Aug. 2, 1932. K. C. BLACK 1,869,536

CONTROL APPARATUS

Filed April 22, 1930

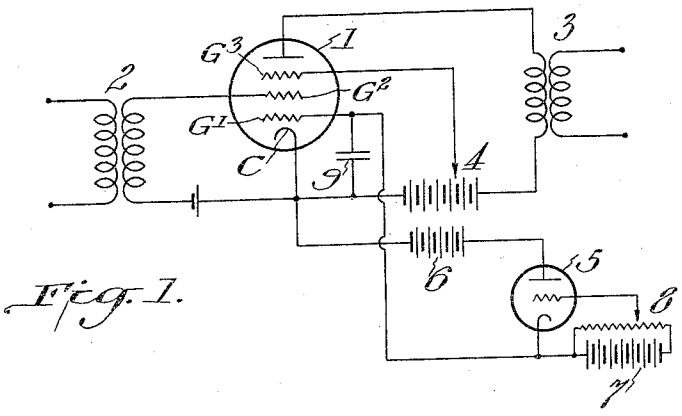


Fig. 1.

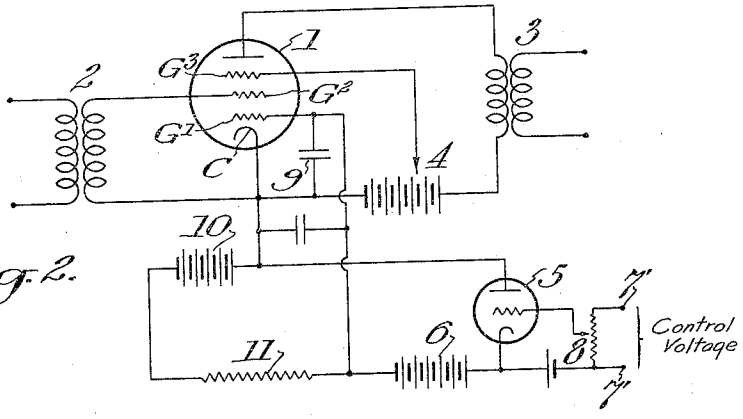


Fig. 2.

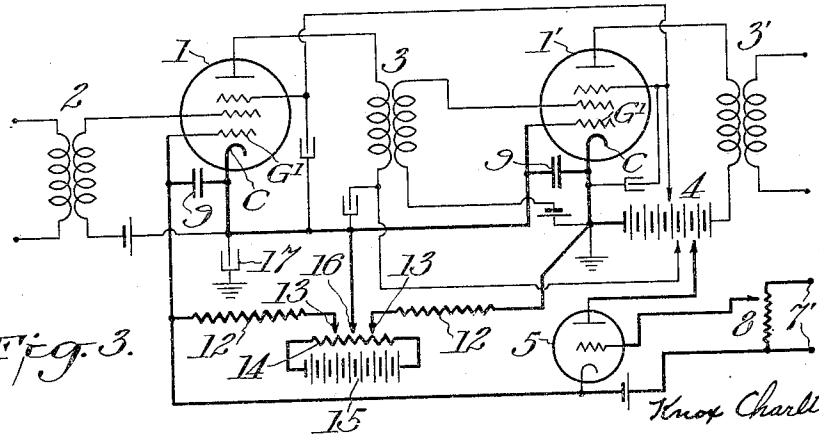


Fig. 3.

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UNITED STATES PATENT OFFICE

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CONTROL APPARATUS

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This invention relates to methods of and apparatus for controlling the operation of vacuum tube devices such as amplifiers, oscillators and modulators.

Various circuit arrangements have been proposed for the control of vacuum tube amplifiers by placing the control grid to cathode impedance of the controlled tube in series with the cathode to anode impedance of a controlling tube. Such systems are open to the general objection that the action of the controlling tube places a positive bias on the control grid and that, for many purposes, satisfactory operation calls for a negative bias on the control grid.

Objects of the invention are to provide control methods and apparatus by which the bias on a vacuum tube grid may be adjusted from positive to negative values by the action of a controlling tube. Further objects are to provide methods of and apparatus for controlling the operation of a vacuum tube by adjusting the bias voltage on a grid which is not subject to the signal voltage, the adjustment being effected by a second tube which is in series with the grid-cathode impedance of the controlled tube. More specifically, objects are to provide methods of and apparatus for employing one tube to control the operation of a second tube by adjusting the bias voltage applied to a grid thereof which is normally operated at a positive potential.

These and other objects of the invention will be apparent from the following specification, when taken with the accompanying drawing, in which:

Figs. 1, 2 and 3 are circuit diagrams illustrating different embodiments of the invention.

In Fig. 1, the controlled vacuum tube 1 is a pentode amplifier having an input circuit 2 connected between the control grid G^2 and the cathode C, and an output circuit 3 between the plate and the cathode, the screen grid G^3 being energized from the source 4 of plate current. The plate-cathode impedance of the control tube 5 is in series with the space charge grid-cathode impedance of the controlled tube 1. This reference to a series arrangement of the inter-electrode impedances, and similar statments in the specification and claims is to be understood as excluding circuits in which an external plate-cathode impedance of the controlling tube is shunted across the terminals of two electrodes of the controlled tube. The cathode C of the tube 1 is connected to the plate of the control tube 5 and the space charge grid G^1 is connected to the cathode of tube 5, either or both of these connections including a source of current 6. The control tube 5 may be of the triode type and its operation is controlled by adjusting the bias voltage established by the source 7 through the voltage divider 8. A bypass condenser 9 is preferably connected between the space charge grid G^1 and the cathode C to maintain these elements at the same potential as regards signal frequencies.

It will be apparent that the amplification of the tube 1 is determined by the direct current bias established on the grid G^1 by the battery 6 and control tube 5. Neglecting such minor effects as contact potential, the bias on grid G^1 may be adjusted from a definite maximum positive value to zero by regulating the bias applied to the control tube, reaching zero when the grid of tube 5 is carried so far negative as to prevent the flow of plate current.

It will be noted that the normal operation of tube 1 is preserved throughout the entire range of amplification control since the normal operation of the pentode calls for a positive potential upon the space charge grid G^1. The system is therefore to be distinguished from known circuits in which the control grid bias is adjusted over a range of positive values by a regulation of the plate-cathode impedance of a controlling tube. Furthermore, the invention provides for the complete separation of the signal voltage and the control voltage as each of these voltages is applied to but one grid.

Under some circumstances it is desirable to carry the control bias voltage to negative values, and one arrangement for effecting such operation is shown in Fig. 2. The general arrangement may be the same as shown in Fig. 1 and the corresponding circuit elements are therefore identified by the reference

numerals employed for Fig. 1. In addition to the control tube 5, a source of voltage such as battery 10, and a high resistance 11 are serially connected between the space charge grid G^1 and the cathode C of tube 1. The battery 10 is so arranged that it tends to establish a negative bias on grid G^1 but the resistance 11 is given such a high value that, when a substantial current is passed by the control tube 5, the effect of such current predominates and the grid G^1 has a positive bias. When the bias on the control tube 5 becomes sufficiently negative to block the flow of current through tube 5, the bias on grid G^1 is determined by the battery 10 and has its maximum negative value. The bias on grid G^1 may therefore be adjusted between predetermined positive and negative limits by a suitable choice of the controlling voltage or bias applied to the tube 5.

The source of the control voltage is not indicated in Fig. 2, but it is to be understood that any appropriate direct or alternating current source may be connected across the terminals 7'. For manual control of the amplification of tube 1, a battery or other source of direct current may be used, and for automatic regulation the terminals 7' may be fed from the rectifier element or a direct current amplifier of an automatic volume control system. The circuit of Fig. 2 may be used as a modulator, in which case the control voltage impressed across the terminals 7' of the tube 5 will be of an audio or other modulating frequency. Modulation may also be effected when the signal circuits of tube 1 cause the same to operate as an oscillator, the intensity of the oscillation being varied at a lower frequency by the alternating voltage impressed upon the control tube 5.

The system of control may, of course, be extended in the usual manner to impress the controlling voltage upon a plurality of controlled tubes in parallel. The controlled tubes may also be arranged in series, so far as their controlled grid-cathode impedances are concerned, and a typical circuit for such series control is shown in Fig. 3. The signal or high frequency circuits of the controlled tubes 1, 1' may be arranged in any desired manner as the control voltages are applied to grids which are not subjected to signal voltages. As illustrated in Fig. 3, the tubes are arranged for cascade amplification, the signal voltage circuits of the two tubes being each substantially identical with the the signal circuits of the preceding views, the output transformer of tube 1 passing the amplified signal to tube 1' which has an output transformer 3' for connection to an appropriate load circuit. The particular signal circuits do not, however, constitute an essential part of the control system.

As shown by the heavier lines, the control system places the space charge grid-cathode impedances of the controlled tubes in series with each other and in series with the plate-cathode impedance of the control tube 5. To permit the bias upon either of the grids G^1, or upon both, to swing to a negative value, the grid G^1 of tube 1 and the cathode C of tube 1' are connected, through high resistances 12 and adjustable taps 13, to the resistance or voltage divider 14 which shunts the battery or other direct current source 15, the lead connecting the cathode of tube 1 to the grid G^1 of tube 1' being also connected to resistance 14 through a tap 16. The cathode of tube 1' may be connected directly to ground, and a part of the common plate battery 4 of the controlled tubes may constitute the source of direct current potential in the control circuit. The usual bypass condensers 9 maintain the grids G^1 at the signal potentials of the cathodes, and the cathode of tube 1 may be grounded, for signal potentials only, through the condenser 17. The operation of this circuit will be apparent from the description of the Fig. 2 circuit.

While I have described a control obtained by adjustment of the bias voltage applied to a space charge grid, it will be apparent that the same principles apply equally well when the control is applied to any accelerating grid.

I claim:

1. The combination with a vacuum tube having a cathode, a plate, a control grid and a second grid; and circuit elements connecting said cathode to said control grid and plate to establish signal circuits; of means maintaining said second grid at the signal potential of said cathode, and means including a vacuum tube in series with the second grid and cathode for controlling the bias on said second grid between predetermined negative and positive values.

2. The combination with a vacuum tube having a cathode, a plate and a grid; and means including a vacuum tube controlling the bias applied to said grid; of means for impressing a negative bias on said grid as the positive bias applied through said first means approaches its minimum value.

3. The combination with a vacuum tube having a cathode, a plate and a grid; of means including a vacuum tube having its plate-cathode impedance in series with the grid-cathode impedance of said first tube for adjusting the bias on said grid between finite positive and negative limiting values.

4. The combination with a vacuum tube having a cathode, a plate, a control grid and a second grid; and circuit elements connecting said cathode to said plate and control grid to establish signal circuits; of means maintaining said second grid at the signal potential of said cathode, and means including a vacuum tube for adjusting the bias on

said second grid between positive and negative limiting values.

5. The combination with a plurality of vacuum tubes having circuit elements associated with certain of the electrodes of the respective tubes to constitute signal circuits; of a grid in each tube and means for maintaining the several grids at the signal potentials of their respective cathodes; means connecting the grid-cathode impedances of the several tubes in series with each other and with the plate-cathode impedance of a control vacuum tube and a source of potential; and means for impressing an operation-controlling voltage between the grid and cathode of said control vacuum tube.

6. The invention as set forth in claim 5, in combination with means for impressing a negative bias upon the grid of one of said vacuum tubes when the voltage applied to the control tube grid substantially prevents the passage of plate current therethrough.

7. In combination with an amplifier comprising a tube provided with an anode, cathode, grid, and auixilary electrode, and amplification control tube having its cathode-anode impedance in series with the cathode and auxiliary electrode of said amplifier tube, and a device for determining the direct current potential of said auxiliary electrode including means for regulating the conductivity of said control tube.

8. In combination with an amplifier comprising a tube provided with an anode, cathode, grid, and auxiliary electrode, an amplification control tube having its cathode-anode impedance in series with the cathode and auxiliary electrode of said amplifier tube, and a device for determining the direct current potential of said auxiliary electrode including means for regulating the conductivity of said control tube, and a source of potential connected in series with the cathode and auxiliary electrode of said amplifier tube.

9. In combination with a controlled electron discharge tube provided with an anode, cathode, grid, and second grid, a control tube, a source of potential in series with the cathode-anode impedance of said control tube and the cathode and second grid of the controlled tube, a path including a source of potential and a high resistance connected between the cathode and second grid of the controlled tube, the negative terminal of said second source being connected with the second grid, and the said resistance having such a value that the effect of the second source upon the bias of the said second grid is negligible so long as the control tube passes an appreciable anode current.

10. In combination with an amplifier comprising a tube provided with an anode, cathode, grid, and auxiliary electrode, an amplification control tube having its cathode-anode impedance in series with the cathode and auxiliary eletrode of said amplifier tube, and a device for determining the direct current potential of said auxiliary electrode including means for regulating the conductivity of said control tube, said regulating means comprising an adjustable biasing device for the grid of said control tube.

11. The combination with a vacuum tube having a cathode, a plate, a control grid, a screen grid and a second grid; and circuit elements connecting said cathode to said control grid and plate to establish signal circuits; of means for adjusting the positive potential of the screen grid, of means maintaining said second grid at the signal potential of said cathode, and means including a vacuum tube in series with the second grid and cathode for controlling the bias on said second grid between predetermined negative and positive values.

In testimony whereof, I affix my signature

KNOX CHARLTON BLACK.