a choke of the very best sort should be selected.

Uses of the Amplifiers

When using a tuning system of extremely high gain, we may fall back on a recently popular layout; that is, the use of a power detector with one audio stage. V1 of Fig. 1 would thus be converted into the detector with V2 as the power output tube. The tone quality would be good, to be sure, and much better than if any other type of interstage coupling were used. If at all possible, a type 45 tube should be substituted for the 47 because of the inherent weaknesses of the pentode tubes in operation and performance. Likewise, a screen-grid tube is not at all satisfactory in place of V1. The high resistance necessary in its plate circuit precludes the use of this system without the use of automatic bias and other desirable factors which are to be found in the well-known Loftin-White circuits. Screen-grid tubes are subject to many of the weak points of the pentode in tone, and are never recommended by the author in audio amplifiers.

Another possible use of two stages is with diode detectors, as shown in Fig. 2. If the R.F. end of the receiver gives sufficient gain, there is a good possibility of excellent performance insofar as the 47 pentode may be dispensed with and a triode power tube used in its place. Since the amplifying half of the 55 is diode-biased, there is no need for an audio bypass condenser which means better tone. It should be noted here, that in many cases the voltage drop across R4, due to the rectified signal, may be insufficient to properly bias the triode half of the 55, except on strong local stations. For this reason the plate voltage on the 55 should be as low as possible without too much sacrifice.

In the quest for greater gain, the most logical development of the two stage layout is, naturally, the use of three or more stages using practically the same system as the two-stage amplifier. Figure 3 shows a three stage amplifier designed along these lines. It is actually very simple to construct and requires only one tapped resistor, a point which promises long, trouble-free life. Every technican knows how often the numerous resistor units fail, especially in resistance coupled systems, and the promise of substantial wire wound components and unchanging voltages should be appealing.

We may extend the idea to four or even five stages should it be necessary. There is no technical difficulty other than the necessity for a high potential. Regardless of the number of stages, only one tapped resistance is used, and the tone quality is superior to resistance-capacity coupling. It should be noted that a separate filament winding is used for each stage to avoid high poten-

(Continued on page 111)

DIRECT-COUPLED AMPLIFIERS

Most men are afraid to build direct-coupled amplifiers because they don't know what makes the wheels go 'round. The author, in this series of articles, gives a number of modern arrangements using the direct-coupling principle; and, at the same time, explains each and every step. Nothing is left to the vivid imagination of the builder.

Direct-coupled amplifiers have long been known for their simplicity, low cost, and, most important of all, for their excellent fidelity characteristics.

Here is your chance to understand and build direct-coupled amplifiers.

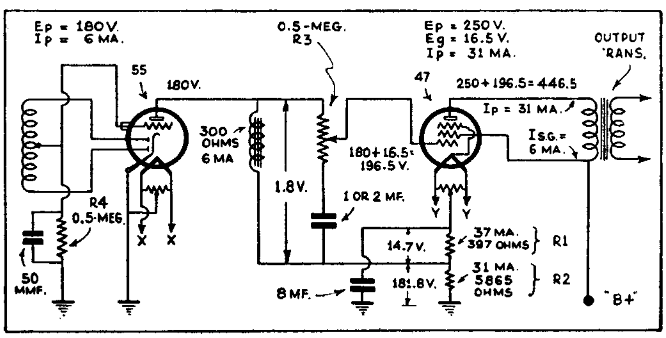


Fig. 2
Another direct-coupled amplifier featuring the 55, duo-diode triode.

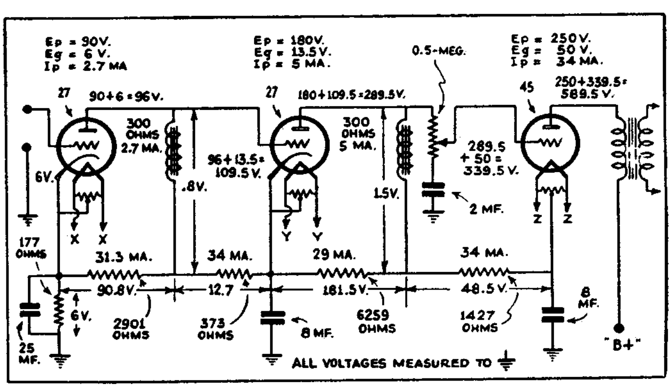


Fig. 3
Complete information on a three-stage direct-coupled amplifier.

DIRECT-COUPLED A.F. AMPLIFIERS

(Continued from page 81)

tials between the elements of the tubes.

Since the very high potential necessary calls for more expensive parts, which are sometimes hard to obtain, we will, next month, go into more elaborate types of direct-coupled circuits which give high gain and even better tone without demanding other than the standard components in universal use today.