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ELECTRIC CIRCUIT ARRANGEMENT FOR DISCHARGE TUBES

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Fig. 1

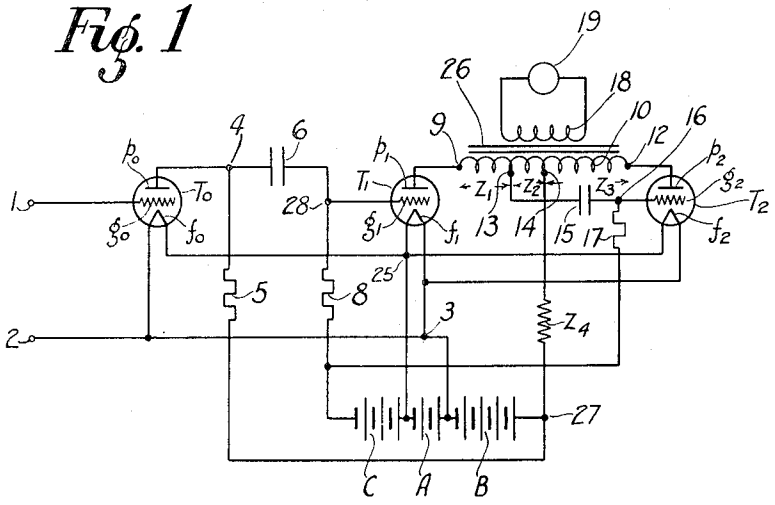
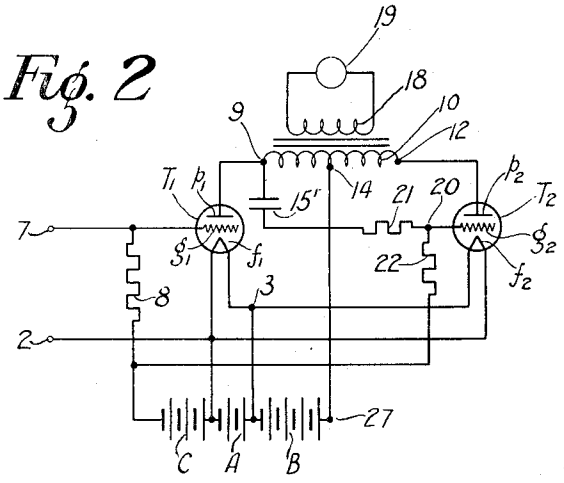


Fig. 2



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ELECTRIC CIRCUIT ARRANGEMENT FOR DISCHARGE TUBES

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7 Claims. (Cl. 179—171)

My invention relates to novel electric circuit arrangements for discharge tubes in which the output of two or more tubes is combined to supply energy into a common load.

I shall illustrate my invention in connection with a radio receiving set and more particularly as embodied in the output stage thereof. However, it should be well understood that my invention is in no way limited to such application, and can be used in other stages of receiving sets, or in any electric circuit arrangements in which the output of two or more tubes is combined to supply energy into a common load.

Present day radio set loudspeakers, to give a reproduction of satisfactory volume and quality, require for their operation a considerable amount of output, and it is therefore desirable that the tubes feeding in such devices should be able to amply supply such output without distortion caused by the over-loading of the tubes. On the other hand, commercial and other considerations limit the size of the tubes and the voltages applied thereto.

To keep the voltages and the size of the tubes within the limits so imposed, it has been proposed to use in the output stage and also in intermediate stages of receiving sets instead of a single tube, two or more tubes in parallel arrangement, so as to combine the outputs of the individual tubes. However, a plain multiple arrangement of such tubes has been found unsatisfactory, partly because such arrangement did not provide for an impedance of a value required to obtain the maximum output from the tubes, and partly because distortion created by the tubes is exaggerated in such arrangement.

A more satisfactory result has been obtained by means of the so-called push-pull arrangement in which two—or a multiple of two—tubes are so arranged that their grid circuits are excited from the two halves of the secondary winding of a common input transformer, and the plate circuits are feeding in the two halves of the common primary winding of an output transformer. Thereby the distortion caused by the higher harmonics of the individual tubes is balanced to such an extent that an appreciable higher undistorted output is obtained than when the tubes are used in parallel.

Such push-pull arrangement is widely used, but requires twice the input voltage than the parallel arrangement, furthermore, it has been found difficult to apply it in case resistance and not transformer coupling is used between the output stage and the stage preceding it. These difficulties arise from the facts that the grids of both tubes being excited from the two halves of the coupling resistance, and therefore relatively high voltages have to be applied to the resistance to obtain on the individul tubes a grid swing of sufficient amplitude, and that in case the plate current for the push-pull tubes is supplied from the same electric source as the remainder of the receiver,—which is highly desirable—the filaments of the push-pull tubes must be connected to the center of the coupling resistor, which introduces various grave complications. For these reasons, it has been generally accepted that push-pull arrangement could not be satisfactorily combined with resistance-coupling.

On the other hand, resistance-coupling has several advantages over transformer-coupling, among which are the following: A coupling-resistor is much less expensive than a coupling-transformer, and does not introduce distortion, whereas even the best coupling-transformers do. Furthermore, in case high impedance tubes are used in the stage preceding the output stage, it is impractical to match the impedance of the coupling-transformer with the impedance of such a tube, which is not the case with coupling-resistances. High amplification tubes, the use of which is of evident advantage, however, have as a rule high impedance.

From the above, the importance of combining the advantages of push-pull amplification and resistance coupling is evident and by the application of my invention, I have succeeded in combining in a simple and convenient way the advantages resulting from the push-pull amplification with those of resistance coupling. Thereby I obtain double the voltage amplification and four times the power sensitivity compared to that which can be obtained with the same signal voltage in case of the conventional push-pull arrangement, and this irrespectively increased amplification is obtained whether a coupling-transformer or a coupling-resistance is used in connection with my invention.

From the above it will also appear that my invention lends itself especially well for the elimination of an intermediate amplifying stage, because of the fact that high amplification tubes, for instance, screen grid tubes, can be used in the stage preceding the output stage, and the voltage on the coupling device needs to be only half the value of that required for conventional push-pull. Elimination of an intermediate audio amplification stage, besides representing con-

siderable savings also eliminates one source of distortion and thus improves quality.

In the case just described, I arrange the plate circuits of output tubes essentially in the same way as is the case in the conventional push-pull arrangement, however, I excite only the grid of one of the tubes from the coupling or input device—which is preferably a coupling-resistor—and excite the grid of the second tube from a voltage drop, which is supplied from the plate circuit of the other output tube. Thereby, I so select this voltage drop as well as the other constants of the circuit, that the maximum undistorted output of the tubes may be obtained.

The same principle, which has been here explained as applied to the output stage of a radio receiving set, can be applied in various electrical circuit arrangements where the output of two or more tubes is combined to supply energy into a common load.

Referring now to the drawing which forms part of this specification, Figure 1 is a circuit arrangement illustrating my invention as applied to the output stage of a radio receiver.

Fig. 2 is an alternative arrangement of my invention.

Referring now to Figure 1, T_0 represents a vacuum tube of the usual three-electrode type which might be the tube of a radio frequency amplifying stage of a detector circuit, or of an intermediate audio amplifying stage. The input signal for this tube is supplied from 1 and 2, 1 being connected to the grid g_0 and 2 being connected to the filament f_0 of the tube. The filament is also connected to a battery A supplying the heating current therefor.

The plate circuit which includes the plate p_0 of the tube T_0 is connected through 4 and a resistance 5 to the positive side of a battery B or other suitable supply of direct current, said battery B being shown in series with the filament battery A whereby the latter is also included in the plate circuit. From the negative end of the battery A the direct current circuit is completed through 25 to the filament f_0 forming the cathode of tube T_0. The output circuit of tube T_0 goes from plate p_0 through a condenser 6, a coupling resistance 8, through battery C back through 25 to filament f_0.

The grid of the tube T_0 is properly biased in any suitable way (not shown).

Inter-connected with the stage heretofore described, is an output stage comprising two tubes, T_1 and T_2 shown as being of the three-electrode type, provided with plates p_1 and p_2, grids g_1 and g_2 and filaments f_1 and f_2 respectively. The grid g_1 of the tube T_1 is inter-connected with the plate circuit of the tube T_0 at 28 between condenser 6 and resistor 8. This resistor supplies the grid swing for tube T_1 and the proper grid bias is obtained from a battery C connected with its negative end to resistor 8, while the positive end of the battery C is connected to the negative end of the battery A.

The filaments f_1 and f_2 are connected through 25 and 3 to the battery A supplying the heating current.

The plate circuits of the tubes T_1 and T_2 are inter-connected with the primary winding 10 of an output transformer 26 in such a way, that the plate p_1 is connected to one end 9 and the plate p_2 to the other end 12 of said winding. A center tap 14 provided on the winding 10 is connected to the positive end 27 of the battery B, whereby the connection 14—27 forms a common return for the plate circuits of tubes T_1 and T_2. The impedance of the branch 14—27 is represented for convenience by Z_4.

The plate circuits of each of the tubes are completed through the batteries B and A to their respective filaments f_1 and f_2.

Between the end 9 of the winding 10 and its center tap 14, is provided an intermediate tap 13 which connects through a coupling condenser 15 to the grid g_2 of T_2. The grid g_2 is also connected through a resistance 17 to the C battery.

The secondary winding 18 of the transformer 26 connects to the load 19, which may be a loudspeaker or any other suitable device.

It should be noted that the grid g_1 of the tube T_1 is excited from the coupling resistance 8 and therefore this grid swings to the full extent of the voltage applied to the coupling device. However, the grid g_2 of the second tube is excited from the plate circuit of the tube T_1, and in the arrangement just described I obtain this by exciting the grid g_2 from the voltage drop provided in the primary winding 10 of the transformer between its taps 13 and 14. It thus appears that while the plate circuits of the tubes T_1 and T_2 are connected in the conventional push-pull arrangement, only one grid obtains its swing from the coupling resistor 8, and thus the full input voltage of this resistor can be applied to this grid.

It should be noted that the voltage impressed on grid g_2 is of such phase, that the plate current of tube T_2 supports the plates current of tube T_1, thereby combining the output of the two tubes.

To obtain maximum undistorted output a balanced condition is required, whereby the grid swings on the two tubes are equal and no signal current flows through the branch 14—27 represented by impedance Z_4. This is obtained when

$$Z_2=\frac{Z_1}{M_2} \quad \text{----------(1)}$$

whereby Z_2 represents the impedance of the primary winding of the transformer between points 13 and 14; Z_3 represents the impedance of tube T_2 plus the impedance of the primary winding of the transformer between points 14 and 12, and M_2 represents the amplification factor of tube T_2.

As the impedance Z_2 and Z_3 have both real and imaginary components, Equation 1 is only fulfilled if the following equations are fulfilled:

$$M_2R_2=R_3 \quad \text{----------(2)}$$

$$M_2\frac{1}{WC_2}=\frac{1}{WC_3} \quad \text{----------(3)}$$

$$M_2L_2=L_3 \quad \text{----------(4)}$$

However, if Equations 2, 3 and 4 are fulfilled no current will flow through impedance Z_4, and this condition will hold for all frequencies, irrespective of the value of impedance Z_4.

It should be well understood, that the balance so selected is for the condition of maximum combined output of the two tubes, and therefore the values governing said selection are to correspond to a signal input which is equal, or slightly greater than the bias applied to tube T_2. It should not be inferred from this that the balanced condition has to be obtained under all operating conditions. When the input signal is of a less value than above specified a current flow might take place through impedance Z_4. However, this is no detriment to the quality of reproduction be-

cause in this case the total output is below the maximum of available undistorted output and therefore distortion will not take place.

It should be well understood that instead of using batteries for the supply of plate and grid circuits, other sources of direct or rectified alternating current may be used, and that instead of using tubes with directly heated filament, indirectly heated tubes may be used. Nor is my invention limited to three-electrode tubes, or vacuum tubes, but can be applied to tubes having another number of electrodes, or to tubes having gas filling.

In Fig. 2, I have omitted the stage preceding the output stage, otherwise the arrangement of the circuits, except for the grid circuit of the tube T_2, is the same as in the showing of Fig. 1. The grid g_2 of the tube T_2 again derives its energization from the plate circuit of tube T_1; in this case, however, the end 9 of the transformer winding 10 is connected to a coupling condenser 15', which in turn is connected to two resistances 21 and 22 connected through battery C to the filament f_1. The branch through the condenser 15' and resistances 21 and 22 thereby forms a multiple circuit to the plate circuit of tube T_1. The grid g_2 is connected to the mid-point 20, between resistances 21 and 22, thereby obtaining a voltage corresponding to the voltage drop in resistance 22.

To obtain the proper amplitude and phase relation for the grid voltage of tube T_2, and thereby obtain a maximum combined output of the tubes T_1 and T_2, the conditions are again defined by the requirement that no signal current should flow through the branch 14—27. The equations defining such condition are somewhat different from those of the previous case, however, their presentation is believed to be unnecessary.

While I have given specific circuit arrangements to illustrate my invention when applied to the output circuit of a radio receiving set, it should be well understood that my invention is not limited to such arrangements or application, but may be used in various arrangements and various applications in which it is desired to obtain the combined output of two or more tubes, and therefore I desire the appended claims to be construed as broadly as permissible in view of the prior art.

What I therefore claim and desire to secure by Letters Patent is:

1. In an electric circuit arrangement, a discharge tube, comprising a plate and a grid, and plate and grid circuits therefor, and a primary winding of an output transformer said winding having a portion forming part of the plate circuit of said tube and having a portion connected to the grid of said tube, the impedance of the portion connected to the grid being substantially equal to the impedance of said tube divided by the amplification factor of said tube.

2. In an electric circuit arrangement, two discharge tubes, each having a plate and a grid, and plate and grid circuits therefor, an output transformer, having a primary winding provided with a tap, one plate circuit including one-half of the winding, the other plate circuit including the other half of the winding, a second tap in the winding in the plate circuit of one tube, the portion of the winding between the first tap and the second tap providing excitation for the grid of the other tube.

3. In an electric circuit arrangement, two discharge tubes each having a plate and a grid, and plate and grid circuits therefor, the plate circuits being connected to the primary winding of a transformer, a center tap on said winding, the plate circuit of one of the tubes including the winding between its center tap and one of its ends, the plate circuit of the second tube including the winding between its center tap and its other end, and an intermediate tap provided in the winding in the plate circuit of the first tube, said intermediate tap being connected to the grid of the second tube, whereby the impedance of the winding between said center tap and said intermediate tap is substantially equal to the impedance of the plate circuit of the second tube, divided by the amplification factor of said second tube.

4. In an electric circuit arrangement, two discharge tubes, each having a plate and a grid, and plate and grid circuits therefor, the plate circuits being connected to a winding of a common transformer, said winding being provided with a center tap, a source of direct current supply the positive end of which is connected to the center tap, the grid of one tube being excited from the plate circuit of the second tube, a bias voltage for said grid whereby when the peak value of the exciting voltage of the grid is substantially equal to the bias voltage, no alternating current flows between the center tap of the winding and the positive end of the direct current supply.

5. In an amplifying stage, resistance coupled to the preceding stage, two discharge tubes, each comprising a plate and a grid, and plate and grid circuits for each of the tubes, a common output transformer associated with said plate circuits to receive the combined output of the two tubes, the grid of one tube being excited from said output transformer.

6. In an electric circuit arrangement, a discharge tube, a grid and a plate therefor, a plate circuit for said tube and a grid circuit excited from the signal to be amplified, a branch circuit in multiple to the output impedance of said plate circuit, said branch circuit including a resistor, and a second discharge tube comprising a plate and a grid, and a plate circuit therefor, the plate circuits of the two tubes feeding into a common output transformer, the grid of the second tube being excited from the voltage drop in one portion of the resistor.

7. In an amplifying stage, resistance coupled to the preceding stage, two discharge tubes each comprising a plate and a grid circuit for each of the tubes, a common output transformer associated with said plate circuit to receive the combined output of the tubes, said transformer having at least two taps, the grid circuit of one of said tubes being connected across said taps.

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