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R. B. MACKENZIE

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COMPENSATED VOLTAGE REGULATOR

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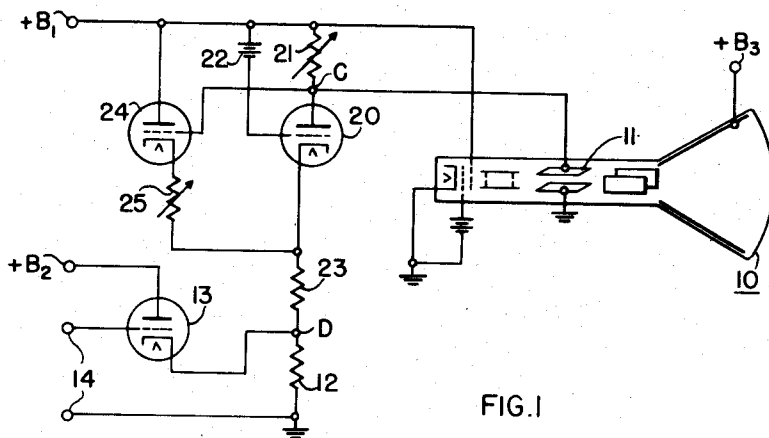


FIG. 1

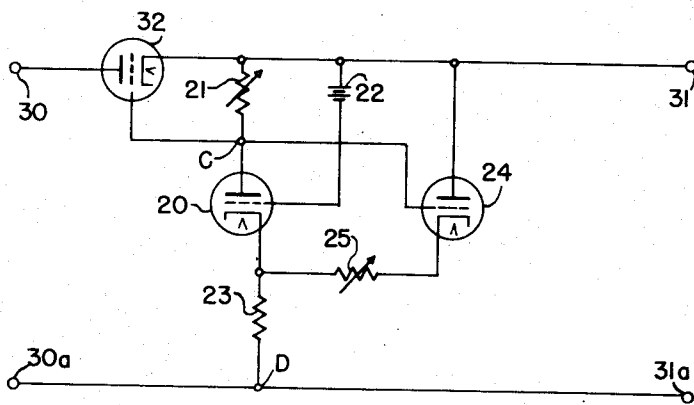


FIG. 2

INVENTOR.
RONALD B. MACKENZIE

BY

John A. Harvey

ATTORNEY

UNITED STATES PATENT OFFICE

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COMPENSATED VOLTAGE REGULATOR

Ronald B. Mackenzie, Wembley, England, assignor to Hazeltine Research, Inc., Chicago, Ill., a corporation of Illinois

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This invention is directed to systems for translating to a first point potential variations which may be established at a second point and relates particularly to thermionic tube circuits for transferring potential variations between points which may be at different direct-current potential levels. Systems of the type under consideration have a variety of applications and are suited, for example, for applying potential variations from a point of low potential to the deflecting electrode of a cathode-ray tube which may be at a relatively high potential. They are also especially adapted for inclusion in a voltage-regulating system.

It has heretofore been proposed to employ simply a coupling condenser for transferring potential variations from one point to another where such points are normally at different direct-current levels. However, if the variation is an exceedingly slow one, taking place over a long period of time, it is not transferred by the ordinary coupling condenser.

Other known arrangements couple the points in question through a tube circuit of the cathode-driven type, wherein the grid or control electrode of a tube is maintained at a relatively fixed potential and the variation to be transferred is supplied to a cathode impedance for transfer to the anode circuit. While such arrangements may be satisfactory for some installations, a part of the potential variation to be transferred is opposed by the effect of the anode-cathode current in the cathode impedance, reducing the total amount available for producing an output in the anode circuit. This feature may be undesirable in certain installations.

It is an object of the present invention, therefore, to provide a system for translating to a first point potential variations established at a second point and which substantially avoids one or more of the aforementioned limitations of prior arrangements.

It is another object of the invention to provide a new and improved system for translating potential variations between a pair of points, which points may be at widely different direct-current potential levels.

It is a further object of the invention to provide a new and improved system for translating potential variations between a pair of points while permitting the transfer ratio to be quickly and conveniently adjusted.

It is another object of this invention to provide a new and improved system for translating between a pair of points, potential variations

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while preserving both the wave form and direct-current component of such variations.

There is employed in a voltage regulator, having input terminals and output terminals connected in series relation through the anode-cathode path of a multi-element vacuum tube including a control electrode, a system for translating to the control-electrode potential variations established between the output terminals. This system comprises a first electron-discharge device having an anode connected to the aforesaid control electrode and having a cathode. The system also includes a cathode impedance connecting the aforesaid cathode to the above-mentioned output terminals and constituting with the device a signal-translating stage having input and output circuits. The system further includes a second electron-discharge device having a control electrode and a cathode respectively connected to the anode and the cathode of the first device and providing a feed-back path from the output to the input circuits of the stage for developing across the aforesaid impedance a potential variation opposing that occasioned by signal translation through the stage, thereby to determine the gain of the stage, the amplitude ratio of the potential variations transferred from the output terminals to the first-mentioned control electrode, and the voltage regulation between the input and output terminals.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a schematic representation of a system embodying the invention for translating potential variations established at a first point normally at a low direct-current potential level to a deflecting electrode of a cathode-ray tube which is at a higher direct-current potential level; and Fig. 2 is a schematic representation of a voltage regulator including the invention.

Referring now more particularly to Fig. 1, the arrangement there represented includes a direct-current amplifying system for translating to a first point, designated C, potential variations established at a second point, designated D. For the application of the invention under consideration, the point C is directly connected with a vertical deflecting electrode 11 of a conventional cathode-ray tube 10. Since the cathode-ray tube and its power supply may be conventional, only

those elements which are essential to an understanding of the invention have been shown in detail. The point D is the high-potential terminal of a resistor 12, serving as the load impedance of a cathode-follower circuit including a triode vacuum tube 13. The anode of that tube is directly connected with a space-current source $+B_2$ which may represent a lower direct-current potential level than that normally established on the electrode 11 of the cathode-ray tube by its power-supply system including the source $+B_1$. The signal variations to be transferred to the point D may be applied to input terminals 14, 14 associated with the cathode and control electrode of tube 13.

The system for translating potential variations from the point D to the point C comprises a first electron-discharge device, shown as a triode vacuum tube 20 having anode, cathode, and control electrodes. Its anode is directly connected with the point C and, through a variable resistor or anode impedance 21, it is connected with the space-current source $+B_1$. A constant-voltage device, such as a bias battery 22, maintains the control electrode at a fixed reference potential relative to source $+B_1$ while a cathode resistor 23 connects the cathode to the point D. The resistors 12 and 23 in conjunction with tube 20 constitute a signal-translating stage, in the nature of a direct-current amplifier, between the points C and D having both input and output circuits. Since the signal variations are applied directly to the cathode impedance, this stage is of the so-called cathode-driven type.

A second electron-discharge device, also shown as a triode vacuum tube 24, is arranged to provide a feed-back path from the output to the input circuits of the stage, including tube 20, for developing across resistor 23 a potential variation opposing that occasioned by signal translation through the stage. More specifically, the anode of tube 24 is directly connected with the source $+B_1$ while its control electrode is connected to the point C. A variable cathode resistor 25 connects the cathode of tube 24 to the cathode of tube 20 and the circuit of the former is seen to be that of a conventional cathode follower.

In considering the operation of the described arrangement, it will be seen that the anode-cathode currents of both tubes 20 and 24 traverse resistor 23. Since tube 24 acts as a cathode follower, it tends to keep the potential across resistor 25 approximately equal to that across tube 20 and, if the latter has a high amplification, variations in this potential are approximately equal in magnitude but opposite in sense to the variations in potential across anode resistor 21. By adjusting resistor 25 to a value approximately equal to the value of resistor 21, any varying components of anode-cathode currents in the two tubes are balanced, being maintained substantially equal in magnitude but opposite in sense. These varying current components cancel one another in the circuit elements which are common to both tubes with the result that there is substantially no potential change of cathode resistor 23 when the anode-cathode current of tube 20 is varied to transfer a potential from the point D to the point C. Voltage variations appearing across resistor 12 are, therefore, transmitted without attenuation to the cathode of tube 20 and are almost entirely available for establishing the desired output or potential variation at the point C. It is evident then that

the variations appear in amplified form and without a phase reversal at the point C for application to the deflecting electrode 11. The variations thus obtained at the point C are replicas of those applied to point D and include the variation of direct-current component.

Expressed somewhat differently, a potential variation at the point D varies the anode-cathode current of tube 20 to transfer that variation to the point C. The change of anode current tends normally to establish a potential change across cathode resistor 23 but the feedback, provided by cathode follower 24, causes a potential change across this resistor which is equal to but opposite in sense from that otherwise occasioned by signal translation through tube 20. By proportioning the circuits as described, a potential variation at the point D is transferred to the point C without causing any appreciable potential change across cathode load 23 of tube 20. Where a suitable time-base signal is applied to the horizontal-deflecting electrode of tube 10, the variations in potential at the point C may be observed on the screen of the cathode-ray tube.

The arrangement of Fig. 1 is flexible in that the gain from point D to point C and the amplitude ratio of potential variations at those points may be determined by controlling the magnitude of the feedback provided by the cathode-follower circuit including tube 24. Where the value of resistor 25 is selected to exceed the value of resistor 21, the varying components of current traversing cathode impedance 23 are no longer balanced. Instead, the component from tube 20 predominates, causing a voltage change, opposite in sense to that applied to the point D, to be established across resistor 23. For such operating conditions, the stage 20 is degenerative. This reduces the effective total voltage applied to the cathode of tube 20 and is equivalent to signal attenuation. On the other hand, where resistor 25 has a value substantially less than that of the anode load resistor 21, the stage is regenerative and augments the gain of tube 20 to increase its amplification. Additional control may be obtained by using a tube 24 which has greater transconductance than that of tube 20.

In Fig. 2, the invention is illustrated in connection with a voltage regulator to effect a desired regulation between input terminals 30 and 30a, to which may be connected an unregulated power supply, and output terminals 31 and 31a. The input and output terminals are connected in series relation through the anode-cathode path of a multi-element vacuum tube 32, shown as a triode including a single control electrode. In this embodiment, the control electrode of tube 32 is connected with the point C while output terminal 31a is connected with the point D. Intermediate the points C and D is a system which is generally similar to that described in connection with Fig. 1 for transferring potential variations between these points, corresponding components of such systems being identified by the same reference characters. Regarding the output terminal 31 as a point of fixed potential, if the potential of the other output terminal 31a changes, a potential variation is applied to the cathode of tube 20 and is transferred to the anode thereof and to the control electrode of tube 32. The potential thus applied to the control electrode of the series regulating tube 32 varies the impedance thereof to compensate the potential change experienced at the output ter-

terminal 31a. By proportioning the anode impedance 21 and the cathode impedance 25 in the manner discussed in connection with Fig. 1, the output voltage of terminals 31, 31a may be maintained substantially constant or variations of potential at the output terminals may be either under or overcompensated by the system including the circuits of tubes 20 and 24. Undercompensation follows when stage 20 is degenerative while overcompensation results from the use of a regenerative stage.

Fig. 2, essentially, is a regulated power supply wherein the regulating tube 32 is connected in series relation with an input terminal 30 and an output terminal 31. In parallel with the input and output terminals and positioned between regulating tube 32 and output terminal 31 is a network comprising a positive resistance 23 in series with a negative resistance including the tubes 20 and 24. If the impedances 21 and 25 are adjusted to have the varying current components supplied to resistor 23 from tubes 20 and 24 equal in magnitude but opposite in sense, then the negative resistance is substantially equal in value to the positive resistance. A suitable tap on the described network is connected to the control electrode of regulating tube 32. While the tap may be positioned at the cathode of tube 20, usually some amplification is desired and for this reason the connection to the control electrode is made in the anode circuit of tube 20, as illustrated.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a voltage regulator having input terminals and output terminals connected in series relation through the anode-cathode path of a multi-element vacuum tube including a control electrode, a system for translating to said control electrode potential variations established between said output terminals comprising: a first electron-discharge device having an anode connected to said control electrode and having a cathode; a cathode impedance connecting said cathode to said output terminals and constituting with said device a signal-translating stage having input and output circuits; and a second electron-discharge device having a control electrode and a cathode respectively connected to said anode and

said cathode of said first device and providing a feed-back path from the output to the input circuits of said stage for developing across said impedance a potential variation opposing that occasioned by signal translation through said stage, thereby to determine the gain of said stage, the amplitude ratio of potential variations transferred from said output terminals to said first-mentioned control electrode, and the voltage regulation between said input and output terminals.

2. In a voltage regulator having input terminals and output terminals connected in series relation through the anode-cathode path of a multi-element vacuum tube including a control electrode, a system for translating to said control electrode potential variations established between said output terminals comprising: a first electron-discharge device having an anode connected to said control electrode and having a cathode; a cathode impedance connecting said cathode to said output terminals and constituting with said device a signal-translating stage having input and output circuits; and a cathode-follower signal-translating stage including a second electron-discharge device having a control electrode and a cathode respectively connected to said anode and said cathode of said first device and providing a feed-back path from the output to the input circuits of said first-mentioned stage for developing across said impedance a potential variation opposing that occasioned by signal translation through said first-mentioned stage, thereby to determine the gain of said first-mentioned stage, the amplitude ratio of potential variations transferred from said output terminals to said first-mentioned control electrode, and the voltage regulation between said input and output terminals.

RONALD B. MACKENZIE.

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