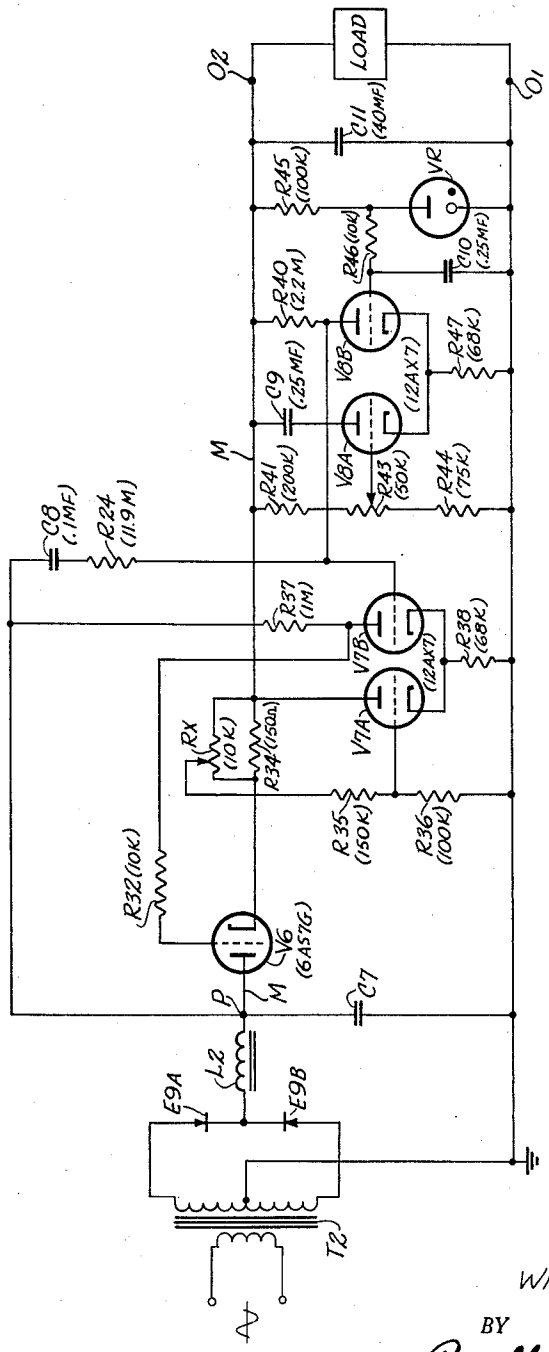
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LOAD COMPENSATED VOLTAGE REGULATED POWER SUPPLIES

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INVENTOR.
WILLIAM F. MARANTETTE

BY
Reynolds, Bench & Christensen

ATTORNEYS

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LOAD COMPENSATED VOLTAGE REGULATED POWER SUPPLIES

William F. Marantette, Manhattan Beach, Calif., assignor to Boeing Airplane Company, a corporation of Delaware

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This invention relates to electronic voltage regulating apparatus and more specifically concerns a novel circuit arrangement for increasing the effectiveness of certain types of voltage regulators or stabilizers in relatively simple manner. The invention is herein illustratively described by reference to its presently preferred form; however, it will be appreciated that certain changes and modifications therein may be made without departing from the essential features presented.

The type of voltage stabilizer circuit upon which the present illustration is based is used extensively, since it compensates not only for changes of input voltage but also for the effect of changing load current, and it has a low internal impedance between its output terminals. This circuit is essentially a two-stage, inverse-feedback circuit having means amplifying changes of output voltage and applying the amplified changes to the control grid of a second amplifier having its space discharge path arranged in series with the load circuit. The effective combined gain of this two-stage circuit determines the degree of regulation achieved. For certain applications requiring very close regulation of a direct voltage it becomes a problem to provide the necessary gain without unduly complicating the circuit or rendering it unstable.

In essence, the present invention provides a relatively simple and very desirable arrangement for stabilizing the output voltage against variation caused by changes of load current. The action of the novel circuit may be compared with voltage stabilizers of the above-described basic type having extremely high gain approaching infinity.

Still another object of the invention is an improved voltage stabilizer circuit having variable load compensation means by which a substantially constant output voltage may be produced as a function of changing load current, or a sloping (positive or negative) output voltage characteristic may be achieved if desired.

In accordance with the invention the improved stabilizing action which compensates for load current changes is achieved by interposing a resistance element in the load current path. The end of this resistance element opposite that nearest the output or stable-voltage terminal of the circuit is coupled to a mixing or adding circuit so that the latter is subjected to a rising or falling signal potential with changes in load current. The mixing or adding circuit is also impressed with a second signal potential representing the difference between a constant reference potential and a portion of the stablized output voltage. The resultant control voltage thus produced by the mixing circuit represents the summation of the two signal potentials and is applied to the control element of the series-connected amplifier mentioned above. This resultant control voltage correctively varies the series-connected amplifier impedance and thereby the voltage drop across said amplifier as necessary in order to regulate circuit output voltage.

If the series resistance is carefully selected or adjusted

to a certain value the output voltage-current characteristic of the stabilizer circuit may be made virtually as flat or constant as the basic form of stabilizer circuit having no such load compensation feature, but incorporating amplifiers having very large gain approaching infinity. A larger or smaller series resistance may also be used if it is desired to achieve a sloping output voltage-current characteristic in the stabilizer circuit.

These and other features, objects and advantages of the invention will become more fully evident from the following description by reference to the accompanying drawing which comprises a schematic diagram of the improved stabilizer circuit.

Referring to the diagram, direct voltage to be stabilized or regulated is produced by the full-wave rectifying circuit comprising transformer T2 and rectifiers E9A and E9B, the output of which is passed through the L-section filter comprising choke L2 and condenser C7. The resultant unregulated direct voltage appearing at the filter output point P is positive with reference to ground potential; however, it will be appreciated that the principles of the invention may be applied to voltage stabilizer circuits in which a negative potential is regulated. The stabilizer circuit output voltage appears between the grounded terminal O1 and the positive terminal O2. A load drawing current from the regulated power supply is shown connected across these output terminals.

Conductor M interconnects the positive output terminal O2 and the rectifier output point P, hence carries the load current delivered by the power supply. A triode amplifier tube V6 is interposed in conductor M with the anode of this tube connected to point P and the cathode to terminal O2. Since the space discharge path through the tube V6 carries the load current, the output voltage appearing between terminals O1 and O2 may be varied by controlling the potential applied to the control grid of such tube. The output voltage developed by the circuit through the action of tube V6 is established at a normal value by that portion of the stabilizer circuit which is sensitive to departures of output voltage from the regulated value, according to known basic principles. That portion of the circuit which operates to produce this result will now be described. Suitable components and component values are indicated on the diagram for a practical circuit.

A gaseous discharge voltage regulator tube VR, having its cathode connected to ground, has its anode connected through a load resistance R45 to that portion of conductor M which carries the positive output potential. The potential at the anode of regulator tube VR remains substantially constant despite any tendency for the circuit output voltage to vary, hence serves as a reference potential which is applied through grid leak resistor R46 to the control grid of triode amplifier V8B. A condenser C10 serves as the by-pass for the grid circuit. The resistors R41 and R44 connected in series with the winding of potentiometer R43 serve as a voltage divider connected effectively across the circuit output terminals O1 and O2. The wiper of potentiometer R43 is connected directly to the control grid of triode amplifier V8A, the anode of which is connected directly to conductor M or output terminal O2. Amplifier V8A is of the cathode-follower type since its load resistance R47 is connected between cathode and ground. As shown, amplifier V8A is cathode-coupled to amplifier V8B and as a result the potential appearing at the cathode of V8B is directly proportional to that applied to the control grid of V8A. The latter in turn is directly proportional to the stabilizer circuit output voltage as presented at terminals O1 and O2. Consequently, the difference of potential between the control grid and the cathode of V8B is the difference between a constant reference potential and a variable po-

tential which changes directly in proportion to any change in circuit output voltage.

The amplified difference of potential appearing at the anode of V8B, representing a departure of stabilized output voltage from the desired value, is applied directly to the control grid of a second-stage triode amplifier V7B, wherein there is further amplification of this difference potential before its application as a control signal to the control grid of the series-connected amplifier V6. Should the output voltage appearing across terminals O1 and O2 tend to rise above normal voltage, the anode potential of V8B will rise proportionately but to an amplified degree, whereas the anode potential of V7B will drop proportionately but to a greater amplified degree for increasing the resistance presented by the space discharge path of amplifier V6. A greater voltage drop then takes place in amplifier V6, tending to restore the circuit output voltage to its normal value. A reverse action takes place to the same ends if output voltage tends to drop below normal voltage. The degree to which any such output voltage departure is offset or compensated by varying the resistance of tube V6 is, of course, dependent on the degree of amplification taking place in the amplifier circuit converting such voltage deviations into an amplified control signal applied to the control grid of V6. Were it possible in a practical circuit to achieve virtually infinite amplifier gain, that portion of the circuit thus far described would exercise a sufficient regulatory action for all practical purposes since the output voltage in that case could never vary appreciably from the preselected normal value. However, practical considerations prevent such an attainment in most cases.

For optimum results in that portion of the circuit thus far described, the plate load resistance R40 for amplifier V8B is chosen so that the quiescent current in this amplifier is a small fraction of that flowing through the companion amplifier V8A, and amplifier V8B is thereby operated at maximum gain level. The same basic design considerations apply to the choice of plate load resistor R37 for tube V7B. Furthermore, plate supply voltage for this latter tube is derived directly from the filter output terminal P ahead of series-connected amplifier V6 in order that the potential applied to the control grid of V6 may be above the cathode potential of this tube. Grid resistor R32 is a parasitic oscillation suppressor. Resistor R37 limits the flow of grid current in amplifier V6.

As an incidental refinement, removal of ripple voltage from the stabilizer circuit output voltage is accomplished by superimposing upon the normal signal applied to the control grid of V7B a selected portion of the ripple voltage appearing at point P in the circuit. Thus, the control grid of V7B is connected to circuit point P through a large series resistance R24 and a D. C. blocking condenser C8. The ripple voltage phase inversion taking place in amplifier V7B produces a resultant amplified ripple voltage correction signal which when applied to tube V6 effects substantially complete nullification of the ripple voltage which would otherwise be transmitted from point P through tube V6 to the output terminal O2. A voltage divider is formed by series-connected resistances R24 and R40, providing the correct amount of ripple voltage applied to the grid of V7B to achieve substantially complete cancellation.

In accordance with the present invention the control signal developed at the anode of tube V7B is not merely the amplified difference potential, produced at the anode of tube V8B, but is the summation of this amplified difference potential and a second signal potential which is proportional to load current. As previously mentioned, the effect of combining the two signals for control purposes may be made substantially equivalent to the action of a conventional stabilizer circuit having a very large gain approaching infinity. To achieve this result a resistance R34 is interposed in the conductor M such that one end of this resistance has a potential equal to the potential of output terminal O2, whereas its opposite end has a potential equal to that potential plus the product of such resistance and the load current flowing in conductor M. The latter end of resistance R34 is connected to the cathode of amplifier V6 directly and to one end of a voltage divider comprising resistances R35 and R36, the intermediate point between which is connected directly to the control grid of amplifier V7A. The anode of amplifier V7A is placed at the potential of output terminal O2, whereas its cathode is connected to ground through a load resistance R38. The cathodes of V7A and V7B are interconnected. Hence the potential applied to the cathode of amplifier V7B is directly proportional to the sum of the potential at output terminal O2 and the IR drop in resistance R34, or a fraction of such voltage drop depending upon the setting of potentiometer RX having a large resistance winding connected in shunt to resistance R34 and having its wiper connected to resistance R35.

Inasmuch as the potential at the output terminal O2 is substantially constant, whereas load current may vary considerably, it is correct to state that the potential applied to the cathode of amplifier V7B varies directly in accordance with changes in load current. If load current increases, there will be a proportionate increase in the potential at the cathode of V7B and the effect thereof will be an increase in the resultant amplified control signal applied by amplifier V7B to the control grid of series-connected amplifier V6. Likewise, if the load current decreases, there will be a proportionate decrease in the potential applied to the control grid of V6. By proper choice of the value of resistance R34, and, if necessary, corrective adjustment of potentiometer RX, such increase or decrease of potential applied to the control grid of V6 accompanying increase and decrease of load current will compensate precisely for the normally expected respective decrease and increase of output voltage appearing across terminals O1 and O2. Potentiometer RX is not necessary if the value of resistance R34 is chosen initially with exactitude for accomplishing the desired load compensation in the stabilizing circuit. However, by incorporating this potentiometer in shunt to the resistance R34, or by adopting an equivalent arrangement for adjusting the amount of compensating voltage derived from load current and applied to the control grid of amplifier V7A, a refined adjustment for precise compensation may be made. Alternatively, adjustments of this potentiometer may be made to achieve over-compensation or under-compensation, where desired.

It will be observed that the load current compensation circuit just described does not replace nor remove the need for the previously described portion of the circuit which provided corrective action in response to changes in output voltage. Instead, it supplements the action of the latter and relieves the latter of any regulatory action beyond that necessary to establish the normal operating voltage between terminals O1 and O2 when the load current is equal to zero in the ideal case. Practically speaking, however, that portion of the circuit producing a control signal proportionate to departures of output voltage from the normal value serves the additional purpose of regulating output voltage throughout changes of load current to the extent, if any, that the load current compensating section of the circuit comprising resistance R34, voltage divider R35 and R36, together with amplifier V7A, fails to provide precise compensation. Since the over-all gain of amplifiers V8B and V7B is normally quite limited, the regulatory action which they afford may be over-ridden in one case so as to produce an output voltage-current characteristic of positive slope, if the size of resistance combination R34, RX is sufficiently greater than the effective value required for precise load current compensation, or of negative slope if such resistance is of a smaller size so that the circuit undercompensates.

That portion of the circuit providing load current compensation greatly extends the range of permissible load current variation which may take place without the output voltage exceeding given upper and lower limits.

Since there is no appreciable time constant or lag involved in the operation of the current compensation portion of the circuit, the operation is virtually independent of the rate of change of load current. This is true except as to very high frequencies. As to the latter, a filter condenser C11, connected across the output terminals O1 and O2, is desirable, and this condenser also has the effect of overcoming any tendency for the circuit to oscillate. Condenser C9 by-passing the upper portion of the voltage divider provides enhanced damping of high-frequency fluctuations tending to develop in the output voltage. These are fed directly to the control grid of V8A, amplified and applied with degenerative phasing to the control grid of V6.

I claim as my invention:

1. In combination, a source of direct voltage, a load circuit, means including a variable resistance device carrying load current from said source to said load circuit and having control means operable to vary the resistance of said device in accordance with variations of voltage applied to said control means and thereby vary the voltage drop occurring in such device, said circuit means further including a resistance element carrying at least a portion of such load current and thereby developing a first control voltage proportional to such load current, means providing a substantially constant reference voltage, means comparing said constant reference voltage with a variable voltage proportional to that applied to said load circuit for producing a resultant second control voltage proportional to the difference between said constant reference voltage and said variable voltage, hence proportional to departures of said load voltage from a normal value, and circuit means applying said first and second control voltages in additive relationship to the control means of said variable resistance device whereby the resistance of said variable resistance device, hence the voltage drop therein, is increased in response to an increase of voltage applied to the load circuit and in response to a decrease of load current.

2. The combination defined in claim 1, wherein the resistance element includes means for varying the resistance thereof, hence the voltage drop occurring in said resistance element for a given value of load current.

3. A voltage stabilizer circuit including input connections for the reception of a direct voltage to be stabilized, output connections for application of stabilized output voltage to a load circuit, a variable resistance device interposed between said input and output connections for carrying load current delivered from said output connections, said variable resistance device having control means operable to vary the resistance of said device in accordance with variations of voltage applied to said control means and thereby vary the voltage drop occurring in such device, a resistance element interposed between said input and output connections to carry at least a portion of such load current and thereby develop a first control voltage proportional to such load current, means providing a substantially constant reference voltage, means comparing said constant reference voltage with a variable voltage proportional to said output voltage for producing a resultant second control voltage proportional to the difference between said constant reference voltage and said variable voltage, hence proportional to departures of said output voltage from a normal value, and circuit means applying said first and second control voltages in additive relationship to the control means of said variable resistance device whereby the resistance of said variable resistance device, hence the voltage drop therein, is increased in response to an increase of output voltage and in response to a decrease of load current.

4. The combination defined in claim 3, wherein the resistance element includes means for varying the resistance thereof, hence the voltage drop occurring in said resistance element for a given value of load current.

5. A voltage stabilizer circuit including input connections for the reception of a direct voltage to be stabilized, output connections for application of stabilized output voltage to a load circuit, variable resistance means interposed between said input and output connections for carrying load current delivered from said output connections, said variable resistance means control means operable to vary the anode-cathode resistance thereof in accordance with the variations of voltage applied to said control means, and thereby vary the voltage drop occurring in said variable resistance means, a resistance element interposed between said variable resistance means and one of said output connections to carry at least a portion of such load current and thereby develop a first control voltage proportional to such load current, means including a gaseous discharge tube connected across said output connections and providing a substantially constant reference voltage, voltage divider means connected across said output connections and providing a voltage proportional to said output voltage, a first voltage-comparing amplifier means having an output terminal and two input terminals, one of said input terminals receiving said constant reference voltage and the other of said input terminals receiving said voltage divider voltage for producing a resultant second control voltage at said output terminal proportional to the difference between said latter two voltages, a second voltage-comparing amplifier means having an output terminal and two input terminals, and means applying at least a portion of said first control voltage to one of said latter input terminals, the other of said latter input terminals receiving said second control voltage, the output terminal of said second voltage-comparing amplifier means being connected to said variable resistance device control means, whereby the resistance of said variable resistance means, hence the voltage drop therein, is increased in response to an increase of output voltage and in response to a decrease of load current.

References Cited in the file of this patent

UNITED STATES PATENTS

2,443,541	Neustadt	June 15, 1948
2,594,006	Friend	Apr. 22, 1952

FOREIGN PATENTS

472,326	Great Britain	Sept. 22, 1937
608,666	Great Britain	Sept. 20, 1948

OTHER REFERENCES

D. C. Stabilized Power Supply of Low Impedance, by V. H. Attree-Review of Scientific Instruments, vol. 25, August 1948, pp. 263–268 incl.