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POSITIVE GRID PUSH-PULL CIRCUITS

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Fig. 1

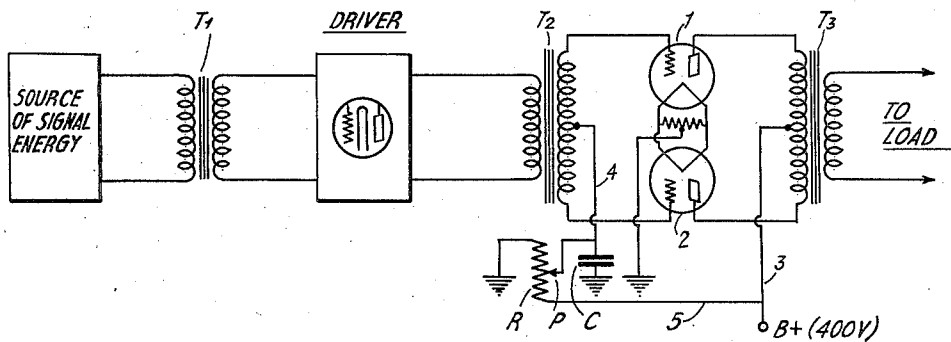


Fig. 4

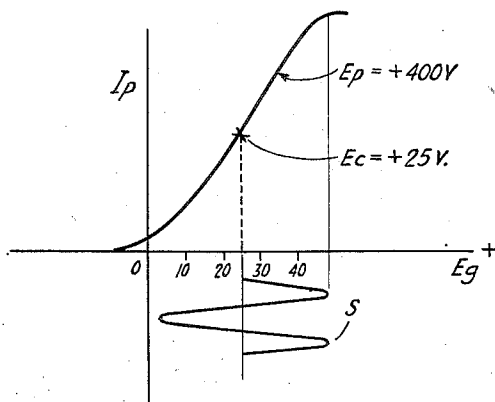


Fig. 2

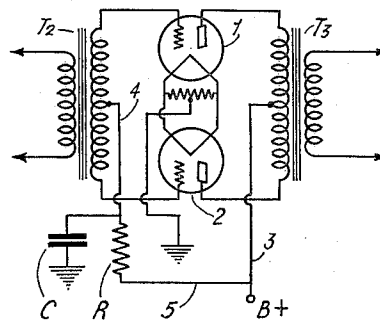
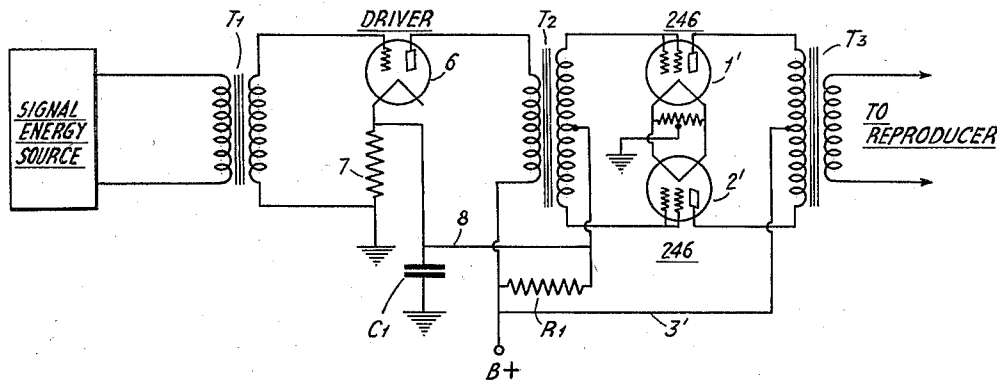


Fig. 3



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POSITIVE GRID PUSH-PULL CIRCUITS

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13 Claims. (Cl. 179—171)

My present invention relates to push pull amplifier circuits, and more particularly to push pull power output circuits provided with positively biased signal control grids.

5 When the demand for increased power output from a radio receiver reached a point where it was no longer economical to increase the output of the class A push-pull audio output systems, there was provided the class B push-pull audio output system. The latter for a given cost permitted an
10 output of from two to three times the power output of the class A output systems. After the class B push-pull audio amplifier had been adopted for battery operated receivers, it was found necessary
15 to provide another type of class B audio output system which could be particularly employed with alternating current operated receivers. This improved type of class B audio output system utilized no bias on the signal control grids of the push
20 pull tubes. Such zero bias class B audio tubes are described, and push pull output circuits embodying such tubes are shown by L. E. Barton in the Proceedings of the Institute of Radio Engineers of July, 1932 in an article entitled "Application of the class B audio amplifier to AC operated
25 receivers".

I have found that there are certain disadvantages inherent in push pull power output stages employing grids biased negatively, or zero. Accordingly, it may be stated that it is one of the
30 main objects of the present invention to provide a push pull output stage with signal control grids biased positively, instead of negatively or zero, as at present, the grids having a positive bias of
35 such magnitude that the push pull tubes are working all the time instead of only one at a time, as in push pull circuits of the class B type, the input impedance of the push pull circuit, as seen from the driver stage, being substantially constant.

40 Another important object of the present invention is to provide a power amplifier output stage including a pair of tubes connected in push pull, the signal grids of the push pull tubes being coupled to a driver stage and the anodes being
45 coupled to a load, the said signal grids being maintained at a fixed positive bias substantially half way up to maximum plate current on the characteristics of the push pull tubes whereby the power sensitivity of the circuit is doubled with respect
50 to push pull circuits used at present with the same load, the same power output being obtained from half the former grid swing.

Another object of the present invention is to provide a push pull power output stage including
55 means for maintaining the signal grids positively

biased to a magnitude such that the signal voltage swing is substantially within the positive region of the grid voltage-plate current characteristics of the push pull tubes, the grid resistance of the push pull stage, as seen from the driver, being substantially constant, and the push pull stage being driven without distortion and with good regulation of direct current drain.

Another object of the invention is to provide a push pull power output stage wherein the cathode of the preceding driver stage helps keep the bias constant on the signal grids of the push pull stage.

Still another object of the invention is to provide a push pull audio frequency amplifier stage
15 including a pair of tubes coupled to a preceding driver stage and a following load, and wherein the signal grids of the push pull tubes are maintained at a positive potential of such magnitude that the pair of push pull tubes will stand a power output
20 of the order of 24 watts on the plates between them with all the advantages of low distortion and good direct current drain regulation.

Still other objects of the invention are to improve generally the efficiency of push pull audio
25 amplifier output circuits, and to particularly provide circuits of this type which are not only economical, durable and reliable in operation, but economically manufactured and assembled for use in apparatus requiring amplification of audio
30 frequency energy.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims, the invention itself, however, as to both its organization and method
35 of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing,

Fig. 1 diagrammatically shows a circuit embodying the present invention,

Fig. 2 shows a modification of the biasing means shown in Fig. 1,

Fig. 3 shows a modification of the circuit of Fig. 1,

Fig. 4 graphically demonstrates the E_g-I_p characteristic of each push pull tube of Fig. 3.

Referring now to the accompanying drawing
50 wherein like reference characters designate like circuit elements in the different figures, there is shown in Fig. 1 in conventional manner a circuit arrangement which includes a source of signal energy which is coupled by means of an audio
55

frequency transformer T₁ to a conventional driver stage. This driver stage may include a tube arranged to operate as a class A amplifier in the well known manner.

5 The signal energy source may be the microphone of a public address system, the detector output of a radio receiver of any well known type, or the sound source of talking moving picture equipment. In other words, it is to be clearly understood that the present invention is adapted for general use with a source of signal energy of audible frequency. The output of the driver stage is coupled, as at T₂, by a step-up audio frequency transformer to a push pull amplifier stage which embodies the present invention.

10 The push pull stage includes a pair of tubes 1, 2. The anodes of both tubes are connected to opposite sides of the primary coil of the output transformer T₃, and the midpoint of the primary coil is connected by the lead 3 to the positive terminal of a source of anode potential B (not shown) having a magnitude of the order of 400 volts. The secondary coil of transformer T₃ may be connected to any desired load, such as a reproducer of the electromagnetic, electrodynamic or electrostatic type.

15 The midpoint of the secondary coil of transformer T₂ is connected by a lead 4 to a desired point on the bleeder resistor R, an adjustable tap connecting this bleeder to the lead 4. One side of the bleeder is grounded while the other side is connected by a lead 5 to the lead 3. All points on the bleeder R, of course, are more positive than ground. The cathodes of tubes 1 and 2 are grounded in the usual manner by connecting the electrical midpoint of their common resistor to ground. The lead 14 is by-passed to ground by a condenser C which is preferably a low voltage electrolytic condenser of very high capacity, this being particularly suitable for by-passing the positive grid return point. The tap P is adjusted to a point on the bleeder resistor R such that a positive direct current potential is maintained on each of the signal grids of tubes 1 and 2 of a magnitude of the order of 20 volts.

20 In Fig. 2 a modification of this grid biasing arrangement is shown, and it will be noted that the bleeder resistor R is arranged in series between the grids and the positive terminal of the plate potential source. This arrangement insures a constant current system. Otherwise, the arrangement in Fig. 2 is the same as in Fig. 1. The theoretical, as well as practical advantages, of the arrangement shown in Figs. 1 and 2 will now be explained.

25 Since the principles of the invention involved are the same in both Figs. 1 and 2, except for the modified grid biasing arrangement of Fig. 2, attention will be directed to Fig. 1, and to the fact that the essential feature of the present invention is to provide a power output stage, of the push pull type, with the signal grids biased positively instead of negatively, or zero, as at present, this resulting in the securing of the advantages of class A push pull operation with the additional advantages of substantially no distortion, substantially constant grid resistance, when seen from the driver stage, and substantially less plate potential for similar power outputs of class B push pull circuits known in the prior art. That these additional advantages can be secured has been demonstrated both from the analytical, as well as experimental view-point.

30 From the analytical view-point it can be shown

that considered from the grid side of the push pull circuit embodying the present invention, the grid resistance is constant, as seen from the driver stage, and equal to the positive grid bias divided by the plate current at peak swing voltage.

Now, suppose that the pair of tubes in Fig. 1 are given a bias of +20 volts, and the grid swing is made from zero to +40 volts, or 20 volts peak. It can be shown that the power output in the common anode circuits of the push pull stage embodying the present invention is not appreciably lessened with regard to the power output obtainable in push pull circuits known heretofore.

35 The reason is found in the fact that both tubes are now working all the time, instead of only one at a time as in prior types of push pull output stages. It should be noted that the power sensitivity is doubled, since the same output is obtained from half the former grid swing. As stated heretofore, on the grid side of the push pull stage embodying the present invention the grid resistance seen by the driver is now constant. This can be driven without distortion by a driver that can furnish an undistorted output which is equal to one half the product of the positive grid bias and the plate current at peak swing voltage.

Another way of looking at the construction is to consider that distortion on the grid side is caused not by the grid conductance but by variations in the same. It is shown in the analysis that for the range over which both grids draw current, the grid conductance is essentially constant, hence small distortion occurs. This is not true with zero or negative bias (Class B or Class A'); hence with positive bias the driver conductance does not have to be made very large to swamp out variations in the grid conductance; it can be made equal to the now constant grid conductance, hence better conductance of power and less driver power is required. At the same time it can be shown that the grids need not be driven as hard to get the same output from the tubes, which means a further saving in driver power over that required in Class B.

40 To summarize some of the advantages which have been found to be obtainable in connection with a push pull power output stage embodying the present invention, it may be pointed out that the power output obtainable is substantially the same as in push pull circuits of the class A and class B type; the power sensitivity is substantially doubled; the driver stage undistorted power output rating necessary may be as low as 0.4 watts. The distortion is negligible; a good regulation of direct current drain is secured with about 80-100 m. a. with no signal, and 125 m. a. with maximum signal; and the output impedance is constant over the signal cycle and is low with respect to the speaker impedance, where the load is a loud speaker.

45 The source of bias, when choosing the method of obtaining the positive bias for the grids of the circuits of Figs. 1 and 2 (as well as in connection with Fig. 3 to be later described) should have low alternating current impedance, because even harmonic components of grid current must flow in it. Direct current resistance should be low, but this is not so important. In fact, some direct current resistance might be an advantage, because it will act to reduce the bias as the signal increases, and thus keep down the corresponding increase in plate current drain. It should be noted that it is not necessary to carry

50 From the analytical view-point it can be shown

the present positive biasing arrangement to the extreme limit.

Any positive bias at all will give less distortion, and require less driver power reserve than the negative bias, or zero bias, systems. Hence, the practical mode of procedure is to bias the push pull tubes positive as much as they will stand, and then to swing the grids as hard as necessary to give the required output, regardless of the fact that either, or both, plate current cut-off and grid current cut-off points are overpassed.

It will now be seen that the essential feature of the present invention is to positively bias the signal grids of the push pull tubes to such a magnitude that substantially the entire signal voltage swing is confined within the positive region of the characteristic of each of the push pull tubes.

In Fig. 2, if the grid should happen to draw more current with increasing signal, the positive bias will decrease correspondingly owing to the greater IR drop in resistance R. Hence for strong signals the direct current plate current of the output tubes will not increase as much as it would if the bias were constant, and the current drain of the stage does not vary as greatly as it would with constant bias. In Fig. 1, the bias is provided by the drop in the ground side portion of R, and any change in the average grid current has correspondingly less effect on the voltage developed at the point P.

In Fig. 3 there is shown a modified form of the invention wherein the signal energy source, which may now be the detected output of a radio receiver, is coupled, as explained in Fig. 1, to the input electrodes of a driver tube 6. The anode of the tube 6 may be connected, through the primary coil of transformer T₂, to the positive terminal B of the plate potential source of the push pull tubes 1' and 2'. The push pull tubes in this modification are of the 246 type. This type of tube is not a part of the present invention, and has in fact been described by L. E. Barton in the Proceedings of the Institute of Radio Engineers for July, 1932.

Hence these tubes have been conventionally shown as including a pair of grids tied together, one of which is coarse meshed and the other fine meshed. These tubes have been disclosed for use in class B, zero bias, push pull amplifier circuits by L. E. Barton in the aforementioned article. The same tubes may be used for use in the present invention, and are therefore shown in the modification of Fig. 3.

In Fig. 4 there is shown the E_p - I_p characteristic of each of the push pull tubes of Fig. 3. It will be noted that each tube is operated with a plate potential E_p having a magnitude of the order of +400 volts, the midpoint of the primary of the transformer T₂ being connected by a lead 3' to the positive terminal of the plate potential source B. In this modification, however, the cathode of the driver tube 6 helps keep the positive bias on the grids of the tubes 1' and 2' constant. This is accomplished by connecting the ungrounded side of the cathode resistor 7 of the driver stage to the midpoint of the secondary of transformer T₂ through a lead 8. The lead 8 is grounded through a condenser C₁ of the same type as the condenser C in Figs. 1 and 2.

It is also to be noted that this arrangement would be easier to work for a push pull driver stage, in which no currents at fundamental frequency flow through the cathode resistor, but only at even harmonics. If desired, an added

source of biasing current from the positive terminal of the B supply may be provided by means of a resistor R₁ connected between lead 8 and the lead to the primary coil of transformer T₂.

The cathode impedance of the tube 6 acts as a voltage regulator for if the cathode voltage is raised less plate current flows in 6, thus opposing the change in cathode potential. Actually the condition is as if resistor 7 were shunted by G_m of the tube which might be in the order of 1000 ohms. The result is that the tube in this connection acts somewhat like a rather inefficient glow tube device. In this circuit the chief function of the resistor R₁ is to supply current to make up for that drawn by the grids; thus, if plate current in tube 6 were 6 m. a. and the grids draw 4 m. a., there would be only 2 m. a. to flow through 7 to provide bias which might not be enough in a given case. However, it is conceivable that the circuit would be operative even if R₁ were open.

Considering Fig. 4 again it will be noted that it has been designated on the characteristic that each tube is to be operated with a positive bias E_c of the order of magnitude of +25 volts. The signal voltage swing in such a case is shown by the curve S, and it will be noted that it is substantially confined within the positive region of each characteristic. To run a pair of 246 tubes in this manner would require a positive bias on the grids of 25-30 volts and the primary current would be 60 milliamperes per tube or more (no signal) which at 400 volts direct current would be 24 watts plate dissipation. A pair of 246 tubes will stand 24 watts on the plate between them, and will deliver 12 watts good output by this system, with all the advantages of low distortion and good current drain regulation mentioned heretofore. Of course, if desired, 250 type tubes may be employed, these tubes rating at 25 watts, or 210 type tubes using carbon plates, which rate at 25 watts, may be employed.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. Electric wave repeating apparatus comprising divided input and divided output circuits with a pair of vacuum tubes connected in opposition therebetween, each of said tubes having a grid and a cathode, said grids being at a substantially high positive potential with respect to said cathodes in the absence of signal waves in said input circuit, a positive potential source connected between the anodes of the tubes and said cathodes, and means, in shunt with said source, and connected to the grid circuits of said tubes for providing said positive bias.

2. Electric wave repeating apparatus comprising divided input and divided output circuits with a pair of vacuum tubes connected in opposition therebetween, each of said tubes having a grid and a cathode, said grids being at a substantially high positive potential with respect to said cathodes in the absence of signal waves in said input circuit, a driver tube preceding said pair of tubes, and means common to the cathode circuit of said driver tube and the grid circuits of said pair of tubes for maintaining said positive bias constant.

3. An amplifier for alternating current waves

comprising a pair of tubes connected in push-pull relationship, a source of positive voltage for the anodes of said tubes connected between the cathodes of the tubes and the common anode circuit of the tubes, and a path, including impedance, connected between the grids of the tubes and the positive side of said source.

4. An amplifier for alternating current waves comprising a pair of tubes connected in push-pull relationship, a source of positive voltage for the anodes of said tubes connected between the cathodes of the tubes and the common anode circuit of the tubes, and a path, including a variable impedance, connected between the grids of the tubes and the positive side of said source.

5. An amplifier for alternating current waves comprising a pair of tubes connected in push-pull relationship, a source of positive voltage for the anodes of said tubes connected between the cathodes of the tubes and the common anode circuit of the tubes, and a path, including a variable electronic impedance, connected between the grids of the tubes and the positive side of said source.

6. An amplifier for alternating current waves comprising a pair of tubes connected in push-pull relationship, a source of positive voltage for the anodes of said tubes connected between the cathodes of the tubes and the common anode circuit of the tubes, and a path, including impedance in the form of an adjustable resistor, connected between the grids of the tubes and the positive side of said source.

7. An amplifier for alternating current waves comprising a pair of tubes connected in push-pull relationship, said tubes having a substantially linear grid voltage-plate current characteristic over a substantial range of positive grid voltages, a source of substantially high positive voltage for the anodes of said tubes connected between the cathodes of the tubes and the common anode circuit of the tubes, and a path, including impedance, connected between the grids of the tubes and the positive side of said source, said impedance being of sufficient magnitude to maintain the grids positively biased to such point on the grid voltage-anode current characteristic of the tubes that waves impressed on the amplifier are reproduced in form in the amplifier anode circuit.

8. An audio signal amplifier comprising a pair of tubes connected in push-pull relation, a source of audio signal waves, a driver tube having its input electrodes coupled to the wave source, a source of direct current voltage, having a point of positive potential thereof connected to the anode of the driver tube and the common anode circuit of the pair of tubes, an impedance in the space current path of the driver tube, and a direct current connection between a point of positive potential on said impedance and the grids of said pair of tubes.

9. In an arrangement as defined in claim 8, said impedance comprising a resistor in the driver

tube cathode circuit, and said connection being between the grids of the push-pull tubes and the cathode side of the said resistor.

10. An audio signal wave amplifier including a pair of tubes in push-pull relation, said tubes having a substantially linear grid voltage-plate current characteristic for values of grid voltage between approximately zero and 50 volts positive, means for impressing signal waves on the common input circuit of the amplifier, means for biasing the grids of the tubes positive with respect to the cathodes thereof with a voltage of the order of 25 volts, and means for maintaining the anodes of the tubes at a voltage of the order of 400 volts whereby impressed signal waves are reproduced in form in the amplifier output.

11. A push-pull amplifier comprising a pair of electron discharge tubes, each including at least a cathode, grid and anode electrodes, input and output circuits connected thereto, said tubes having a substantially linear grid voltage-plate current characteristic over a substantial range of positive grid voltages, a source of high positive potential connected to the anodes of said tubes, and means for maintaining, in the absence of signal voltages on the input circuit, the grid electrodes of said tubes at a relatively high positive potential but materially lower than that applied to the anode electrodes.

12. A power output amplifier comprising a pair of push-pull connected electron discharge tubes, each including at least a cathode, grid and anode electrodes, input and output circuits connected thereto, said tubes having a substantially linear grid voltage-plate current characteristic for values of grid voltage between approximately zero and 50 volts positive, a source of high positive potential connected to the anodes of said tubes, and means for maintaining, in the absence of signal voltages on the input circuit, the grid electrodes of said tubes at a positive potential of the order of magnitude of 20 volts.

13. A power output amplifier comprising a pair of push-pull connected electron discharge tubes, each including at least a cathode, grid and anode electrodes, input and output circuits connected thereto, said tubes having a substantially linear grid voltage-plate current characteristic over a substantial range of positive grid voltages, a source of high positive potential connected to the anodes of said tubes, and means for maintaining the grid electrodes of said tubes at a positive potential materially lower than that applied to the anode electrodes, said potential means applied to the grids being sufficient to bias the grids, in the absence of signal waves on the amplifier input, to a point substantially midway on the tube characteristic whereby signal waves to be amplified are reproduced in the output circuit of the amplifier substantially without distortion.

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