

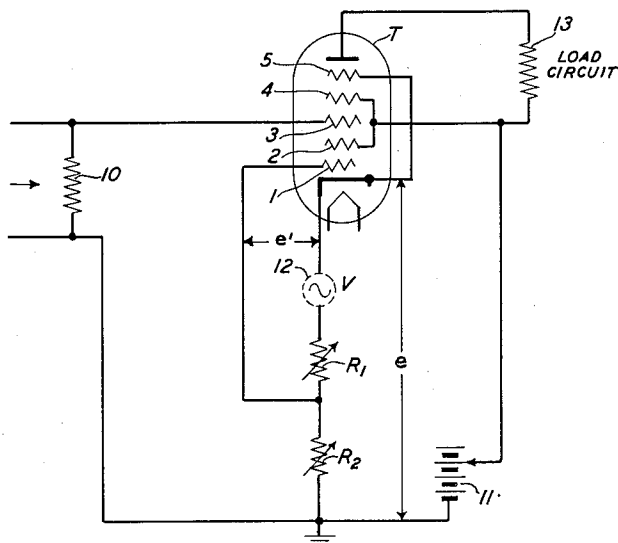
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AMPLIFIER COMPENSATED FOR CATHODE EMISSION CHANGES

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AMPLIFIER COMPENSATED FOR CATHODE
EMISSION CHANGE

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The invention relates to direct current amplifiers and to amplifiers for voltages of low frequency, for example, frequency extending below the audible frequency range, or frequency less than ten cycles per second.

An object of the invention is to stabilize space current of such amplifiers against change in cathode emission, as for example, to reduce cathode drift in sensitive direct current amplifiers.

In S. E. Miller Patent 2,308,997, January 19, 1943, such stabilization depends on constancy of the ratio of emissions from different portions of a cathode. The present invention avoids that limitation by suitably using a multigrid tube having first, second, third and fourth grids arranged in the order named between the cathode and the plate with the first grid next to the cathode.

In one specific form of the invention, the first grid serves as the grid of a triode whose anode is formed by the second and fourth grids, which are directly connected together. The current to the plate and second and fourth grids comes from the space current supply source (B-source) and through a cathode resistor to which the first grid is connected so as to receive a feedback voltage that tends to keep the space current from the cathode constant. The third grid is the signal grid. It varies the ratio in which the constant electron current divides between the plate and the second and fourth grids, and so gives the signal in the plate circuit. If desired, the tube may have a fifth grid positioned between the fourth grid and the plate and directly connected to the cathode, to serve as a suppressor grid.

Other objects, aspects and features of the invention will be apparent from the following description and claims.

The single figure of the drawing is a schematic circuit diagram of one form of the invention.

The Miller patent mentioned above discloses an amplifier that reduces cathode drift by suitable use of a twin tube having a common cathode. One of the twin grids controls a negative feedback through cathode resistors in order to neutralize or reduce the cathode voltage drift. Ideal operation apparently would require emission changes in the two cathode surfaces supplying space current to the two sets of tube elements to be identical or at least bear some fixed relation to each other.

In effect, this requirement can be satisfied in accordance with the present invention, by using the same identical emission surface for both tube structures. This may be done by suitably using, instead of the twin tube, a multigrid tube. One

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suitable circuit for the tube is shown, by way of example, in the drawing.

The tube T is indicated, for example, as a pentagrid type of tube, and may be, for instance, an RCA tube of type 6SA7 with grids 1, 2, 3, 4, and 5 positioned, in the order named, between the cathode and the anode. Grid 3 is a control grid which may be the signal grid. The currents to be amplified may be sent through a coupling resistor 10, connected in series with cathode resistors R₁ and R₂ between the cathode and the signal grid 3. Thus, resistor 10 serves as a source of voltage to be amplified. This voltage may be a direct current voltage; or it may include components of frequency below the audio frequency range, as, for example, components of frequency below ten cycles per second (the audio frequency range extending down to approximately 20 cycles per second).

Connected between the cathode and plate, in series with resistors R₁ and R₂, are a space current supply source 11, and a utilization circuit, or load device, 13. The space current supply source, shown as a battery for the sake of simplicity, may be any suitable direct current source. For example, it may be a power source with its voltage closely regulated. The amplifier may be a direct current amplifier, or low frequency amplifier, of high sensitivity. For example, it may be an amplifier adapted to be used for measuring small direct current potentials or small low frequency potentials. The load 13 may be a device responsive to direct current voltage; or it may be responsive to current or voltage including components of frequency below the audio frequency range, as, for example, components of frequency less than ten cycles per second. It is desirable to avoid transmission to the load 13 of disturbing voltages in the signal frequency range or below the audio frequency range, due, for example, to cathode drift or fortuitous or undesired variations in cathode emission.

The grids 2 and 4 are maintained positive, with respect to the cathode, by source 11, and the current to the grids 2 and 4, as well as the current to the plate, comes from the source 11 and through the resistances R₁ and R₂. The grids 2 and 4 may constitute a screen grid surrounding the grid 3 and may act as the anode of a triode having grid 1 as its control grid. The signal grid 3 is used to modulate the electron stream or space current passing through this screen grid 2, 4 to the plate.

Control grid 1 may be directly connected to the junction of the cathode resistors R₁ and R₂, for controlling feedback into the cathode resis-

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tors to neutralize the cathode voltage drift. The cathode drift voltage is indicated as a fictitious generator 12 of a voltage V , that would produce the same effect on the potentials of grids 1 and 3 relative to the cathode as would the cathode drift which the source 12 represents. The voltage applied to grid 1 due to V is transmitted to the circuit of grids 2 and 4 by virtue of the transconductances from grid 1 to grids 2 and 4, and consequently a voltage is fed back to grid 1 from the resistance R_1 common to the circuit of grid 1 and circuit of grids 2 and 4, this feedback voltage being opposite in phase to V . The screen grid, by thus acting as the anode of the triode and producing negative feedback to grid 1, tends to prevent voltages in the cathode circuit, such as the cathode drift voltage V , from affecting the space current from the cathode. However, a change in temperature or emission characteristic of any point on the cathode is not completely neutralized before it can affect the space current modulated by the signal grid; because in compensating for a spurious voltage V in the cathode circuit, a change must be made in the space current from the cathode. To prevent this change in space current from reaching the plate, a compensating change can be made in the signal grid-cathode circuit. This is easily done by overcompensating for the voltage V , so that a change in cathode voltage to ground (i. e., in voltage e) of opposite sign is obtained. This voltage is in the signal grid circuit, and circuit constants should be adjusted so that the current to the plate is unchanged.

Assume that by the proper adjustments of potentials in the circuit shown in Fig. 1 space charge can be maintained in front of grid 3, and that the current flow to the plate is independent of the voltage on grid 1 over the normal operating range. Then in order that voltage V from source 12 shall have no effect on plate current the voltage drop across R_1 and R_2 must be equal and opposite in sign to V , i. e., voltage e must be zero.

The three equations below may be written to cover the triode section of the tube consisting of cathode, grid 1, and all anode elements of the tube.

$$e = V - i_1(R_1 + R_2) \quad (1)$$

$$e' = V - i_1 R_1 \quad (2)$$

$$g_m' = \frac{i_1}{e'} \quad (3)$$

where i_1 is space current from the cathode, e' is voltage between grid 1 and cathode, and g_m' is the effective mutual conductance of the triode in the circuit, g_m being the mutual conductance of the tube with no external resistance in series with r , the internal resistance of the triode.

From Equations 1, 2, and 3, it may be determined that

$$e = i_1 \left(\frac{1}{g_m'} - R_2 \right) \quad (4)$$

If e is zero, then

$$R_2 = \frac{1}{g_m'} \quad (5)$$

This equation may also be written

$$R_2 = \frac{R_1 + R_2 + r}{\mu_1} \quad (6)$$

where μ_1 is the amplification factor of the triode section of the tube. When $r \gg (R_1 + R_2)$, then

$$R_2 = \frac{1}{g_m} \quad (7)$$

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However, the above assumption of an unchanging space charge in front of grid 3 may not always be true. The current flow which maintains the cathode potential e at zero in the presence of V may cause a change in the space charge in front of grid 3 with a resulting change in plate current. This change in plate current i_3 will be of the same sign as the change in cathode current i_1 and will bear a relationship to the cathode current which can be called k where

$$k = \frac{i_3}{i_1} \quad (8)$$

k will be positive and less than 1. Therefore in order to maintain the plate current constant when voltage V appears in the circuit a voltage, $-e_3$, which will cause a current $-i_3$ should be impressed between grid 3 and the cathode.

The grid 3 voltage e_3 to cause a current change i_3 is

$$e_3 = \frac{i_3}{g_{m_3}} \quad (9)$$

but from Equation 8

$$i_3 = k i_1 \quad (10)$$

Therefore

$$e_3 = \frac{k i_1}{g_{m_3}} \quad (11)$$

and the increase ΔR_2 in the value of R_2 which will provide this voltage is given by the following equation:

$$\Delta R_2 i_1 = \frac{k i_1}{g_{m_3}} \quad (12)$$

where g_{m_3} is the mutual conductance of the pentode section of the tube. The new value of R_2 for the condition of varying space charge in front of grid 3 is given by the following equation where the value given in Equation 5 is increased by the value indicated in Equation 12

$$R_2 = \frac{1}{g_m'} + \frac{k}{g_{m_3}} \quad (13)$$

The signal on grid 3 in this type of circuit can have at most only a negligible effect on the cathode current. Therefore there is no negative feedback for signal voltages on grid 3. The only restriction in the choice of resistances R_1 and R_2 as regards the signal channel is that the voltage drop across them appears in the grid bias path of grid 3. The effective signal voltage amplification G_3 is given by the following equation where R_3 is the value of load resistance 13 which will normally be small compared to the internal impedance of the pentode section, and g_{m_3} is the mutual conductance of the pentode section of the tube.

$$G_3 = R_3 g_{m_3} \quad (14)$$

Where complete neutralization of cathode drift is not required resistance R_2 may be omitted and a substantial reduction in drift can still be obtained. This reduction in e , the voltage on grid 3, is indicated by the following equation:

$$\frac{e}{V} = \frac{\mu_1 R_1}{R_1(\mu_1 + 1) + R_2 + r} \quad (15)$$

where μ_1 is the amplification factor for the triode. When k is zero, the ratio of plate current due to V with R_1 in the circuit to that with R_1 omitted is also e/V . Omission of R_2 has at the most only a negligible effect on the gain from grid 3 to the plate circuit.

While the above description is based on the

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use of an indirectly heated unipotential cathode, it may also be used with a filamentary cathode. A change in the direct current filament current produces not only a temperature change but also a change in the voltage drop across the filament. Changes in space current due to both may be neutralized. This is also true for filaments heated with alternating current.

Grid 5 may be operated, for example, as a suppressor grid. For such use, it may be connected to the cathode, as shown, and may function similarly to the suppressor in a pentode.

What is claimed is:

1. An amplifier comprising an electric discharge device having a cathode, an output anode, and consecutive first, second, and third grids positioned in uninterrupted succession in the order named between the cathode and the anode with the first grid nearest the cathode and the third grid nearest the anode, a source of direct current, a direct current path comprising a resistance connecting the cathode and the negative terminal of said source, a load circuit capable of transmitting direct current connected between the anode and a point on said source at a potential positive with respect to that of the cathode, a conductor of negligibly low impedance for direct current directly connecting the second grid to a point on said source at a potential positive with respect to the cathode without interposition of resistance between the last-mentioned point and the second grid, a source of input signal voltage to be amplified, a circuit comprising the latter source and said first-mentioned resistance in series affording a direct-current path between the third grid and the cathode and adapted to apply said voltage to be amplified across the third grid and the cathode and maintain the third grid negative with respect to the cathode, and means conductively connecting the first grid to a point on said first-mentioned resistance such that the portion thereof between said last-mentioned point and the negative terminal of said first-mentioned source has the value

$$\frac{1}{g_m'} + \frac{k}{g_{m_3}}$$

where g_m' is the mutual conductance of the triode formed by the cathode, the first grid, and the second grid, where k is the ratio of the anode current to the cathode current, and where g_{m_3} is the mutual conductance of the multigrid device formed by the cathode, the third grid, the second grid, and the anode.

2. An amplifier comprising an electron dis-

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charge tube having a cathode, a plate, and first, second, third, and fourth grids positioned consecutively in uninterrupted succession in the order named between the cathode and the plate with the first grid nearest to the cathode, a source of direct current, a direct-current path comprising a resistance connecting the cathode and the negative terminal of said source, a load circuit capable of transmitting direct current connected between the plate and a point on said source at a potential positive with respect to that of the cathode, circuits of negligibly low impedance for direct current directly connecting the second and fourth grids conductively to a point of said source at a potential positive with respect to the cathode without interposition of resistance between that point and those grids, a source of input signal voltage to be amplified, a circuit comprising the latter source and said first-mentioned resistance in series providing a direct-current path between the third grid and the cathode and adapted to apply said voltage to be amplified across the third grid and the cathode and maintain the third grid negative with respect to the cathode, and a conductor connecting the first grid to a point on said first-mentioned resistance such that the portion thereof between said last-mentioned point and the negative terminal of said first-mentioned source has the value

$$\frac{1}{g_m'} + \frac{k}{g_{m_3}}$$

where g_m' is the mutual conductance of the triode formed by the cathode, the first grid and the interconnected second and fourth grids, where k is the ratio of the plate current to the cathode current, and where g_{m_3} is the mutual conductance of the multigrid tube formed by the cathode, the third grid, the interconnected second and fourth grids, and the plate.

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