

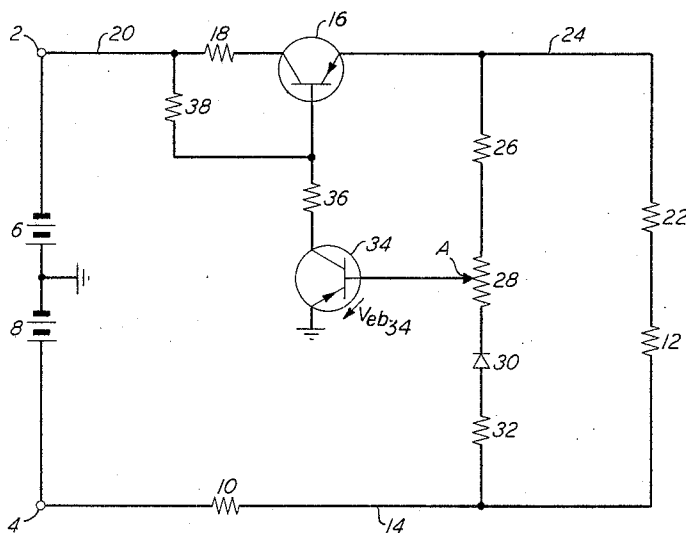
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VOLTAGE REGULATOR EMPLOYING A VOLTAGE DIVIDER HAVING AN
INTERMEDIATE POINT AT A REFERENCE POTENTIAL

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VOLTAGE REGULATOR EMPLOYING A VOLTAGE DIVIDER HAVING AN INTERMEDIATE POINT AT A REFERENCE POTENTIAL

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This invention relates to an electronic regulator and more particularly to a direct current voltage regulator which will maintain electrical symmetry between a positive voltage and a negative voltage with respect to a reference potential such as ground irrespective of a non-symmetrical variation of the input voltage or of changes in the output voltage due to load conditions.

Many load devices require that symmetrical voltages with respect to a reference such as ground potential be applied and maintained at all times. One such device requiring symmetrical voltages is described, for example, in the copending application by the applicant of the present invention entitled, "A Broadband Gate," filed April 14, 1961, Serial No. 113,974, now Patent No. 3,127,564, and assigned to the assignee of the present invention. This application discloses an electronic gate wherein the gate is made to change between a high impedance state and a low impedance state by changing the polarity of a symmetrical control voltage which is applied to the gate. The control voltage is prevented from passing to the transmission lines connected to the gate by reason of the fact that the gate forms a balanced bridge to this direct-current control voltage. Thus, it is imperative that the control voltage be symmetrical at all times, i.e., since the arms of the bridge are equal, the currents through the arms must likewise be equal in order that no voltage appear at the output of the bridge; this condition can only be achieved if the control voltage is symmetrical.

In the above-described gate, as well as in many other circuits, the symmetry of a supply or control voltage is a necessary condition if optimum performance is to be obtained.

Thus, the object of the present invention is to simplify and improve the performance of voltage sources designed to produce symmetrical outputs.

Accordingly, one embodiment of the present invention comprises a plurality of transistors, a voltage divider, and a double-ended source of direct-current potential which may comprise two separate sources (i.e., the negative terminal of one source is connected to the positive terminal of the other source to form a supply having opposite polarities and the common point of these two sources is taken as a reference and may thus be grounded). The collector-emitter circuit of a first transistor is connected in series between one of the two sources of supply voltage and the load. A resistor is connected between the other source and the load. The voltage divider is connected in parallel with the load and comprises a number of resistors and a diode. The base of the first transistor is connected, through a biasing resistor, to the collector of the second transistor; the emitter of which is grounded. The base of the second transistor is con-

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nected to a tap on the voltage divider and a biasing resistor is connected between the base of the first transistor and the double-ended source to thereby bias said first transistor. The circuit is adjusted so that a symmetrical voltage appears initially at the load. Thereafter any unsymmetrical voltage changes at the load will appear across the voltage divider network and be detected and amplified by the second transistor which will thereupon readjust the resistance of the first transistor to maintain a symmetrical voltage across the load.

The following detailed description taken in conjunction with the drawing will fully illustrate the features of the present invention.

In the drawing, the single figure is a schematic circuit diagram of a regulator according to the invention. As shown, a pair of input terminals 2 and 4 is connected to sources of direct-current voltage of opposite polarity. Conveniently the sources may comprise a battery 6 and a battery 8. The negative terminal of battery 6 and the positive terminal of battery 8 are connected to the input terminals 2 and 4, respectively; the other terminals of each battery are connected to ground. (It is to be understood that the sources are indicated as batteries only by way of illustration and may be any source of direct-current voltages such as power supplies.) A resistor 10 is connected between terminal 4 and a load resistor 12 by a lead 14. The collector of a PNP transistor 16 is connected in series with a resistor 18 which is connected to terminal 2 by a lead 20. The emitter of transistor 16 is connected to a load resistor 22, equal to the value of resistor 12 by a lead 24. The load is schematically depicted herein as comprising resistors having equal value of resistance. It is to be noted however, that this is for illustrative purposes only and the load is not to be limited to resistors but can be any load requiring symmetrical voltages such as the gates of the aforementioned application.

A voltage divider comprising a resistor 26, a potentiometer 28, a diode 30 and a resistor 32, which may be equal in value to resistor 26, are connected between leads 14 and 24. The base of a PNP transistor 34 is connected to the slider of potentiometer 28. The anode of the diode 30 is connected to resistor 32. The emitter of transistor 34 is grounded and the collector of transistor 34 is connected to the base of transistor 16 through a resistor 36. A biasing resistor 38 is connected between lead 20 and the base of transistor 16.

Initially, in the present embodiment, the voltage at the base of transistor 34 is adjusted by means of the slider of potentiometer 28 so zero voltage will appear between the junction of resistors 22, 12 and ground. This will mean that the voltages on leads 24 and 14 must be equal and opposite to one another since the resistors 22 and 12 are equal. These symmetrical output voltages will be obtained due to the voltage drops across resistor 10 and transistor 16, respectively. For this condition diode 30 will be forward biased, as will be more fully discussed below. The resistors 18 and 36 are used for lowering the collector-to-emitter potential of the transistors and thus decreasing their power dissipation. For the assumed initial condition, the current through resistor 38 will comprise the current flowing out of the base of transistor 16 and the current flowing out of the collector of tran-

sistor 34, and further, the voltage drop across this resistance will determine the collector-base bias of transistor 16, thereby fixing the collector-to-emitter voltage drop of transistor 16 at some predetermined level.

If one of the supply voltages is either increased or decreased this change will appear at the load and also across the voltage divider. This change in voltage across the voltage divider will be detected by transistor 34, in the manner noted below, thereby changing the collector current of transistor 34, either increasing or decreasing this current. This will change the current through resistor 38 which will change the collector-to-base bias of transistor 16 thereby readjusting the collector-to-emitter drop of transistor 16 to maintain a symmetrical voltage at the load.

It is of special importance to note that the diode 30 must have a voltage drop which is equal to twice the voltage drop from the emitter to the base of transistor 34 to balance the voltage divider about ground. It is believed the following example will more clearly point out the operation of the present invention and also the reason for the foregoing limitation.

By way of illustration it is assumed in the following that the respective output voltages across resistors 12 and 22 will be plus 10 volts and minus 10 volts with respect to ground.

The emitter-base circuit of transistor 34 may be thought of as a forward biased PN diode. It is characteristic of such diodes that voltage across the forward-biased circuit will be fairly independent of the current through it. Therefore point A on potentiometer 28 may be thought of as being maintained at the same potential with respect to ground at all times and this potential will be equal to the voltage from the emitter to the base of transistor 34. Assuming for example this potential is minus 5 volts, point A may be thought of as always being at minus 5 volts. As noted above, for proper operation of the circuit about the reference ground diode 30 must have a voltage drop of twice the emitter-to-base voltage drop of transistor 34, the voltage across this diode will be 10 volts. Assuming the initial quiescent condition noted hereinabove, the voltage at leads 14 and 24 may be shown as follows to be plus 10 volts and minus ten volts, respectively.

The drop across the base-emitter circuit of transistor 34 will always be negative. Since the current flowing into this circuit is negligible compared with the current flowing through the voltage divider it follows that the voltage drop in the series circuit extending from lead 14 to lead 24 and including the equal resistors 32 and 26 will have to be made up of a larger drop across the portion including resistor 32 and diode 30 and a smaller portion across resistor 26 because point A is at a negative potential with respect to ground. Potentiometer 28 is for balancing purposes and may be assumed to make equal contributions in the drop of the two branches. It therefore follows that whatever the magnitude of the drop across the emitter-base circuit of transistor 34, the drop across diode 30 must be of twice that magnitude to balance the voltage divider with respect to ground.

The operation of the circuit may now be considered by assuming a change in the voltage appearing on one lead. If the voltage at lead 14 now drops to $7\frac{1}{2}$ volts, a severe dissymmetry in the output occurs unless corrected by the regulator. The voltage drop across resistor 32 must be $2\frac{1}{2}$ volts because there is now a $12\frac{1}{2}$ volt drop from lead 14 to point A and the diode voltage drop is 10 volts. The voltage drop across resistor 26 must equal the voltage drop across resistor 32 and will be minus $2\frac{1}{2}$ volts for the above-noted reason. Thus, the voltage on lead 24 will now be equal to the minus 5 volts which is at point A added to the minus $2\frac{1}{2}$ volts across resistor 26 which equals minus $7\frac{1}{2}$ volts. This is equal to the assumed change of voltage on lead 14 (i.e., plus

$7\frac{1}{2}$ volts) although the preferred embodiment contemplates equal resistances in the voltage divider, it is obvious that the magnitude of the voltages appearing on leads 14 and 24 will be in the same ratio as the respective resistors 32 and 26. The transistors operate as follows to maintain the symmetry.

As noted above, the emitter-base circuit of transistor 34 may be thought of as a forward biased PN diode and, for all practical purposes, the voltage across this junction will be independent of the current through it. However, the voltage across a forward biased diode is never really independent of the current through it but will vary slightly. Although this variation need not be considered when taking into account the voltage at point A since the voltage variation is minute, it may not be excluded when considering the collector current of transistor 34. That is, this very slight variation of voltage with respect to the reference ground at the base of transistor 34 will change the collector current of transistor 34 substantially. Thus, when the voltage on lead 14 changes, as in the above-noted example, it will be transmitted to the base of transistor 34 and the current flowing out of the collector of transistor 34 and, therefore, through the resistor 38, will be changed due to this very slight variation of voltage at the base of transistor 34. This change in collector current will change the voltage drop across resistor 38 thereby changing the collector to base bias of transistor 16. This will change the collector-to-emitter voltage drop across transistor 16 to maintain the symmetrical voltage on leads 24 and 14.

It is to be noted that only one embodiment of the invention has been disclosed in this application. However, it will be obvious to those skilled in the art that changes can be made in the circuitry without departing from the spirit of this invention. That is, one may use NPN transistors rather than the PNP transistors disclosed and connect the regulating transistor in series with the positive source rather than in series with the negative source as described above.

What is claimed is:

1. A power supply system including a double-ended source of direct-current potential having positive and negative terminals relative to an intermediate reference potential, a load circuit having two terminals, and circuit means connecting said source to said load for maintaining a predetermined ratio between the voltages at the two terminals of said load with respect to said reference potential, said circuit means comprising a variable impedance inserted between one terminal of said source and one terminal of said load, a resistive voltage divider connected between the terminals of said load, said divider having an intermediate point for which the resistance between said point and one load terminal bears said predetermined ratio to the resistance between said point and the other load terminal, a transistor having its base electrode connected to said point and its emitter electrode connected to said reference potential and having an inherent emitter-base voltage drop such that said point has a potential different from said reference potential, and a source of bias potential included in said voltage divider for making the potential difference between said intermediate point and the potential of the voltage center of said divider equal to said emitter-base drop and the potential of said center equal to said reference potential.

2. A power supply system including a double-ended source of direct-current potential having positive and negative terminals relative to an intermediate reference potential, a load circuit having two terminals, and circuit means connecting said source to said load for maintaining a predetermined ratio between the voltages at the two terminals of said load with respect to said reference potential, said circuit means comprising a variable impedance inserted between one terminal of said source and one terminal of said load, a resistive voltage divider con-

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nected between the terminals of said load, said divider having an intermediate point for which the resistance between said point and one load terminal bears said predetermined ratio to the resistance between said point and the other load terminal, means responsive to said voltage difference comprising a transistor having its base electrode connected to said point and its emitter electrode connected to said reference potential and having an inherent emitter-base voltage drop, and a diode having a voltage drop equal to twice said emitter-base voltage drop included in series in said voltage divider.

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