July 29, 1947. H. L. MANSFORD 2,424,893

AMPLIFIER CIRCUITS

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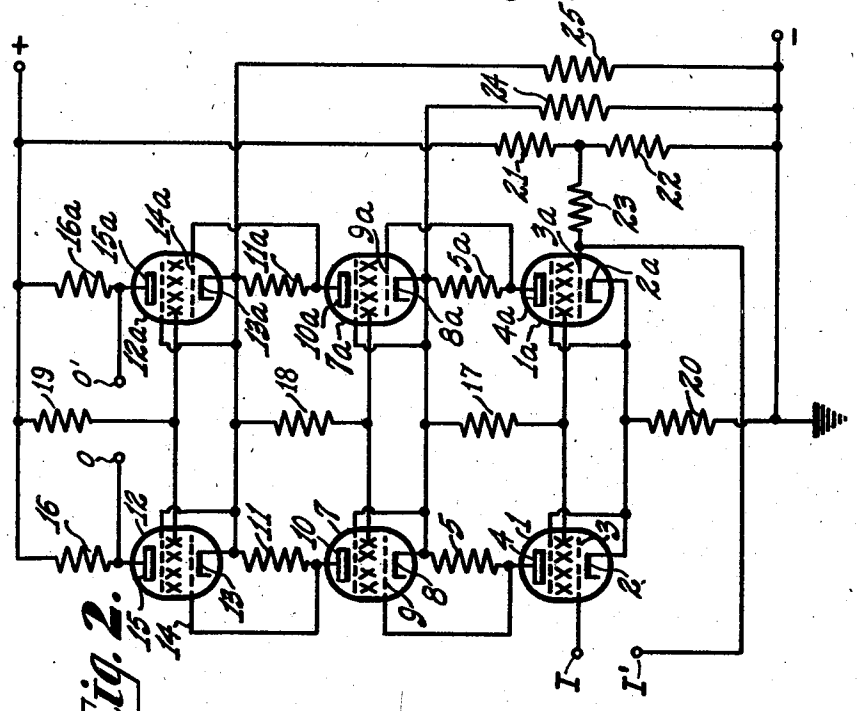


Fig. 2.

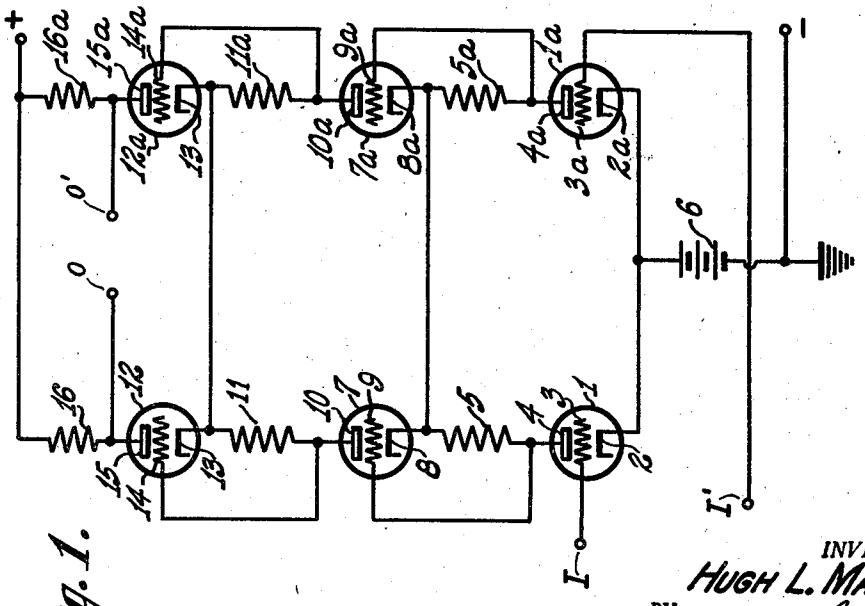


Fig. 1.

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AMPLIFIER CIRCUITS

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The present invention relates to amplifiers and more particularly to amplifiers operating down to low frequencies including direct current (D. C.).

In known amplifiers the tubes of the amplifier are usually coupled in cascade so that the anode circuit of each tube is in parallel with the source of anode voltage. When low frequencies, including D. C., are to be amplified, the couplings between successive tubes are usually such as will pass D. C. and generally include means for providing grid bias so as to avoid impressing the positive voltage of the anode of one tube upon the grid of the next tube.

Known arrangements of this kind suffer from the disadvantage that instability can arise as a result of back-coupling via the impedance of the source of anode voltage.

It has also been proposed to connect the individual tubes of a multi-tube amplifier with their anode-cathode paths in series across the source of anode voltage. This reduces the instability due to coupling via the impedance of the source of anode voltage but has the great disadvantage that because substantially the same current must flow through all the series-connected tubes, the change of current caused by the signal applied to the control electrode of the first tube of the series is the same as the change of current in the rest of the tubes. The arrangement is thus equivalent to a single tube amplifier with an increased anode impedance and with the output taken from only part of this anode impedance and therefore gives substantially no more amplification than can be obtained from a single tube amplifier.

The object of the present invention is to provide an amplifier in which the disadvantages above referred to are substantially avoided.

According to the present invention there is provided an amplifier comprising a source of anode voltage, a plurality of pairs of thermionic tubes, the tubes of each of said pairs having their cathodes connected to a common point and their anodes connected to a common point, means associated with each of said pairs for varying the voltage of the control electrodes of each tube of each pair differentially so as to cause equal and opposite changes in the anode currents of both tubes of each pair, whereby in operation the total anode current of each of said pairs remains substantially unchanged, and connections between the common points to which the cathodes and anodes of tubes of different pairs are connected such that the anode circuits of said pairs are effectively connected in series across said source.

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Preferably, said means for varying the voltages of the control electrodes of each of said pairs other than the lowermost pair comprises impedances included between the anodes of the tubes of the preceding pair and the common point to which said anodes are connected and connections between said anodes and said control electrodes respectively, and if desired a resistance may be connected in shunt with at least one of said preceding pairs so that the total anode current of at least one pair is greater than that of a preceding pair.

In order that the said invention may be clearly understood and readily carried into effect it will now be more fully described with reference to the accompanying drawings, in which:

Fig. 1 illustrates a simplified circuit according to the invention, and

Fig. 2 is a circuit diagram illustrating a practical embodiment of the invention.

Referring now to Fig. 1, reference numerals 1, 1*a* indicate triode tubes of the lowermost pair having cathodes, control grids and anodes respectively numbered 2, 2*a*, 3, 3*a*, 4, 4*a*. Cathodes 2, 2*a* are directly connected to a common point, namely, to the positive pole of a source of grid bias 6, the negative pole of which is connected to the negative pole of the source of anode voltage (not shown). The anodes 4, 4*a* are also connected to a common point via impedances 5, 5*a* respectively.

Signals to be amplified are applied to grids 3, 3*a* in push-pull by way of input terminals I and I'. The changes of the anode currents of tubes 1, 1*a* will herefore be equal and opposite and the total anode current passed by these tubes in operation will be constant. A further pair of tubes, indicated in Fig. 1 by numerals 7, 7*a*, have cathodes 8, 8*a*, control grids 9, 9*a* anodes 10, 10*a*, respectively, their cathodes 8, 8*a* being directly connected to the common point to which anodes 4, 4*a* of the preceding pair of valves are connected and their anodes 10, 10*a* being connected to a further common point via impedances 11, 11*a*. Control grids 9, 9*a* are directly connected to anodes 4, 4*a* respectively and due to the voltage drop across impedances 5, 5*a*, tubes 7, 7*a* are therefore driven in push-pull when tubes 1, 1*a* are so driven. As in the case of tubes 1, 1*a*, the total current flowing into the common point to which anodes 10, 10*a* are connected is constant due to the fact that the current changes in the anode circuits of tubes 7, 7*a* are equal and opposite and the presence of tubes 7, 7*a* in series with the anode cur-

rent-supply to tubes 1, 1a has no deleterious effect.

The constant total anode current required by tubes 7, 7a and tubes 1, 1a can again be provided through a further pair of tubes 12, 12a driven in push-pull in a similar manner. Thus, cathodes 13, 13a, control grids 14, 14a, anodes 15, 15a and output impedances 16, 16a of tubes 12, 12a respectively are connected similarly to the corresponding elements of the preceding tubes 7, 7a, but the common connection of the upper ends of impedances 16, 16a is taken to the positive pole of the source of anode voltage so that the same constant current flows through the anode circuits of each pair of tubes 12, 12a, 7, 7a and 1, 1a in series. It will be appreciated that further pairs of tubes driven in push-pull can if desired be connected in series with the three pairs shown in Fig. 1.

In the circuits shown in Fig. 1, each of the tubes operates as an amplifier for push-pull signals, and, due to the absence of coupling capacities, the amplification is maintained down to the lowest frequencies including, D. C. Further, under conditions of proper balance there will be no variations in the current supplied by the source of anode current due to signals and as there is no feedback path whereby voltages developed across the impedance of the source of anode voltage by small out-of-balance signal currents which may arise in practice can be fed back to the early tubes of the amplifier, there is no likelihood of instability from this cause as is the case with the normal cascade amplifier operating down to the lowermost frequencies. A further feature of the circuit arrangement illustrated in Fig. 1 is that the amplifier is relatively insensitive to signals which are applied to the tubes of each pair in the same sense. In so far as signals of this kind are concerned, each pair of tubes may be regarded as being connected in parallel and behaving in a similar manner to previously proposed series connected amplifier arrangements hereinbefore referred to which are equivalent to single tube amplifiers with tapped down anode impedances. This feature is advantageous in that out-of-balance currents tend to be suppressed and slight ripple on the source of anode voltage does not give rise to any troublesome effects.

It will be appreciated that, provided each pair of tubes 1, 1a, 7, 7a, 12, 12a, etc., are driven in push-pull, the relative phase in which, for example, tubes 1 and 7, are driven is immaterial. Thus, control grid 9 can, if desired, be connected to anode 4a and control grid 9a connected to anode 4 instead of as shown in the figure. Further, if it is not desired to amplify the lowest frequencies, direct connections between the control grids and the anodes of the tubes of the preceding stage need not be used and may be replaced, for example, by resistance couplings or transformer couplings.

As the later stages of the amplifier have to handle larger signal current variations than the preceding stages of the amplifier it is inconvenient to have all the pairs of tubes of the amplifier passing the same total anode current. Reference will now be made to Fig. 2 which illustrates a circuit arrangement in which this limitation is avoided and some other modifications are introduced for convenience. In Fig. 2 elements corresponding to elements of Fig. 1 are given the same reference numerals and it will be seen that the arrangements of Figs. 1 and 2

are similar in principle but differ in detail in one or two respects. Thus, the tubes in Fig. 2 are shown as pentode valves having their suppressor grids connected to their cathodes and having the screening grids of each pair connected together and via a feed resistance to a source of suitable polarising voltage. As shown, the screening grids of tubes 1, 1a are fed via resistance 17 connected to cathodes 8, 8a, the screening grids of tubes 7, 7a are fed via resistance 18 connected to cathodes 13, 13a and the screening grids of tubes 12, 12a are fed via resistance 19 connected to the positive pole of the source of anode voltage. Battery 6 of Fig. 1 has been replaced by the resistance 20 common to the cathode circuits of tubes 1, 1a, and a potentiometer comprising series connected resistances 21 and 22 across the source of anode voltage is provided for adjusting the bias on grids 3, 3a, grid 3a being connected through leak resistance 23 to the junction of resistances 21 and 22, the input circuit, not shown, providing a circuit feeding the bias to control grid 3.

The use of tubes of different current carrying capacities for the different stages of the amplier is made possible by means of shunting resistances 24 and 25. Resistance 25 is connected between cathode 13, 13a and the negative pole of the source of anode voltage and has a value such that it passes the difference between the total anode and screen current passed by valves 12, 12a and the total anode and screen current passed by tubes 7, 7a. Similarly, resistance 24 connected between cathodes 8, 8a and the negative pole of the source of anode voltage passes the difference between the total anode and screen current drawn by tubes 7, 7a and the total anode and screen current drawn by tubes 1, 1a. It will be appreciated that although these shunting resistances are illustrated as resistances they can if desired take the form of further apparatus including tubes such as, for example, further amplifiers according to the present invention, providing that these latter are arranged to operate with a constant total anode current of appropriate value.

It may sometimes happen that the negative bias applied, for example, to control grid 9 by the voltage drop across resistance 5 is unsuitable and this may be adjusted by the introduction of a suitably chosen resistance between control grid 9 and anode 4 and an additional resistance of suitable value between control grid 9 and a point of constant positive voltage such as cathodes 13, 13a or the positive pole of the source of anode voltage. Alternatively, or in addition, resistances may be introduced between the common point of, for example, resistances 5, 5a and cathodes 8, 8a.

Provided that resistance 20 is suitably chosen, one of the grids 3, 3a, may be earthed and the signal applied unbalanced to the other control grid, the signal voltage developed across resistance 20 serving to vary the cathode potential of the other tube and thereby driving it in antiphase. In some cases, the resistance 20 may take the form of the anode cathode path of a high impedance tube such as a pentode and the total current taken by tubes 1, 1a can then be adjusted by a change of the bias on the control grid and the screening grid of this high impedance tube and, if desired, the output of the amplifier can be controlled or reduced to zero by application of a suitable negative bias to this tube. By adding further tubes 3' and 3a' arranged similarly to tubes 3, 3a, and a further tube serving as a common resistance, said tubes 3' and 3a' sharing an-

ode resistances 5 and 5*a* with tubes 3 and 3*a* respectively, a convenient switching circuit is provided which enables the signals applied to tubes 3, 3*a* or 3', 3*a*' to be alternately fed to the output of the amplifier as the tubes in the common cathode circuits are alternately rendered conducting and non-conducting by switching signals.

Although the invention has been described with particular reference to amplification operating down to very low frequencies including D. C. it will be understood that it may be used with advantage even when it is not desired to amplify down to such low frequencies.

What I claim is:

1. An amplifier comprising a source of anode voltage, a plurality of pairs of thermionic tubes, the tubes of each of said pairs having their cathodes connected to a common point and their anodes connected to a common point, means associated with each of said pairs for varying the voltage of the control electrodes of each tube of each pair differentially so as to cause equal and opposite changes in the anode currents of both tubes of each pair whereby in operation the total anode current of each of said pairs remains substantially unchanged, connections between the common points to which the cathodes and anodes of tubes of different pairs are connected such that the anode circuits of said pairs are effectively connected in series across said source, a pair of input terminals connected to the control electrodes of the first pair of tubes, and a pair of output terminals connected to the anodes of the last pair of tubes.

2. An amplifier according to claim 1 in which said means for varying the voltages of the control electrodes of the tubes of each of said pairs other than the first pair comprises impedances included between the anodes of the tubes of the preceding pair and the common point to which said anodes are connected and connection between said anodes and said control electrodes respectively.

3. An amplifier according to claim 2 in which a resistance is connected in shunt with at least one of said preceding pairs so that the total anode current of at least one pair is greater than that of a preceding pair.

4. An amplifying system for direct or alternating potentials, comprising two sets of thermionic tubes each of which is provided at least with a cathode, a grid and an anode, the tubes of each set being arranged in series with the anode of one tube connected to the cathode of a succeeding tube, a connection between the cathodes of corresponding tubes of said sets, a source of anode potential supply having its positive terminal connected to the anode of the last tube of each set and its negative terminal to the cathode of the first tube of each set, means for supplying the potential to be amplified to the grid of the first tube of each set, and means for deriving amplified output potential from the anodes of the last tubes of each set.

5. A system for amplifying direct or alternating potentials, comprising two sets of thermionic tubes each having at least a cathode, a grid and an anode, the tubes of each set being arranged in series with the anode of one tube connected to the cathode of a succeeding tube through a resistance, a source of anode potential supply having its positive terminal connected through a resistance to the anode of the last tube of each set and its negative terminal connected through a resistance to the cathode of the first tube of each set, a connection between the cathodes of corresponding tubes of said sets, a connection from the grid of each tube except the first to the anode of the preceding tube, means for supplying the potential to be amplified to the grid of the first tube of each set, and means for deriving amplified output potential from the anodes of the last tubes of each set.

6. An amplifying system as defined in claim 5 wherein a resistance is connected between the common cathode connection of the first tubes of each set and the common cathode connection of another pair of corresponding tubes.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,329,073	Mitchell et al.	Sept. 7, 1943