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PUSH-PULL AUDIO AMPLIFIER CIRCUIT

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The present invention relates to thermionic amplifiers and more specifically to push-pull connected thermionic amplifiers in which the valves operate alternately, each valve operating to amplify alternate half cycles of the incoming wave. A form of such push-pull connected amplifier which has recently come into common use is that now generally termed the "quiescent push-pull" amplifier. In this amplifier the thermionic valves which are connected in push-pull, receive large negative control grid bias so as to cause each valve to operate on alternate half cycles of the incoming signal wave to be amplified. This form of push-pull connected amplifier presents the advantages that the load upon the source of anode potential for the valves is smaller than is the case when the valves are biased at about the middle of the straight portions of their characteristics while there is the further advantage that relatively large values of grid swing can be accommodated thus enabling a large A. C. output for a small D. C. input to be obtained. These advantages of the quiescent push-pull connected amplifier have recently caused the said amplifier to come into fairly common use as audio frequency amplifiers in so-called "battery driven" radio receivers because, of course, in such receivers the reduction of the load upon the anode battery or batteries is of paramount importance, and economy in anode current is of great practical advantage.

Apart, however, from the question of battery driven receivers the quiescent push-pull amplifier offers obvious advantages in connection with receivers in which the anode current is derived not from a battery but from a so-called high tension eliminator, but when the quiescent push-pull amplifier is operated with anode potentials derived from a so-called high tension eliminator the difficulty is met with that unless the said eliminator be unnecessarily large, distortion results.

The cause of this distortion is that small high tension eliminators have as a rule very bad load characteristics or regulation, with the result that any increase in current taken therefrom tends to cause a drop in the output voltage therefrom. With a quiescent push-pull amplifier the anode current fed to the push-pull connected valves of course varies with the incoming signal and therefore with a small high tension eliminator having bad regulation, the voltage applied from that eliminator to the various points in the radio receiver energized therefrom tends to vary with incoming signals and this, of course, causes distortion. It would be possible to meet this difficulty by providing an eliminator having a large output capacity so that small increases in current would not materially affect the voltage but such a method of avoiding the difficulty obviously nul-

lifies one of the main practical advantages of the quiescent push-pull arrangement.

The object of this invention is to provide a push-pull amplifier arrangement wherein the push-pull connected valves operate alternately and which shall be such that the total current taken from the source of anode potential shall be substantially constant substantially independently of input signal strength. By achieving this object it is rendered possible to obtain large A. C. power outputs by means of small or medium high tension eliminators without distortion due to varying loads upon the said eliminators.

According to this invention there is provided in combination with a push-pull connected amplifier which is so arranged that each of the push-pull connected valves operates alternately, each valve dealing with alternate half cycles of the incoming signal, an additional thermionic load device which is included in a circuit connected across the source of anode potential for said push-pull connected valves and whose internal impedance is controlled in dependence upon input signals to said push-pull connected valves in such manner that the total load provided by the said push-pull connected valves and the circuit including the additional thermionic load device remains substantially constant.

The invention is illustrated in the accompanying diagrammatic drawing.

Referring to Fig. 1 which shows one way of carrying out this invention, an audio frequency push-pull connected thermionic amplifier arrangement comprises a pair of power valves 1, 2, in push-pull, the grids 3, 4, of the valves being connected together through the secondary 5 of an input transformer 6, the center point 7 of said secondary being connected through a suitable resistance 8 to the negative terminal GB— of a source of bias potential (not shown) which is of such value that each of the valves 1, 2, operates to amplify alternate half cycles of the incoming signal. One end of the primary 9 of the transformer is connected at 10 to the anode (not shown) of a stage (also not shown) preceding the push-pull connected stage 1, 2, and the other end of said primary is connected through a resistance 11 to the positive terminal HT+ of the source of anode potential (not shown). The junction point 12 of the resistance 11 and the primary 9 is earthed through a suitable condenser 13 for example of two microfarads capacity. The transformer may conveniently have a step-up ratio of 1:6. The anodes 14, 15 of the push-pull connected valves 1, 2, are connected to opposite ends of an output transformer primary 16 whose center point 17 is connected to the terminal HT+ and a loudspeaker or other translating device (not shown) is energized from the secondary 18 of this output transformer. The filaments 19, 20, of the

valves 1, 2, are connected together as in the usual way and energized from a suitable D. C. source (not shown) of filament heating potential whose terminals are indicated at LT+ and LT- one terminal (usually the negative as shown) being connected to the negative terminal HT- of the source of anode potential.

The arrangement as so far described is the well known so-called "quiescent push-pull" connected amplifier arrangement and with the said arrangement the load upon the source of anode potential will vary with incoming signals. In applying the present invention to overcome this difficulty a resistance 21, for example of 50,000 ohms, is connected across the primary 9 of the input transformer 6 and an adjustable tapping point 22 upon this resistance is connected through a condenser 23 say of .005 microfarad to the grid 24 of a further triode 25 whose anode 26 is connected to the terminal HT+ and whose filament 27 is heated from LT+ and LT-. The grid 24 is connected to the cathode 27 through a grid leak 28 of say half a megohm resistance, so that the said triode 25 operates as a cumulative grid rectifier. It will thus be seen that the low frequency input to the grid of the triode 25 which constitutes the additional thermionic load upon the anode potential source at HT+ and HT- is obtained from the primary 9 of the input transformer 6 and that any incoming signal which causes the total anode feed to the two valves 1 and 2 to increase will, (since a signal component is applied also to the grid 24 to depress it negatively) also reduce the anode current taken by the valve 25. By careful adjustment of the point 22 the total load may be caused to be maintained substantially constant.

In the arrangement just described it was assumed that the source of anode potential connected at HT+ and HT- is a so-called mains eliminator and that filament heating and grid bias is obtained by means of batteries (not shown but connected at the appropriate terminals). The invention is, however, also applicable to cases in which anode potentials are obtained from an eliminator, grid bias potentials are obtained in the so-called automatic manner and filament heating is accomplished by A. C. current derived e. g. from a mains supply. When the invention is applied to such an arrangement the modifications to the circuit of Fig. 1 which are required are relatively slight and are as follows, the modified circuit being shown in Fig. 2.

Firstly, the end of the grid leak 28 which was in the arrangement of Fig. 1 connected to the cathode 27, is now connected to a tapping 29 (preferably adjustable) on a resistance 30 shunted across the said cathode 27. The tapping 29 is adjusted to be the effective center of the cathode 27. Similarly the circuit from the center tapping 7 of the secondary 5 of the input transformer 6 now consists of the resistance 8, shown in Fig. 1 in series with a further resistance 31 whose other end is connected to an adjustable center tapping 32 on another resistance 33 shunted across the filament supply terminals which are now marked A. C. since A. C. cathode heating is resorted to. The resistance 31 is shunted by a condenser 34 and the junction of condenser 34 with resistance 8 is connected to the negative terminal HT- of the source of anode potential. With this modified arrangement grid bias is obtained automatically and owing to the manner in which the various grid circuits are completed, (effectively to the electrical centers of the valve

cathodes) the A. C. energization of the valve cathodes will not cause disturbance.

In carrying the invention into practice care should be taken in the selection of the additional valve which provides the additional load. If this valve be unnecessarily large the total anode current taken will be unnecessarily high, whereas if it be too small, large input signal voltages will cause the grid of the additional valve to swing round the bottom bend of the valve characteristic curve and it is of course necessary, if distortion is to be completely avoided, that the said additional valve should operate on the straight portion of its characteristic. In a practical example which has given satisfactory results the push-pull connected valves were of the type known commercially as P.610. The P.610 valve is a low frequency power amplifier triode having a 6 volt filament and taking a filament current of .1 of an ampere, the valve being designed to work with a maximum anode voltage of 150.

At zero grid volts and 100 anode volts, the amplification factor of this valve is 8, the impedance is 3500 ohms, and the normal slope of the characteristic 2.28 milliamperes per volt. With P.610 valves as the push-pull connected valves the additional valve was constituted by a valve commercially known under the trade designation L.610. The L.610 valve also has a 6 volt filament taking .1 of an ampere and also is designed for a maximum anode voltage of 150. At zero grid volts and at 100 anode volts, however, the amplification factor is 15, the impedance 7500 ohms and the normal slope 2.0 milliamperes per volt. With this specific arrangement it was found that the total anode feed did not vary by more than 0.1 of a milliampere (in a total of 10 milliamperes) when varying low frequency voltages between 0.25 and 3.5 were applied to the primary of the input transformer. These input voltages correspond to an output power at the secondary of the output transformer i. e. in the loudspeaker circuit, of 5 and 220 milliwatts respectively.

The first table below gives the results obtained with apparatus as above described, and "driven" by a high tension eliminator with bad regulation. The high tension voltage was 130, and the input at 500 cycles. In this table, column 1 (reading from the left) represented by E_p is the voltage at the primary of the input transformer; column 2 represented by E_s the voltage at the secondary of this transformer; column 3 represented by I_p the anode current in milliamperes taken by the push-pull connected valves (these valves were operated with -12 volts grid bias); column 4 represented by I_L the current in milliamperes taken by the additional or load valve; column 5 represented by I_T the total load in milliamperes; and column 6 represented by O the loudspeaker output in milliwatts.

E_p	E_s	I_p	I_L	I_T	O
-----	-----	2.8	7.0	9.8	-----
.5	3.0	2.9	6.9	9.8	5
1.0	6.0	3.1	6.6	9.7	30
2.0	12.0	3.9	5.8	9.7	70
3.0	18.0	4.7	5.0	9.7	160
3.5	21.0	5.1	4.7	9.8	220

For comparison purposes the same amplifier and mains eliminator was then tested but with apparatus provided by the present invention removed, i. e. the additional valve and its associ-

ated circuit was disconnected and the grid bias on the push-pull connected valves was reduced to -6 volts giving a feed of 12 milliamperes to the valves and this caused the high tension voltage from the eliminator to drop to 120 volts, the arrangement thus constituting a normal push-pull amplifier. The detailed results obtained are set forth in the following table in which columns 1, 2 and 3 correspond respectively to columns 1, 2 and 3 of the first table, (the push-pull valves having as stated -6 volts instead of -12 volts grid bias) and the fourth column corresponds to the sixth column of the first table.

E_p	E_s	I_p	O
-----	-----	12	-----
.5	3.0	12	12
1.0	6.0	12	34
1.5	9.0	12	70
1.8	10.8	11.9	98
2.0	12.0	11.6	120

From the above it will be seen that distortion occurred before 120 milliwatts output was reached.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. In combination a push-pull connected thermionic amplifier of the kind in which each of the push-pull connected valves operates alternately, each dealing with alternate half cycles of the incoming signal; a source of anode potential for the valves of said amplifier; an additional thermionic load device included in a circuit connected across said source of anode potential; and means for controlling the impedance of said thermionic load device in dependence upon the input signals to said push-pull connected amplifier in such manner that the total load provided by said push-pull amplifier and said circuit including the additional thermionic load device remains substantially constant.

2. In combination a pair of thermionic valves connected in push-pull; means for biasing the control grids of said valves in such manner that each operates alternately whereby each valve amplifies alternate half waves of the incoming signal; a source of anode potential for said push-pull connected valves; an additional thermionic valve having its anode-cathode space connected across said source of anode potential; and means

for applying potentials derived from the input potentials to said push-pull connected valves to the grid of said additional valve, the whole arrangement being such that the total load provided by the push-pull connected valves and the additional valve remains substantially constant.

3. An arrangement as claimed in claim 2 and comprising means for adjusting the ratio between the voltage applied to the grid of the additional valve and the voltage applied between the grids of the push-pull connected valves.

4. In combination a pair of thermionic valves connected in pushpull and biased to operate as a so-called quiescent pushpull amplifier; a source of anode potential for said pushpull connected valves; a triode having its anode connected to the positive terminal of said source and its cathode to the negative terminal of said source; a grid condenser in series with the grid of said triode and a grid leak for leaking away charges accumulated upon the grid of said triode, said condenser and grid leak being of such magnitude as to cause said triode to operate as a cumulative grid rectifier; a resistance connected across a circuit for applying input potentials to be amplified to said pushpull connected amplifier; and a connection between a tapping point upon said resistance and the grid of said triode, said connection including said grid condenser.

5. Apparatus as claimed in claim 4 characterized by that the anode potential source is a so-called "mains eliminator".

6. Apparatus as claimed in claim 4 characterized by that the filaments of all the valves are heated by alternating current and the requisite values of grid bias obtained by the so-called automatic bias method known per se.

7. In a push-pull connected thermionic amplifier of the type wherein the push-pull connected tubes operate alternately each thereof dealing with alternate half cycles of the incoming signal; a source of anode potential for the tubes of the amplifier; an auxiliary load device and a circuit including said auxiliary load device connected across said source of anode potential means for controlling the impedance of said auxiliary load device in dependence upon the input signals to said push-pull connected amplifier in such a manner that the total load provided by the push-pull amplifier and said circuit including the auxiliary load remains substantially constant.

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