

[54] **POWER SUPPLY WITH TEMPERATURE COMPENSATED CURRENT FOLDBACK**
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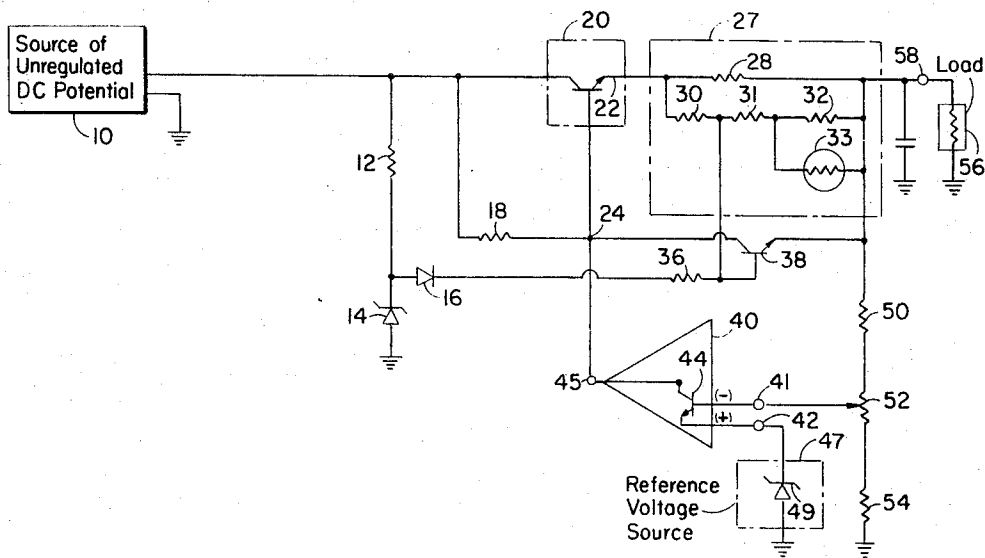
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[57] **ABSTRACT**

A power supply with overload current foldback employs series regulating feedback circuitry for normally controlling the base potential of a series pass transistor. A current limiting transistor selectively connects the pass transistor base and power supply output terminals for reducing pass transistor drive responsive to overload conditions. A temperature responsive load current sensing network is employed to maintain the peak available power supply output current constant, and a constant potential source is utilized for the foldback circuitry to render the foldback characteristic independent of line voltage variations.

2 Claims, 2 Drawing Figures



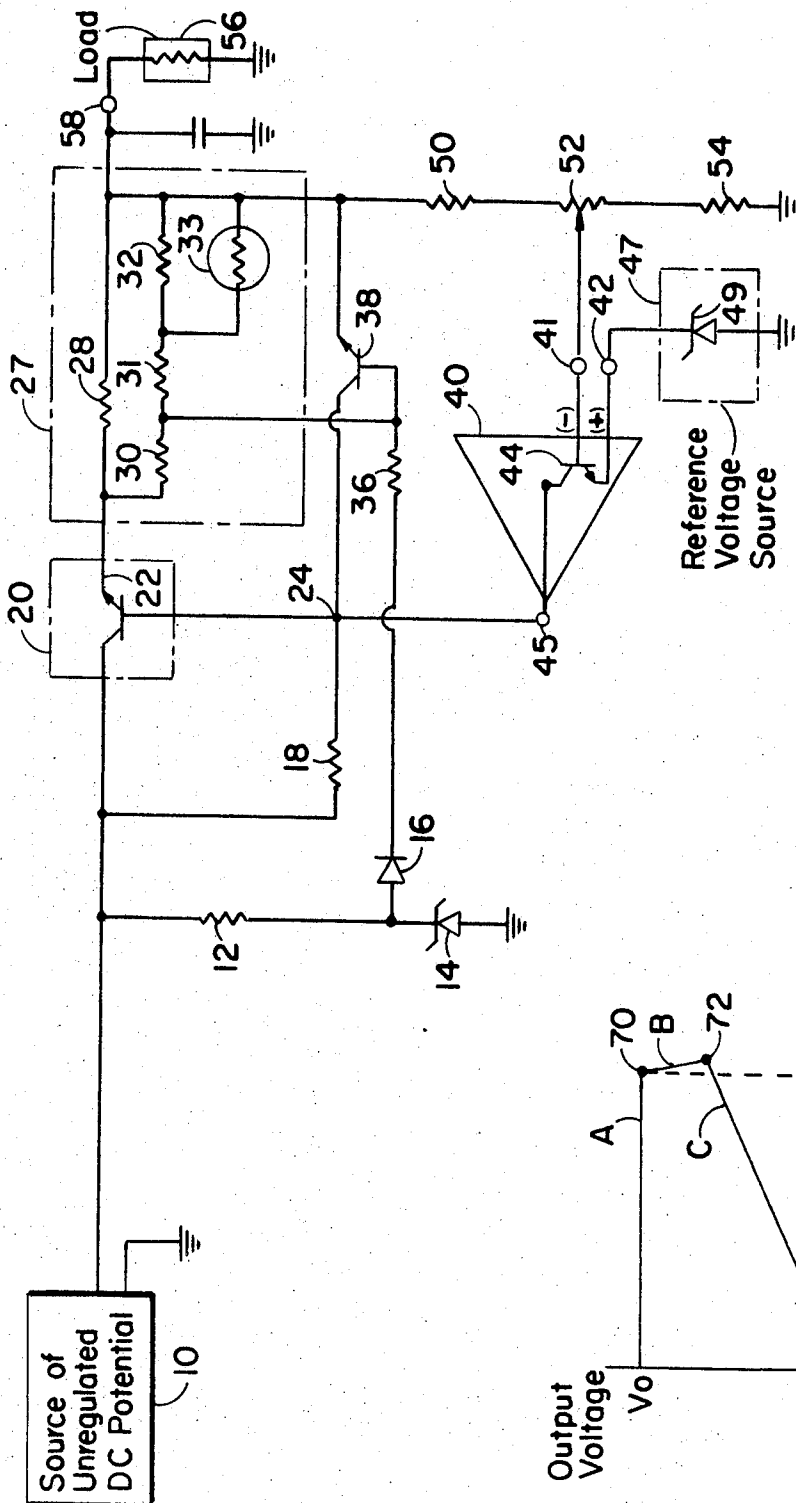


FIG. 1

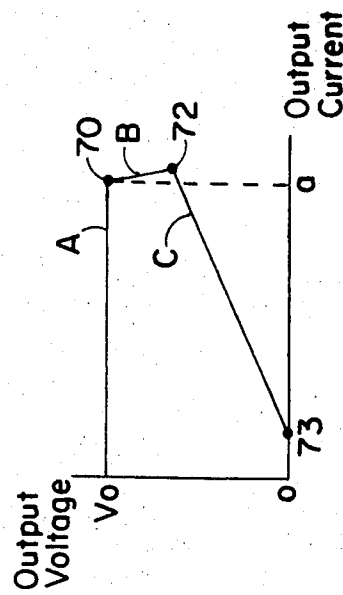


FIG. 2

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POWER SUPPLY WITH TEMPERATURE COMPENSATED CURRENT FOLDBACK

DISCLOSURE OF INVENTION

This invention relates to regulated electronic power supplies and, more specifically, to improved overload protection circuitry therefor.

In a regulated voltage source, it is desirable to provide overload protection, i.e., to limit the maximum current which may be drawn from the supply by a load. Absent such structure, the load current would increase without bound as the load increases (to a short circuit in the limiting case) as the regulator elements attempt to maintain the prescribed source output voltage. If the load current becomes excessive, damage may result in power supply components, or in the load.

A load current sensing impedance has heretofore been placed in series between the voltage series regulator transistor and the load, and the voltage developed across the sensing impedance (a measure of load current) selectively employed when it attains a threshold value for preventing any further significant increase in power supply output current. The mechanism typically employed for this purpose is the controlled reduction of base drive potential from the series pass transistor in the voltage regulator. Further, current foldback has heretofore been employed to quantitatively reduce output current from its maximum permissible level as the overload condition becomes increasingly severe. Current foldback has illustratively been implemented by employing a threshold switching device which is responsive to output potential. The fault-enabled switching transistor or the like removes drive from the series current passing regulator transistor when the output potential markedly decreases, as by the application of a short circuited load to the regulated supply.

However, such prior art protective circuitry has been relatively complex and, moreover, sensitive to changes in temperature, line voltage and other parameters. Thus, for example, the maximum current provided by the composite power supply has varied with such ambient conditions.

It is thus an object of the present invention to provide improved power supply protective circuitry.

More specifically, it is an object of the present invention to provide a power supply exhibiting foldback current limiting, wherein the maximum available power supply current is maintained constant notwithstanding temperature variations.

The above and other objects of the present invention are realized in a specific illustrative foldback current limiting power supply which employs a series pass transistor and a load current monitoring impedance network for providing a regulated potential from an unregulated source thereof to a load. Regulation is effected by conventional feedback principles, wherein a difference amplifier compares a measure of the output potential with a fixed reference voltage. The amplifier automatically supplies to the base of the series pass (voltage dropping) transistor an appropriate voltage such that the selected output potential is maintained substantially constant.

In accordance with the principles of the present invention an additional current limiting protective transistor has its collector-emitter principal conduction path connected between the base of the series regulator

transistor and the power supply output terminal. The base of the protective transistor has supplied thereto a load current dependent signal developing by the current sensing impedance, and a fixed, independently regulated potential via a suitable impedance.

The additional transistor responds to current overload conditions by selectively removing base drive potential from the series pass transistor to prevent the current from increasing significantly beyond its prescribed maximum value. The transistor is also responsive to a decrease in supply output potential for effecting a progressive reduction in output current (current foldback).

The load current sensing impedance includes a temperature dependent element whose impedance varies with temperature in a manner which offsets the temperature-dependent characteristic of the base-emitter junction of the protective transistor. Accordingly, the conduction threshold for this transistor is effectively maintained constant with temperature, thus providing a maximum output current for the composite power supply which does not vary with temperature. The regulated d.c. voltage directly coupled to the base of the current limiting transistor renders the device insensitive to line voltage variations.

The above and other features and advantages of the present invention are realized in a specific, illustrative power supply embodiment, presented in detail hereinbelow in conjunction with the accompanying drawing, in which:

FIG. 1 schematically depicts a power supply with overload current foldback protection illustrating the principles of the present invention; and

FIG. 2 depicts the output characteristic for the FIG. 1 power supply.

Referring now to FIG. 1, there is shown a foldback current limiting power supply for supplying constant potential energy to a load 56 from a source of unregulated d.c. potential. The source of unregulated d.c. potential may illustratively comprise, for example, a transformer, diode bridge and filter capacitor, the d.c. potential thus exhibiting some ripple and also varying in amplitude direct with line voltage changes.

VOLTAGE REGULATION

Voltage regulation for the FIG. 1 power supply is of conventional series regulator feedback construction, and comprises a series pass, voltage dropping regulator element 20, schematically shown as a single transistor 22. The series pass member 20 may comprise plural transistors connected in a Darlington configuration. The series elements 20 is operated to instantly have disposed thereacross that voltage then necessary to maintain the power supply output potential at an output terminal 58 constant. The series pass transistor 22 therefore accommodates at its collector-emitter terminals the instantaneous voltage differences between that supplied by the unregulated source 10 and the desired output at the terminal 58.

This mode of operation is effected by obtaining a measure of supply output potential, as in a voltage divider 50-52-54 and supplying this signal to the inverting input 41 of a difference amplifier 40. A non-inverting input 42 of the difference amplifier 40 is connected to a source of fixed reference potential 47. As shown in

the drawing, the difference amplifier may simply comprise a single transistor connected in a common emitter configuration, and the reference source 47 simply comprising a zener diode. The amplifier 40 output terminal 45 (e.g., the collector of the transistor 44) is connected to the base of the series pass transistor 22. Where an adjustable power supply output voltage is desired, one element in the voltage divider, e.g., the resistance 52, is made variable such that a range of output power supply potentials can selectively provide substantially like voltages at the amplifier inputs 41 and 42.

To illustrate this conventional regulator mode of action, assume that the output potential at power supply terminal 58 attempts to decrease below its predetermined level, as by an increase in load. The decrease in potential is directly coupled to the inverting input 41 of the amplifier 40 such that an increase in potential appears at the amplifier 40 output 45. This increases the potential at the base of the series pass transistor 22 thereby also raising its output voltage such that the drop in output potential is obviated. A similar analysis will demonstrate comparable circuit action for an attempted increase in supply output potential. With reference to a portion A of the FIG. 2 power supply characteristic curve, it will thus be seen that the desired power supply output voltage V_o is maintained constant over the desired range of output current up to a peak value a .

OVERCURRENT ELIMINATION

To prevent the power supply structure of FIG. 1 from supplying more than the prescribed peak current a to the load 56, as for moderate overload conditions, the sensing impedance 27 is disposed between the series pass element 20 and the load 56. The series pass impedance includes a main load current passing, low value resistance 27 having a voltage divider 30 through 33 connected thereacross. A current limiting transistor 38 has its collector and emitter terminals respectively connected to a junction point 24 at the base of the series pass transistor 22, and to the power supply output. The base of the transistor 38 is connected to an intermediate point in the voltage divider 30-33.

During normal operating conditions for the power supply, i.e., in the range A of FIG. 2, the current flowing through the current sensing resistance 28 develops a voltage thereacross which is insufficient in amplitude to turn the transistor 38 on, that is, the voltage produced at the junction of the voltage divider resistors 30 and 31 is less than the conduction threshold for the transistor 38 (typically some value less than a volt). Thus, for proper operation of the power supply, the transistor 38 is nonconductive and performs no circuit function.

When the impedance of the load decreases such that the power supply provides a current exceeding the maximum permissible current value a of FIG. 2, the voltage developed by the resistance 28 and the voltage divider 30-33 connected thereacross reaches the conduction threshold of the transistor 38. The power supply output current is thereafter prevented from substantially increasing above this value a since any such increase in current develops a larger base-emitter drive for the transistor 38, thereby increasing its collector current which flows through a resistance 18 connected

from the collector to the base of the regulator transistor 22. Such a current flow through resistor 18 reduces the base potential of the series pass transistor 20, thus also reducing the voltage at the emitter of transistor 22 and power supply output terminal 58. Accordingly, if the gain of the above-described feedback path between transistors 22 and 38 is large, the load current increases very little above the value a as the supply output potential falls. Beyond the current point a of FIG. 2, corresponding to an operating point 70 on the power supply current-voltage characteristic, the power supply output thus enters a second (quasi-constant current) operating range B wherein output voltage decreases with increasing overload while current only slightly increases.

It is observed at this point that the base-emitter conduction threshold for a transistor, here the transistor 38, varies with changing temperature. In particular, as the temperature sensed by the transistor 38 increases, its conduction threshold decreases. Thus, absent the temperature responsive impedance 33, the peak output current value a for the FIG. 1 regulator would vary inversely with temperature. However, in accordance with one aspect of my invention, the current sensing network 27 includes a temperature responsive resistance 33, e.g., a thermistor, such that the voltage division factor effected by the network 30-33 varies in a manner which compensates for the temperature variation of the transistor. Thus, as temperature increases, the input junction of the transistor 38 becomes more sensitive and, correspondingly, the voltage division factor for elements 30-33 is reduced such that less of the voltage developing across resistance 38 is coupled to the transistor base terminal. Similar compensation occurs for a temperature decrease. Thus, the transistor 38 becomes conductive in response to a load current of magnitude a at any ambient temperature, the power supply thereby exhibiting a fixed break point 70.

CURRENT FOLDBACK

Where severe power supply load abnormalities occur, e.g., a short circuit in the extreme and not uncommon case, it is desired to reduce the output current supplied by the power supply to the load 56 below the peak value a of FIG. 2. Among other salutary benefits, this reduces both the maximum power dissipation in the series pass element 20 and also reduces the current drawn from the unregulated potential source 10.

To this end, the base of the transistor 38 is connected by a resistance 36 to a source of fixed potential developed, for example, by a zener diode 14 energized via a resistance 12. A diode 16 may be included in series with the resistor 36; the diode 16 is not essential as described hereinbelow.

In one mode of operation for the FIG. 1 foldback current limiting power supply, viz., where the diode 16 is employed, the zener diode 14 supplies an output potential less than or equal to the desired supply output voltage. Accordingly, the voltage at the base of the transistor 38 is under normal conditions at least as large as the zener potential. The diode 16 is thus normally reverse biased and non-conductive. Accordingly, the foldback current limiting structure, and its attendant operation, does not affect power supply operation in the supply performance regions A and B considered above.

Assume now that a pronounced load abnormality is impressed across the power supply output terminals. It is assumed for the present discussion that the load is gradually increased such that the fully supply characteristic of FIG. 2 is transversed. The specific response of the FIG. 1 protective circuitry to an overload varies depending upon the nature of the load (e.g., occurring at power supply start up, heavily inductive or capacitive, or the like). However, the foldback property set forth herein is operative for all such conditions. The power supply regulator attempts to supply an unbounded increasing amount of current in an attempt to increase the supply output voltage, following the operating region A of FIG. 2 to the right until the point 70 is reached. At this point, the current flowing through the current sensing resistor 28 is sufficient to turn the transistor 38 on as above discussed, and the supply voltage output drops (operating region B).

When the output voltage drops such that a point 72 of FIG. 2 is reached, the emitter of the transistor 38 is at a potential sufficiently less than that of the zener diode 14 such that the diode 16 is conductive. Accordingly, the transistor 38 thereafter operates with a relatively firm base energization source (substantially the zener voltage through source impedance 36) and becomes very heavily, increasingly conductive for each further incremental output voltage decrease. The transistor 38 thus draws a relatively large collector current through the resistor 18 to very significantly reduce the voltage at the base of the series pass transistor 22. The net effect of the above described regenerative-type action is the operating region C for the FIG. 1 power supply. At the end point 73 for an almost completely short circuited load, the output voltage approached zero, and the output current assumes some low value dependent upon the specific circuit components selected. Thus, for example, the terminal load current may simply comprise that passed by the transistor 38 - the unit 38 operating at saturation to completely cut off the series pass element 20. Depending upon the performance desired, and correspondingly the component values employed, the composite FIG. 1 circuit may latch in this foldback state to require manual restarting (and thereby signal a fault condition to an operator), or may be automatically restarted when the overload is removed.

The diode 16 renders operation of the protection transistor 38 in the overcurrent sensing mode i.e., range B) essentially independent of the current foldback supply a series impedance 12-14-16. The diode is not essential, however. When the diode is not employed, the zener 14 voltage and the resistor 36 are selected to quiescently provide a base-emitter biasing potential for transistor 38 less than its conduction threshold. Current limiting and foldback then proceed as above-described.

The above described arrangement has thus been shown to accommodate power supply overloads of any severity, and to operate in a reliable manner notwithstanding temperature and power line voltage variations.

The above described arrangement is merely illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those skilled in the art without de-

parting from the spirit and scope of the present invention.

I claim:

1. In combination in a power supply circuitry for effecting foldback current limiting, series pass transistor means including first and second terminals having a main conduction path therebetween and a control terminal, a power supply output terminal, current sensing impedance means disposing intermediate a first one of said series pass main conduction terminals and said power supply output terminal, feedback amplifier means including means for comparing a measure of the output potential at said power supply output terminal with a fixed reference voltage and for supplying at said control terminal of said series pass transistor means an output potential dependent upon said comparison, an additional transistor having collector and emitter terminals thereof respectively connected to said control terminal of said series pass transistor means and said power supply output terminal, a potential source, foldback impedance means connecting the base of said additional transistor with said potential source, said current sensing impedance means comprising temperature responsive resistance means connected in parallel with the base-emitter junction of said additional transistor for offsetting the temperature dependent conduction threshold of said additional transistor wherein said current sensing impedance means and said temperature responsive resistance means comprise a first load current passing impedance, resistive voltage divider means connected in parallel with said current passing resistance, said voltage divider including in one branch thereof said temperature responsive resistance means.

2. In combination in a power supply circuitry for effecting foldback current limiting, series pass transistor means including first and second terminals having a main conduction path therebetween and a control terminal, a power supply output terminal, current sensing impedance means disposing intermediate a first one of said series pass main conduction terminals and said power supply output terminal, feedback amplifier means including means for comparing a measure of the output potential at said power supply output terminal with a fixed reference voltage and for supplying at said control terminal of said series pass transistor means an output potential dependent upon said comparison, an additional transistor having collector and emitter terminals thereof respectively connected to said control terminal of said series pass transistor means and said power supply output terminal, a potential source, foldback impedance means connecting the base of said additional transistor with said potential source, said current sensing impedance means comprising temperature responsive resistance means connected in parallel with the base-emitter junction of said additional transistor for off-setting the temperature dependent conduction threshold of said additional transistor wherein said potential source comprises means for providing a constant output potential independent of line voltage variations further comprising a diode connected in series with said foldback impedance means, and wherein said potential source includes means for providing a voltage of sufficiently small value wherein said diode is reverse biased during normal power supply operation.

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