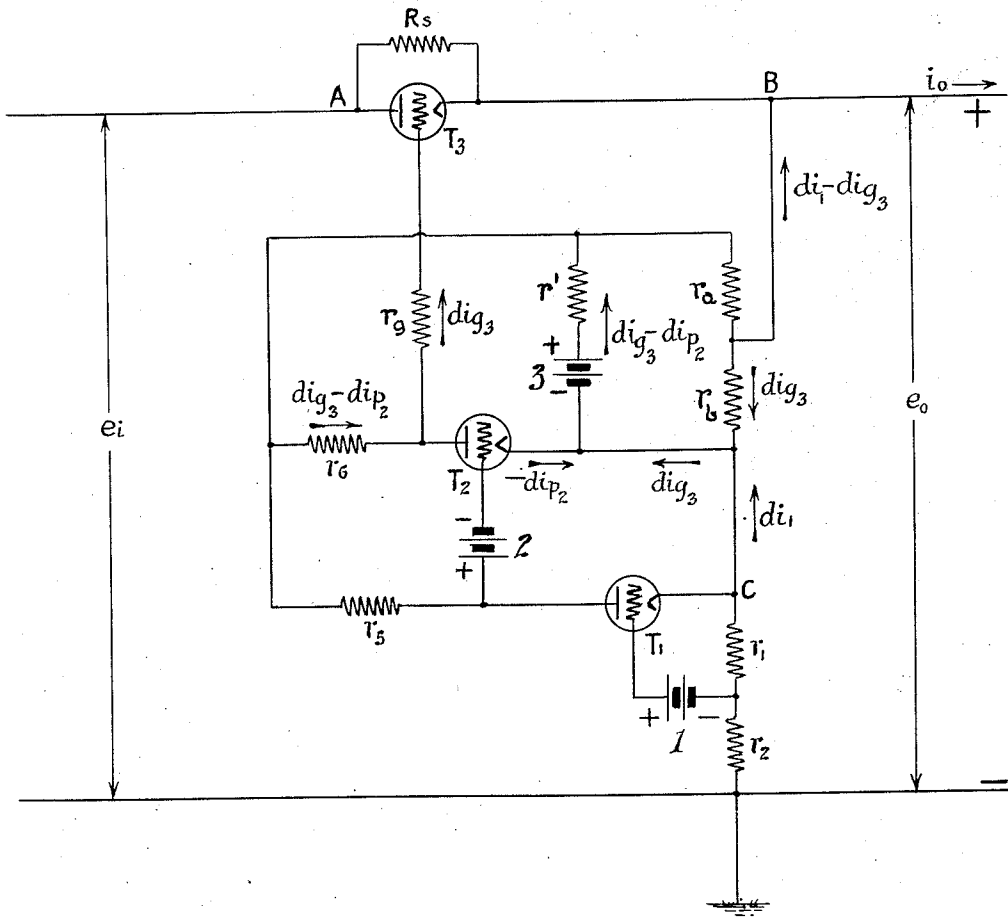


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L. G. PARRATT ET AL
ELECTRONIC VOLTAGE STABILIZER

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INVENTORS
Lyman G. Parratt
John W. Trischka
 BY *Robert V. Morse*
 ATTORNEY.

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ELECTRONIC VOLTAGE STABILIZER

Lyman G. Parratt, Washington, D. C., and John W. Trischka, Ithaca, N. Y., assignors to Cornell Research Foundation, Inc., Ithaca, N. Y., a corporation of New York

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This invention relates to regulating systems used to stabilize the voltage of an electrical circuit; such as are employed for example to keep the voltage constant at the terminals of electrical devices whose power supply has a somewhat variable voltage. The invention belongs to that class of regulators or stabilizers in which a thermionic tube acts as a variable resistance in series with the load, the tube having a control grid arranged to automatically vary the electronic flow in such a way as to offset variations in the voltage. More particularly it belongs to that class of degenerative stabilizers having an amplified control circuit, whereby small variations in the voltage are so amplified as to cause a large change in the tube controlling the current flow, to give close regulation.

One of the objects of the present invention is to so improve the amplified control circuit that it may overcompensate as well as undercompensate, making it possible by judicious adjustment to reach or closely approach perfect compensation or stabilization. It is here accomplished by a circuit involving the use of grid current in the load control tube. This use of grid current, in the circuit to be described, serves to accentuate the action of the amplifier. In the pure degenerative circuits of the prior art the relative magnitude of the potential changes were such that the stabilization ratio was always positive and complete compensation could be approached but not passed. The effect of the grid current in the present stabilizer is to exaggerate the degenerative action and to remove the otherwise inherent restriction on the degree of compensation, permitting a negative or positive stabilization ratio as desired. To distinguish this from the degenerative circuits limited to positive stabilization ratios, we term a degenerative circuit which incorporates such action of grid current a "superdegenerative stabilizer."

Other general objects of the invention are to improve electronic voltage stabilizers; to adapt them to higher loads as well as better stabilization; to reduce the residual ripple; and to reduce the overall cost as well as improve the performance. Further detail objects will become apparent as the description proceeds.

Referring now to the drawing forming part of this specification, the figure shows in simplified form a typical circuit involving the invention.

The conventional symbols are used— e for voltage, i for current, r for resistance, and T for electronic vacuum tubes, with di indicating the increment of current, and the subscripts p and g

denoting plate current or grid respectively. For example, di_{p_2} denotes the increment plate current of the second stage or tube, and di_{g_3} denotes the increment grid current of the third stage or tube T_3 . The arrows indicate the direction of increments, that is, the direction of change rather than the current flow.

Consider for example a typical power line AB having an input voltage e_i , a current output or load i_o , and an output voltage e_o which it is desired to keep constant and free from fluctuations in spite of varying inputs or varying loads. In devices of the general type to which this invention refers, the regulation is maintained by an electronic vacuum tube such as T_3 which acts in the manner of a variable resistance controlling the line. The flow of current thru such tubes is controlled by the potential on their grids; and by arranging the circuit so that the grid becomes more positive when the line voltage drops and more negative when the line voltage rises, a close and practically instantaneous regulation can be obtained. It is a fundamental property of electronic tubes having a filament, grid and plate, that the flow of electricity between filament and plate is increased when the grid becomes more positive and decreased when the grid becomes more negative—since electrons, being negative particles, are attracted by the positive and repelled by the negative.

In the present invention, besides the usual amplifier build-up to operate the grid of the regulating tube T_3 , there is also provided a grid current circuit thru the tube T_3 so arranged as to increase the effectiveness of the regulation. Two stages of amplification are shown, the first tube T_1 having its filament connected to the point C of the bleeder circuit which extends between the two sides of the power line; the grid of the tube T_1 is connected to the positive terminal of the battery 1, whose negative terminal is connected between the resistances r_1 and r_2 . The plate of the tube T_1 is connected to the positive terminal of the battery 2, whose negative terminal is connected to the grid of the tube T_2 . The plate of the tube T_2 is connected by way of the resistance r_3 to the grid of the main regulating tube T_3 . A shunt resistor R_s is provided to dissipate powers in excess of the rated plate power of the tube T_3 .

A battery 3 is provided in the grid circuit of the tube T_3 . The grid current flows thru the resistance r_b , by way of the battery 3, resistances r'_1 , r_6 and r_9 , to the grid of the tube T_3 and back thru B and the resistance r_b .

The usual degenerative action of the circuit presumes a constant potential difference between the points B and C. A change in potential V_B , let us say a negative change due perhaps to a decrease in V_A , causes a decrement in the bleeder current. The decrement of potential drop across r_1 causes the grid of the tube T_1 to become more positive and therefore the plate of the tube T_1 to become more negative. The decrement of potential thereby placed on the grid of T_2 causes an increment of potential to appear on the plate of T_2 and therefore on the grid of T_3 . The final result in this chain of events is a decrement in the potential of the T_3 plate, which decrement partially compensates for the initial decrement in V_B . We conclude that any change in V_B , whether positive or negative, is resisted by the automatic adjustment of the potential drop across the tube T_3 .

With zero grid current in the tube T_3 , the effects of the resistor r_b , whose presence destroys the assumption for pure degeneration, are relatively negligible with suitable circuit constants. The decrement of bleeder current which is the consequence of a decrement in V_B causes a decrement in the potential across r_b . This has two effects: (1) a small potential decrement, which contributes to the degenerative action, is applied directly to the grid of T_3 ; (2) the potential decrement across the resistance r_b , other things being equal robs the potential V_c and in consequence the potential decrement across the resistance r_1 is slightly less than it would be with r_b equal to zero. This effect opposes the degeneration.

The condition in which the present invention is particularly interested is when there is appreciable grid current in the tube T_3 . This grid current i_{g_3} flows thru the resistor r_b , and the change in this current is in phase with the change in grid potential. Hence, for a decrement in V_B for which we have observed a positive de_{g_3} in the degenerative action, we have a positive di_{g_3} which produces a potential increment across the resistor r_b , this increment being in contrast to the decrement mentioned in the preceding paragraph. We readily see from the previous arguments that there are also two effects of opposite phase produced by the grid current in the resistor r_b . The first effect, in opposition to degeneration, is caused by a direct decrease in the T_3 grid potential. The second effect is a decrease in the bleeder current in the resistor r_1 , diminishing the i_{r_1} potential drop, which, after two stages of amplification, increases the grid potential of T_3 . This effect contributes to the degeneration. Because of the two stages of amplification, the second effect is much more important than the first.

With a proper choice of resistors, and with a relatively large change in grid current, the net degenerative action may actually cause over-compensation for the initially assumed change in V_B . Accordingly, with rather simple but judicious adjustment, complete compensation, (that is, infinite stabilization, mathematically speaking), may be obtained. In pure degeneration the relative magnitudes of de_1 and de_o are such that the stabilization ratio $de_1/de_o = S$ is always positive and de_o does not reach zero; or mathematically speaking, S is less than infinity. The effect of the grid current in the present stabilizer is to exaggerate the degenerative action and to remove the otherwise inherent restriction on the degree of the compensation, so that it may over-compensate if desired, and so pass from a positive

stabilization ratio S to a negative stabilization ratio S . It thus becomes possible, in critical adjustment, to make de_o pass thru zero, at which point we have perfect compensation, that is, infinite stabilization.

The expression for the stabilization ratio is

$$S = \frac{de_1}{de_o} = 1 + \frac{R_s}{R_s + r_{p_3}} \left[\frac{r_{p_3}}{R_L} + \frac{an_1n_2\mu_3}{1 - an_1n_2r_b/r_{g_3}} \right]$$

where

$$a = \frac{r_1}{r_1 + r_2 + r_b}$$

and the condition for perfect stabilization is

$$an_1n_2r_b/r_{g_3} = 1$$

where r_p and r_g refer to the cathode-plate and cathode-grid variational resistances of a tube, μ_3 to the amplification factor of the tube, n to the gain of a stage of amplification, and R_L to the load resistance.

The path of the grid current can be seen in Fig. 1 by following the grid current increment symbols di_{g_3} . It is this use of grid current in the circuit of the tube T_3 —which is the regulating tube in series with the load—that reduces the bleeder current in the resistor r_1 and diminishes the potential drop applied to the tube T_1 , which after amplification thus accentuates the regulation of the tube T_3 .

The invention has been illustrated in a simplified form to facilitate the understanding of its principles. With such modifications as will be apparent to those skilled in the art the type of circuit shown provides a suitable method for obtaining a very steady high-voltage D. C. power supply in many applications. The device also reduces the residual ripple from the filter which usually precedes such a stabilizer, so that for the remaining net ripple a less expensive filter will suffice.

While we have in the foregoing described a certain specific circuit by way of example, it will be understood that it is merely for purposes of illustration to make clear the principles of the invention, which is not limited to the particular form shown, but is susceptible to various modifications and adaptations in different installations as will be apparent to those skilled in the art, without departing from the scope of the invention as stated in the following claims.

We claim:

1. In an electronic voltage stabilizer, the combination of a power circuit to be regulated having a load resistance R_L , an electronic control tube in series with said power circuit having a cathode with a cathode-plate variational resistance r_{p_3} and a regulating grid with a cathode-grid variational resistance r_{g_3} , said grid being maintained positive, the control tube having an amplification factor μ_3 , a shunt resistor R_s around said control tube, a multistage amplifier circuit having an even number of stages wherein the gains of successive stages of amplification are represented by n_1 and n_2 , a power supply for said amplifier circuit, a resistance r_1 whose potential drop is applied to the input of the amplifier, a second resistance r_2 in series with the first mentioned resistance, a third resistance r_b carrying grid current of the control tube to exaggerate the degenerative action, the last three mentioned resistances being connected between the side of the load where the control tube is located and the opposite side of the load in the order r_b , r_1 and r_2 , whereby the stabilization ratio S of change of

input voltage to change of output voltage may pass from positive to negative, the relative relationship of the foregoing factors being

$$S = 1 + \frac{R_s}{R_s + r_{p_3}} \left[\frac{r_{p_3}}{R_L} + \frac{an_1n_2\mu_3}{1 - an_1n_2r_b/r_{s_3}} \right]$$

where

$$a = \frac{r_1}{r_1 + r_2 + r_b}$$

2. In an electronic voltage stabilizer, the combination of a power circuit to be regulated having a load resistance R_L , an electronic control tube in series with said power circuit having a cathode with a cathode-plate variational resistance r_{p_3} and a regulating grid with a cathode-grid variational resistance r_{g_3} , said grid being maintained positive, the control tube having an amplification factor μ_3 , a multistage amplifier circuit having an even number of stages wherein the gains of successive stages of amplification are represented by n_1 and n_2 , a power supply for said

amplifier circuit, a resistance r_1 whose potential drop is applied to the input of the amplifier, a second resistance r_2 in series with the first mentioned resistance, a third resistance r_b carrying grid current of the control tube to exaggerate the degenerative action, the last three mentioned resistances being connected between the side of the load where the control tube is located and the opposite side of the load in the order r_b , r_1 and r_2 , whereby the stabilization ratio S of change of input voltage to change of output voltage may pass from positive to negative, the relative relationship of the foregoing factors being

$$S = 1 + \frac{R_s}{R_s + r_{p_3}} \left[\frac{r_{p_3}}{R_L} + \frac{an_1n_2\mu_3}{1 - an_1n_2r_b/r_{s_3}} \right]$$

where

$$a = \frac{r_1}{r_1 + r_2 + r_b}$$

LYMAN G. PARRATT.
JOHN W. TRISCHKA.