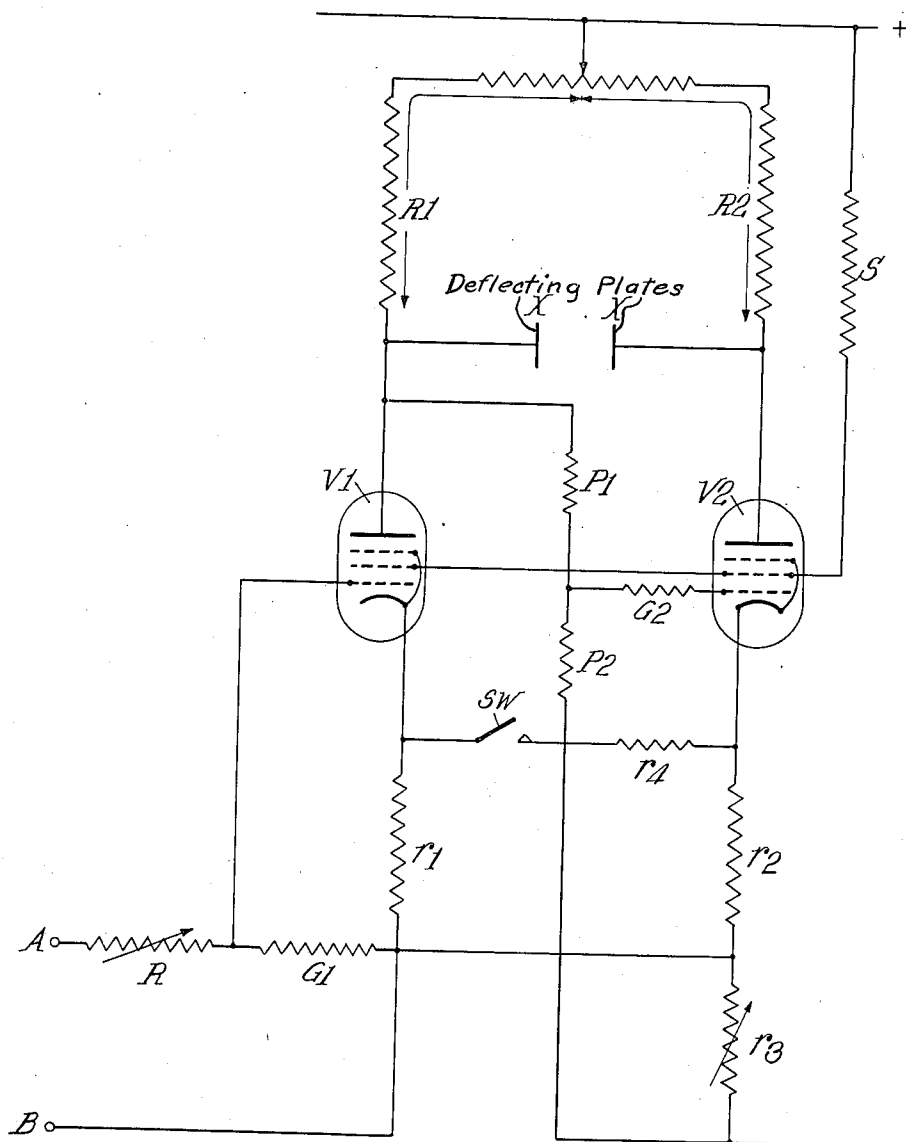


Nov. 25, 1941.

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THERMIONIC AMPLIFIER

2,264,197

Filed May 17, 1940



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2,264,197

THERMIONIC AMPLIFIER

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Application May 17, 1940, Serial No. 335,759
In Great Britain April 17, 1939

4 Claims. (Cl. 250—27)

The present invention relates to thermionic amplifiers and is more particularly concerned with amplifiers giving a balanced output with respect to the battery busbars from an unbalanced input.

The object of the invention is to provide a thermionic amplifier giving a balanced output which is capable of responding to an unbalanced input of a steady or an alternating nature.

Accordingly therefore, to the invention the amplifier comprises two thermionic valves and having a common cathode resistance, the anode of one valve being connected over a direct current path to the grid of the second valve over a resistance potentiometer of such a value that the gain of the first valve at the grid of the second is unity.

The invention has particular application in association with a cathode ray tube since it enables certain well known defects of the tube to be overcome and also it provides certain facilities which enable the tube to be employed with greater accuracy as a precision instrument.

As is well known there are two main types of cathode ray tube or oscillograph in general use, one which depends on the presence of a small amount of gas to secure a good focus of the beam, and one which is substantially fully evacuated and secures focusing action by the co-relation of potentials on certain electrodes. The former is generally known as a gas-filled or soft tube and the latter as a hard tube. Deflection of the cathode ray beam, generally along co-ordinate axes, may be accomplished with both types of tube by means of internal pairs of plates or by external pairs of coils of wire. Although the invention is mainly concerned with the former type of tube, it may be applied equally well to the latter with certain advantages to be described later.

With both types of tubes certain distortions occur when electrostatic deflection is used, such distortion being due to variations in the mean potential of the deflecting plates, with respect to the final anode of the system of focusing electrodes. In the case of the hard tube progressive defocusing of the spot towards its extreme excursions occurs, whilst alteration of the effective deflection sensitivity gives rise to the well known "trapezium distortion" effect. In the case of the gas-filled tube generally only the latter type of distortion occurs. It has been proposed to overcome these defects by applying equal and opposite deflection voltages to the pairs of deflecting plates by means of transformers or push pull thermionic valve stages but owing to the reactive couplings used with these methods deflection of the spot by direct current voltages is impossible. Likewise means for adjusting the initial position of the spot are generally only operative on alternating input.

In the application of the invention to a cathode

ray tube or oscillograph one pair of the deflecting plates is directly connected one to the anode of one valve and the other to the anode of the second valve.

5 The invention will be better understood from the following description taken in conjunction with the accompanying drawing which shows the circuit of the amplifier arranged to provide equal and opposite potentials to a pair of deflecting plates of a cathode ray tube.

10 In the drawing each of the pair of deflecting plates X—X (for, say, the horizontal axis) is directly connected to the anodes of a pair of similar thermionic valves V1 and V2 which are preferably of the pentode type. The anode impedances of the pair of valves consist of resistances R1 and R2 which are nominally equal and of value determined in known manner from the characteristics of the valves when used for amplification purposes. The anode of the valve V1 is connected to one end of a high resistance potentiometer P1—P2, the other end being connected to the negative busbar, whilst the tap is connected to the grid of the valve V2 over the resistance G2 the purpose of which will be described later. The potentiometer P1—P2 is of such a resistance that the ratio of the change of voltage applied to the grid of V2 to the change of anode voltage of V1 due to any input voltage is nominally equal to the inverse of the gain of the valve V1, i. e. the gain of the valve V1 at the grid of the valve V2 is unity, so that for a given input to the grid of V1 equal and opposite changes of voltage occur on the anodes and therefore on the deflecting plates. The cathodes of the valves V1 and V2 are connected to two equal resistances r1 and r2, whose remaining ends are joined together and to a further variable resistance r3, which terminates on the negative busbar. The cathode resistances r1 and r2 are of value derived in known manner for production of grid bias so that the valves may amplify with a minimum of distortion. The voltage to be examined, by deflection of the cathode ray spot, is applied over a suitable potentiometer R, G1 to the grid of valve V1 and the junction of resistances r1, r2 and r3.

Since the gains of the valves V1 and V2 are made equal and produce opposite changes of anode currents the voltage on r3 will be constant and is therefore used, by adjustment of the value of r3, to offset the positive static bias on the grid of V2 derived from the anode of V1 over the coupling potentiometer. In order to produce no resultant voltage between the deflection plates under static conditions r3 is adjusted so that the position of the spot does not alter when the cathodes of the valves V1 and V2 are joined. Since the anode and cathode resistances are nominally equal then it is known that the anode currents are also nominally equal. In cases where the anode currents of the two valves differ widely

when tested under similar conditions it is preferable to have the valve with the higher anode current as V2, so that the above adjustment puts a larger bias than normal on V2. If such a valve were used as V1 then V2 would be under-biased and would produce grid current at a lower input voltage than is desirable.

It will be seen that the above circuit is both statically and dynamically balanced and has no appreciable reactive couplings so that it can be used on direct or alternating input. The types of valve used are not important but it is preferable to use pentode valves, when it is possible to use a reduced screen voltage by connecting the screens together and to a suitable resistance S terminating on the positive busbar. This is possible without unwanted coupling effects in view of the equalisation of anode currents (and hence to a first approximation of screen currents) and of the equal and opposite gains of each valve.

A further advantage of employing pentode valves is that alteration of the initial spot position without alteration of the mean potential between the deflection plates can be secured by converting a portion of the anode resistances R1 and R2 into a potentiometer with the tapping point taken to the positive busbar as shown in the drawing. With the arms of the potentiometer in the centre position conditions are as described formerly but as the arm is moved towards the anode of V1 for instance the latter is raised and the anode of V2 is lowered in potential by equal amounts with respect to the positive busbar; the spot being thereby moved towards the plate connected to the anode of V1. Since the gain of a pentode valve is very nearly proportional to the anode impedance the gain of V1 is thereby reduced whilst that of V2 is increased but the overall gain of the system will fall since V2 is fed from V1. However, the change in the overall gain is not found to be material for the usual degree of alteration of spot position normally required, such as may be obtained by making the total potentiometer resistance equal to one third of the total anode resistances (R1 plus R2).

As is normal the approximate division of the busbar voltage between valve and anode resistance with no input, will be equal, so that in effect the maximum deflecting voltage available is some 80% of the busbar voltage. The latter is therefore determined by the full screen deflection voltage of the tube. The proportion of R1 plus R2 to be used as a shift control therefore is equal to desired range of control for instance one-third. In applying this valve to the circuit account must be taken of the fact that the maximum anode resistance will occur when the control is at either end and this latter value will be determined by the anode characteristics of the valve.

Taking this figure, the change of gain of the whole stage as the shift control is moved from the centre to either end, will be one-sixth at the most, since the gain of V2 tends to be constant whilst that of V1 alters by the change of anode impedance. It is only rarely that shifts of this order have to be used, and then the gain can be restored by the input control.

If pentode valves are used, as is preferred, owing to the constant current characteristics of both screen and anode with changes in anode voltage, the above described method of altering the position of the spot produces very little change in the anode and screen currents. Hence the static grid bias conditions will not be altered,

and the control will be equally effective on both direct and alternating inputs. In addition the mean potential of the plates remains unaltered with alteration of the shift control so that neither defocusing or trapezium distortion occurs.

If triode valves are used these advantages cannot fully be obtained since for maximum gain (or maximum output voltage swing) the anode resistance must be much larger than the internal impedance of the valve and hence the static anode current will change almost in inverse proportion to the change in anode resistance. The feature of shift control can however be used with triode valves provided large changes in shift are not required.

The cathode self-biasing resistances r1 and r2 give a measure of negative feedback in the well-known manner but should the overall gain of the amplifier be just insufficient for certain uses, for instance when the input voltage is very small, the feedback action can be dispensed with to any desired degree by connecting the cathodes together via a resistance r4 by closing the switch SW. This will introduce no change in the static conditions since this is the method whereby the amplifier is set up, but will reduce the feedback on each valve. It is not found practicable to connect the cathodes by resistances less than some one third of either r1 or r2, since a form of instability can be set up in the amplifier due to the direct couplings between the grid of V2, the anode of V1, and the cathodes. A limited degree of gain control can be obtained by making r4 variable.

The cathodes may also be connected by a condenser of value chosen to give reduced feedback at high input frequencies so as to enable the upper working frequency limit to be extended. In addition small inductances may be included in the anode impedances to give the same effect in the well known manner.

It has been mentioned that the voltage to be examined by deflection of the cathode ray spot is applied over a suitable potentiometer to the grid of valve V1 and the junction of resistances r1 and r2. In practice, as is well known, the impedance of this input potentiometer is limited by the interference voltages induced in it by external electrical apparatus. With a given value of input impedance however it is possible to neutralise the effect of the pickup in the amplifier described by placing an additional impedance G2 in the grid lead of V2. For instance, if the input impedance G1 of V1 be made say 100,000 ohms and the portion P1 of the coupling potentiometer between V1 and V2 applied to the grid of V2 is also 100,000 ohms, then the pickup on the latter will be neutralised by the pickup on the former by being amplified by valve V1 and reduced to unity gain on the coupling potentiometer. Thus the interference deflection of the spot will be due only to the anode variations of V1. By introducing in the grid connection of V2 a further resistance G2 the consequent additional pickup on V2 can be made to be of substantially the same phase and magnitude as that on V1 so that the resulting interference deflection of the spot will be zero. It is therefore proposed to use such co-related grid impedances for V1 and V2 and to provide for the main gain control of the input voltage by a series variable resistance R, preferably of the inverse logarithmic type. It is to be noted however that if the pickup is too great the focussing action may be upset. Further the "earthy" con-

nection on the input is taken from the junction of $r1$ and $r2$ to prevent the voltage on $r3$ from appearing on R and $G1$ when a low resistance path exists on the input.

It will be appreciated that the mean voltage of the deflection plates is intermediate between that of the positive and negative busbars and that in the interests of obtaining uniformly good focus over the whole of the screen, the final anode or gun of the cathode ray tube must be brought to the same approximate potential. This may be readily achieved by connection of the anode to a potentiometer connected across the busbars. Incidentally this method of connection can be arranged so as to supply a part of the normal anode voltage requirements of the tube.

With a typical circuit using H. F. pentodes the maximum anode resistance was found to be 75,000 ohms, giving a shift potentiometer of 50,000 ohms for $\frac{1}{3}$ shift control. The cathode resistances $r1$ and $r2$ were 1,000 ohms and $r3$ was some 2,000 ohms. The stage gain was 50 giving an overall gain of 100 which was found to be adequate for deflections of one volt, whilst with $r4$ at 300 ohms and by closing switch SW the gain could be increased by approximately three times without instability. Valves with commercial limits of 30% can be accommodated by adjustment of $r3$, whilst pickup (mainly 50 cycles in this case) could be made imperceptible at any gain when $G1$ and $P2$ were 100,000 ohms and R and $P1$ were 5 megohms, by making $G2$ 200,000 ohms.

As mentioned previously the type of amplifier described may be used with magnetic deflection of the cathode ray beam by replacing the anode resistances or a part thereof by deflection coils. It will be seen that the static anode currents will now produce no permanent deflection of the beam, since the coils must be connected in magnetic opposition in order to produce a magnetic deflection field from the opposite changes of anode currents due to an input voltage. Likewise the "shift" control consisting of a potentiometer which is part of the anode impedances can also be used; whilst the method of setting up the amplifier remains unchanged.

Since the amplifiers may be constructed with commercial resistances and valves, two such amplifiers may be accommodated in a small space about the tube socket with the bulk of the couplings wired between the valve holder tags.

Although in the above description reference has only been made to one pair of deflection plates or coils the amplifier may be applied equally well to the remaining co-ordinate pair of plates or coils. In this case arrangements can be made, if so desired, to offset the normal differences in deflection sensitivities of the two axes of the tube by an appropriate difference in the gains of the amplifiers.

It will be appreciated by those skilled in the art that the amplifier described may be used for purposes other than in connection with cathode ray oscillographs, and more especially where a balanced output with respect to the battery busbars is required from an unbalanced input of steady or alternating nature. An example of such use is the amplifier required for feeding a push pull thermionic valve stage.

The use of the amplifier is not limited to the linear portion of the characteristic of the valve, provided the valves are substantially matched, so that changes of anode current are of similar

magnitude. The static neutralizing bias across $r3$ will still be substantially independent of the changes of anode current. A typical non-linear use of the amplifier is to be found in the operation of relays or impulsing circuits from rectilinear voltage inputs of variable amplitude. The advantage to be obtained by employing the amplifier in this manner is that the current load from the busbars is rendered sensibly constant so that a power supply having a large internal resistance can be used for instance a mains rectifier unit.

I claim:

1. A thermionic amplifier for controlling the potential to the deflecting plates of a cathode ray tube, comprising two thermionic tubes having a common cathode resistance, a direct current source of potential for energizing said tubes, a connection from the anode of each tube to one of said deflecting plates, the anode of one thermionic tube connected through a direct current connection to the grid of the second thermionic tube by means of a resistance potentiometer connected between said anode and the common cathode resistance with a point thereon connected to the grid of the second tube, the gain of the first thermionic tube at the grid of the second tube being unity, and a pair of anode resistances joined together to form a potentiometer with the adjustable point thereof connected to the positive terminal of said potential source.

2. A thermionic amplifier as claimed in claim 1 wherein the adjustment of the center point of the anode resistance potentiometer adjusts the initial spot position of the cathode ray beam.

3. A thermionic amplifier having a balanced output comprising two thermionic tubes for controlling the potential on the deflecting plates of a cathode ray tube, a direct current source of potential for energizing said tubes, said thermionic tubes being connected in such a manner that the grid potential of one is controlled by the anode potential of the other over a direct current path such that the gain of the first thermionic tube at the grid of the second tube is unity, a connection from the anode of each tube to one of the plates of the cathode ray tube, and means for adjusting the initial spot position of the cathode ray beam, without altering the potential difference between the plates or the static potential differences between the grids of the thermionic tubes, comprising a potentiometer having its ends connected to the anodes of the two thermionic tubes and its adjustable point connected to the positive terminal of said potential source.

4. A thermionic amplifier for controlling the potentials on the deflecting plates of a cathode ray tube, comprising two thermionic tubes having a common cathode resistance, a connection from the anode of each tube to one of said plates, a direct current source of potential for energizing said tubes, a direct current connection from the anode of one thermionic tube to the grid of the second tube such that the ratio of the change of voltage applied to the grid of said second tube, to the change of anode voltage of said one tube due to any input voltage, is nominally equal to the inverse of the gain of said one tube, and a pair of anode resistances joined together to form a potentiometer with its adjustable point connected to the positive terminal of said potential source.

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