United States Patent

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[72] Inventors **Jack W. Hunger**
Hennepin, Minn.;
David D. Kemp, Santa Clara, Calif.

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[73] Assignee **Honeywell Inc.**
Minneapolis, Minn.

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[54] **DC VOLTAGE REGULATOR EMPLOYING AN FET CONSTANT CURRENT SOUCE AND CURRENT FLOW INDICATOR**
7 Claims, 1 Drawing Fig.

[52] **U.S. Cl.** **323/4,** 307/235, 323/16, 324/76
[51] **Int. Cl.** **G05f 1/58**
[50] **Field of Search** ..... 323/16, 22 (T), 22 (Z), 4 (Termatrex), 9 (Termatrex), 16—22 (Termatrex); 307/(Inquired), 23; 340/(Inquired), 213, 248; 324/76; 317/(Inquired)

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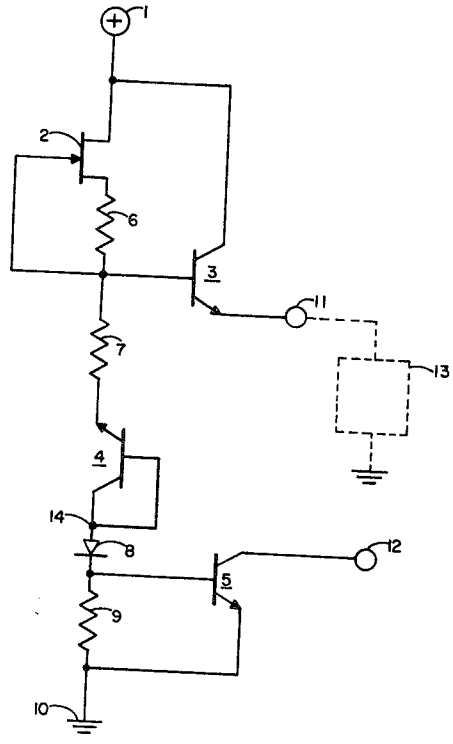
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Primary Examiner—J. D. Miller
Assistant Examiner—G. Goldberg
Attorneys—Charles J. Ungemach, Ronald T. Reiling and Albin Medved

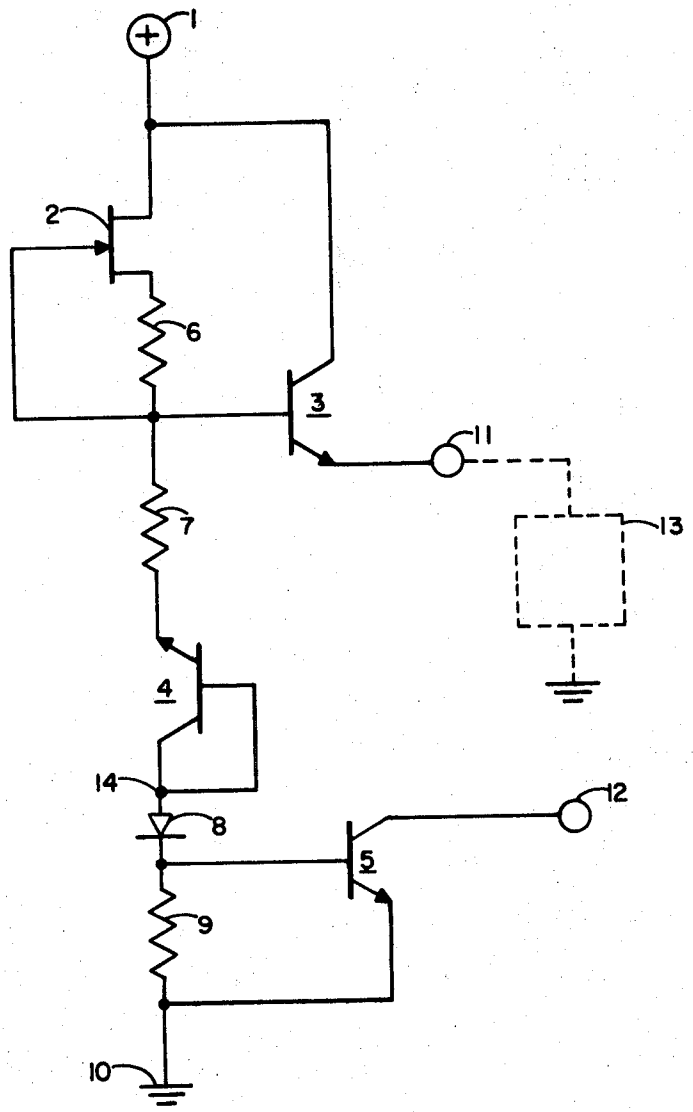
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ABSTRACT: A DC voltage regulator employing a constant current source and a voltage reference source to control a variable impedance to regulate an input voltage. A low voltage sensing output is provided by using a sensing transistor as a switch and temperature compensation element. The sensing transistor functions as a voltage responsive switch to produce a signal indicative of the level of the input voltage relative to a predetermined level. The sensing transistor is normally saturated to connect the sensing output to the ground.



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3,571,694



INVENTOR.
JACK W. HUNGER
DAVID D. KEMP

BY Albin Medved

ATTORNEY

DC VOLTAGE REGULATOR EMPLOYING AN FET CONSTANT CURRENT SOUCE AND CURRENT FLOW INDICATOR

THE INVENTION

This invention is an improvement in DC voltage regulator circuitry.

Prior art voltage regulator circuits have employed the use of a voltage reference element in combination with temperature compensation elements to control a transistor to thus provide a regulated voltage output. Constant current sources are known in the art to provide more accurate regulation when used in combination with a voltage reference element. There is, however, no teaching in the prior art voltage regulator circuits of means for monitoring the level of input voltage without the addition of special circuitry.

The present invention combines the use of a constant current source with a temperature compensated voltage reference to provide base drive to a transistor which regulates the output voltage. A low voltage sensing output is provided by using a sensing transistor as a switch and temperature compensation element. In the preferred embodiment of the present invention an FET constant current source is used, and the voltage reference level is determined by the reverse emitter to base breakdown characteristic of a transistor. Additional temperature compensation for the voltage reference element is provided by a diode in series with the base emitter junction of the sensing transistor. The sensing transistor is normally saturated and functions as a switch which connects the sensing output to the ground.

The use of a constant current source in combination with a voltage reference element to control the drive to a transistor is described on page 54 of the Aug. 30, 1963 issue of ELECTRONIC DESIGN magazine. The present invention includes the use of a transistor to provide a low voltage sensing output as well as temperature compensation.

It is, therefore, an object of this invention to provide an improved DC voltage regulator circuit having inherent low voltage sensing means.

DESCRIPTION OF THE DRAWING

The sole FIGURE of the drawing is a schematic of the preferred embodiment of the present invention.

Referring to the drawing, an input means 1 for connection to a positive terminal of an unregulated DC power source is connected to a collector of an NPN transistor 3. Transistor 3 further has a base and an emitter. The emitter of NPN transistor 3 is connected to a regulated voltage output 11. Input means 1 is further connected to the source of a J-FET (Junction Field Effect Transistor) 2. FET 2 further has a drain and a gate. A resistor 6 is connected between the drain of FET 2 and the base of NPN transistor 3. The gate of FET 2 is also connected to the base of NPN transistor 3.

FET 2, having its gate connected through resistor 6 to its drain, forms a constant current source.

Further connected to the base of NPN transistor 3 is a resistor 7 having its opposite end connected to the emitter of an NPN transistor 4. The collector of NPN transistor 4 is connected to the anode of a diode 8. The base and collector of NPN transistor 4 are connected together at junction 14.

The cathode of diode 8 is connected to the base of an NPN transistor 5. A resistor 9 is connected between the base of NPN transistor 5 and a reference potential terminal 10. The collector of NPN transistor 5 is connected to a sensing output 12. The emitter of NPN transistor 5 is connected to reference potential terminal 10.

NPN transistor 4, diode 8, resistor 9 and NPN transistor 5 comprise a constant voltage reference means, sensing output 12 indicating the presence of current flow through the voltage reference means.

NPN transistor 3 serves as a gate for controlling the current from input means 1 through load means 13.

OPERATION

Referring to the FIGURE, a positive DC input signal of at least the level required at output 11 is applied to input means 1. The current through resistor 6 will depend on the value of the resistor, as the current through FET 2 is dependent on the voltage between the gate and the source which in turn is dependent on the voltage across resistor 6. This current will be maintained at a constant level so long as the voltage at input means 1 does not drop below the level of the required regulated output voltage. As the voltage across resistor 6 tends to increase due to increased current, the pinch-off voltage on FET 2 is approached causing the FET to become less conductive and therefore decreasing the current through resistor 6. A constant current source is thus provided between input means 1 and the junction between resistors 6 and 7.

NPN transistor 4 (having its base connected to its collector) acts as a Zener diode due to the reverse emitter to base breakdown characteristic. Diode 8, operating in the forward direction, provides temperature compensation. NPN transistor 5 is turned on in response to current flow through resistor 9. As the input voltage at input means 1 increases, the point of reverse emitter to base breakdown of NPN transistor 4 is reached and current begins to flow through resistor 7, diode 8, and resistor 9. The voltage drop across resistor 9 rises to forward bias the base-emitter junction of NPN transistor 5, thus turning it on. The base-emitter junction of transistor 5 acts as a diode in series with diode 8 providing additional temperature compensation as well as means for indicating the presence of current flow through resistor 7, diode 8, and resistor 9.

NPN transistor 3 provides current gain from the reference voltage at the gate of FET 2 to the load 13. Transistor 3 is connected in the conventional emitter-follower manner. The voltage drop across resistor 7 is used to calibrate the voltage level at output 11. FET 2 and resistor 6 provide a constant current for the constant voltage reference means. With a constant current flowing through the constant voltage reference means, a constant voltage with respect to reference potential terminal 10 is maintained at the base of transistor 3. Therefore, any variation in the voltage at output 11 will cause a corresponding change in the base-to-emitter voltage of transistor 3, thereby effectively controlling the conductivity of transistor 3. Transistor 3 becomes more conductive as the voltage at output 11 decreases and more current is delivered to the load to increase the voltage at output 11 to the required level.

The emitter-base junction of transistor 4 has a positive temperature coefficient while diode 8 and the base-emitter junction of transistor 5 have a negative temperature coefficient. The base-emitter junction of NPN transistor 3 also has a negative temperature coefficient. Proper design of the several components results in an overall temperature coefficient of near zero.

To illustrate the operation of the low voltage sensing, consider a decrease of the voltage level applied to the input means 1 below the required regulated output voltage level. The current through resistor 7 will decrease and the voltage at the emitter of transistor 4 with respect to reference potential terminal 10 will also decrease. This decrease will continue until the reverse emitter-base breakdown voltage of transistor 4 is reached. At this voltage, current conduction through resistor 9 will decrease such that transistor 5 is no longer forward biased, thus turning off transistor 5. The turnoff of transistor 5 indicates an insufficient voltage level at input means 1. As the voltage is again increased at input means 1, the voltage at the emitter of transistor 4 increases until the reverse emitter to base breakdown voltage of transistor 4 is reached, allowing current to flow through resistor 7, diode 8, and resistor 9. As the voltage across resistor 9 increases, transistor 5 is turned on, connecting sensing output 12 to reference terminal 10. The turn-on of transistor 5 indicates sufficient voltage at input means 1 for voltage regulation. A decrease below this level

causes transistor 5 to turn off, opening the circuit between sensing output 12 and reference potential terminal 10. Sensing output 12 may be connected to a supervisory means or, in a munition fuzing application, sensing output 12 may be connected to a silicon controlled rectifier gate to cause self-destruct of the munition upon failure of the unregulated voltage at input means 1 to provide the required level of regulated output voltage.

Circuit modifications such as polarity inversion, replacement of NPN transistor 4 with a Zener diode or replacement of the current source comprising FET 2 and resistor 6 will be evident to those skilled in the art.

The scope of the present invention is not intended to be limited to the embodiment shown in the drawing but only by the scope of the appended claims.

We claim:

1. Voltage regulator apparatus comprising:
input means for connecting to a source of unregulated DC voltage;
reference potential means;
regulated voltage output means for connection to a load;
variable impedance means connected between said input means and said regulated voltage output means, said impedance means having a voltage responsive control means;
constant current means connected to said input means and having an output;
voltage reference means connected to said reference potential means and said output of said constant current means, for providing a reference voltage at a first terminal, said voltage reference means including a means responsive to the current therethrough for producing a voltage signal at a second terminal;
means connecting said first terminal to said control means of said variable impedance means; and
voltage sensing means, including a voltage responsive switching means, connected to said second terminal.

2. Apparatus as recited in claim 1 wherein said variable impedance means is a transistor.

3. Apparatus as recited in claim 1 wherein said voltage reference means includes temperature compensation means.

4. Apparatus as recited in claim 3 wherein said voltage reference means includes a transistor operated in reverse emitter-base breakdown region.

5. Apparatus as recited in claim 1 wherein said means for supplying a constant current comprises:
a junction field effect transistor having gate, source and drain electrodes; and
a resistor connected between said drain electrode and said gate electrode whereby a constant current tends to flow between said source electrode and said drain electrode.

6. Apparatus claimed in claim 1 wherein said voltage sensing means is a transistor operated as a switch.

7. Voltage regulator apparatus, comprising:
input means for connection to a power source;
reference potential means;
regulated voltage output means for connection to a load;
a first transistor having emitter, base and collector electrodes, said collector electrode connected to said input means, said emitter electrode connected to said regulated voltage output means;
a field effect transistor, having source, drain and gate electrodes, said source electrode connected to said input means, said gate electrode connected to said base electrode of said first transistor;
a first resistor connected between said drain and said gate of said field effect transistor;
a second transistor, having emitter, base and collector electrodes, said base electrode connected to said collector electrode;
a second resistor connected between said base electrode of said first transistor and said emitter electrode of said second transistor;
a diode having an anode and a cathode, said anode connected to said base of said second transistor;
a third resistor connected between said cathode of said diode and said reference potential means;
a third transistor having base, emitter and collector electrodes, said base electrode connected to said cathode of said diode, said emitter electrode connected to said reference potential means; and
sensing output means for indicating the presence of current flow through said diode connected to said collector electrode of said third transistor whereby the voltage at said regulated voltage output means is maintained constant with respect to said reference means and said sensing output means indicates low input voltage conditions.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,571,694 Dated March 23, 1971

Inventor(s) Jack W. Hunger and David D. Kemp

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 4, line 1, delete "claim 8" and substitute

--claim 1--.

Signed and sealed this 16th day of November 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents