United States Patent

Matsumura et al.

[15] **3,643,152**

[45] **Feb. 15, 1972**

[54] **COLLECTOR FOLLOWER-TYPE TRANSISTORIZED VOLTAGE REGULATOR WITH THERMISTOR STARTING CIRCUIT**

[72] Inventors: **Koji Matsumura**, Kodaira; **Kunio Seki**, Higashimurayama, both of Japan

[73] Assignee: **Hitachi, Ltd.**, Tokyo, Japan

[22] Filed: **Mar. 6, 1970**

[21] Appl. No.: **17,184**

[30] **Foreign Application Priority Data**

Mar. 12, 1969 Japan.....44/18325

[52] **U.S. Cl.**.....**323/22 T**, 317/31, 323/68

[51] **Int. Cl.**.....**G05f 1/56**, G05f 1/64

[58] **Field of Search**.....317/31; 323/22 T, 22, 68; 321/16, 18; 320/40

[56] **References Cited**

UNITED STATES PATENTS

3,384,808	5/1968	Luettge et al.	323/22 T
3,022,457	2/1962	Doan	323/22 T
3,211,989	10/1965	Mintz et al.	323/22 T
3,393,347	7/1968	Webb	317/31

Primary Examiner—Gerald Goldberg

Attorney—Craig, Antonelli & Hill

[57] **ABSTRACT**

In a transistorized voltage regulator, in which a voltage source is connected to an emitter input circuit of a regulating transistor and a load to its collector output circuit, the starting circuit consists of a thermistor having a positive resistance-temperature coefficient connected between the emitter input circuit and the base of the regulating transistor. The thermistor supplies a starting current to the regulating transistor at the starting moment when an operating voltage is applied to the emitter input circuit of the transistor. On the other hand, since it is heated by an electric current flowing therethrough and has a high resistance at a high temperature the thermistor is substantially electrically isolated from the voltage regulator in the normal operation of the transistor. Thus, a regulator effectively operating even in a low-level load current is obtained.

6 Claims, 4 Drawing Figures

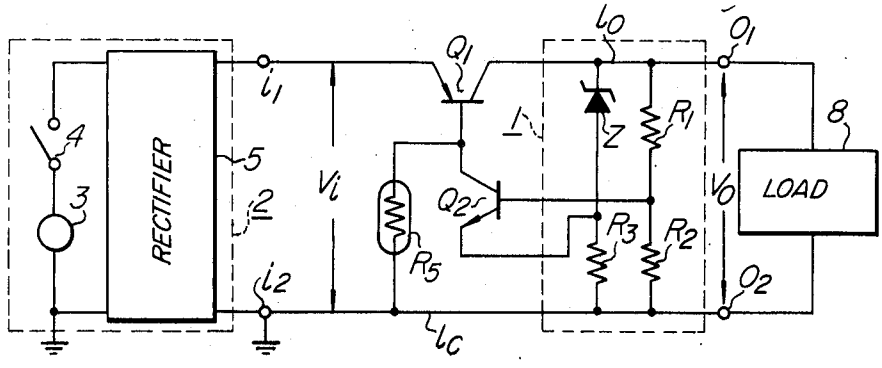


FIG. 1 PRIOR ART

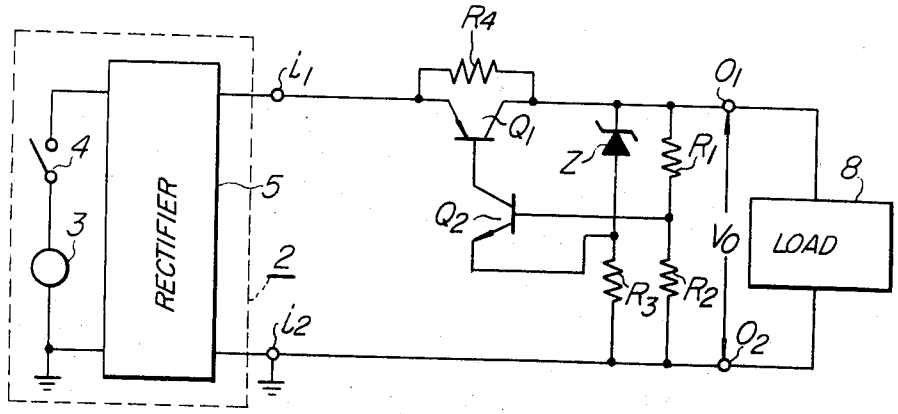


FIG. 2

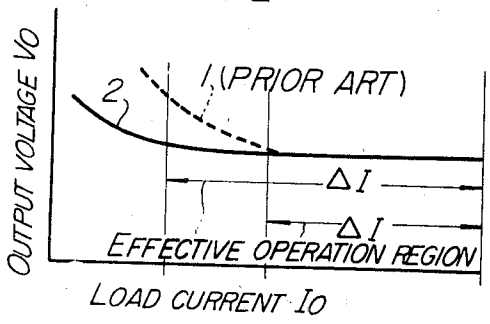


FIG. 4

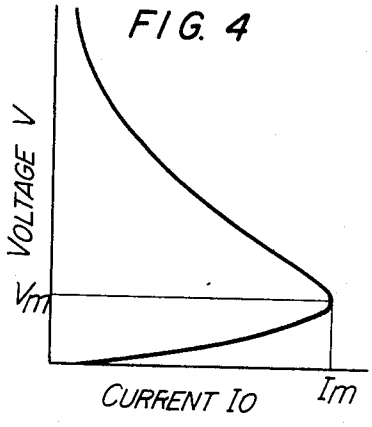
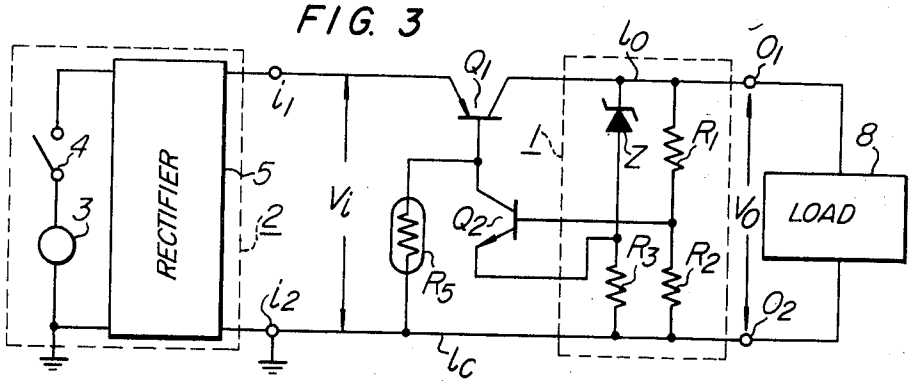


FIG. 3



INVENTORS

KOJI MATSUMURA and KUNIO SEKI

BY Craig, Antonelli, Stewart & Hill
ATTORNEYS

COLLECTOR FOLLOWER-TYPE TRANSISTORIZED VOLTAGE REGULATOR WITH THERMISTOR STARTING CIRCUIT

This invention relates to a transistor voltage regulator which supplies a constant DC voltage to a load. V_o

In a series voltage regulating circuit which supplies a constant voltage to a load regardless of a voltage variation in the voltage source by inserting a regulating transistor between the voltage source and load, publicly known is the collector follower type, in which a load is connected to the collector side and a voltage source to the emitter side of a regulating transistor.

The voltage regulator of the collector follower type has a better ripple reduction factor than the usual emitter follower type, but a disadvantage is that a starting circuit is required.

A circuit in which a resistor is inserted between the emitter and collector of a regulating transistor or between the base of a regulating transistor and a voltage supplying line is well known as a starting circuit. In either circuit, however, there is a defect of hindering with the voltage regulating action at light load, i.e., the effective operation region is restricted by the load variation.

One object of this invention is to provide a series voltage regulator of the collector follower type where the voltage regulation is not affected at a light load.

According to this invention, a thermistor having a positive resistance-temperature coefficient is coupled between the base of a regulating transistor and the common reference potential, and the starting current is given to the regulating transistor through this thermistor.

The above and other objects and features of this invention will be made more apparent from the following explanation with reference to the accompanying drawings, in which:

FIG. 1 shows a circuit diagram of a prior art voltage regulator;

FIG. 2 shows the characteristics of the prior art voltage regulator shown in FIG. 1 and that of a voltage regulator according to this invention, respectively;

FIG. 3 shows the circuit diagram of a voltage regulator according to this invention; and

FIG. 4 shows the voltage-current characteristic of a thermistor having a positive resistance-temperature coefficient as used in this invention.

In order to make it easy to understand the unfavorable fact that the starting circuit causes a trouble to the voltage regulation at a light load, a conventional voltage regulator as shown in FIG. 1 will be first explained with an emphasis on its operation.

In FIG. 1, Q_1 is a regulating transistor, Q_2 is an error signal amplifying transistor, R_1 and R_2 are error signal detecting resistors, R_3 is an emitter resistor of the transistor Q_2, Z is a reference diode, R_4 is a starting resistor inserted between the emitter and collector of the transistor Q_1, **8** is a load, and a circuit **2** is a voltage source comprising an AC source **3**, a rectifier **5**, and a switch **4**.

In this circuit, at a starting moment when the switch **4** is closed, a starting current (base current) is given to the transistor Q_2 through the starting resistor R_4. As the transistor Q_2 operates, the transistor Q_1 starts to operate. Namely, the operation of this voltage regulator is initiated by the starting resistor R_4. Without this resistor R_4 neither the transistor Q_1 nor the transistor Q_2 starts to operate even if the switch **4** is turned on, so that no prescribed voltage can be supplied to the load **8**.

Therefore, the resistor R_4 is indispensable for the start of the voltage regulator. However, this starting resistor has such a disadvantage that it gives troubles to the voltage regulation at a light load, as seen in FIG. 2. When the load current is low (light load), the load terminal voltage V_o rises, losing the voltage regulating action. Thus, in the voltage regulator of this type, the effective operation region of the load is reduced. So, the regulator becomes impractical at a light load.

Next, the voltage regulator according to the invention will be explained.

In FIG. 3, transistor Q_1 is a regulating transistor for controlling the voltage supplied to the load, and a circuit **1** is a voltage detecting circuit formed in the collector circuit of the transistor Q_1. The voltage detecting circuit comprises the resistors R_1 and R_2 for detecting the collector voltage of the transistor Q_1, a reference diode (Zener diode) Z for obtaining a reference potential, and a resistor R_3. The transistor Q_2 connected to the voltage detecting circuit **1** amplifies the error signal detected by the voltage detecting circuit **1** up to the level of the base controlling signal of the transistor Q_1. The emitter voltage of the transistor Q_2 with respect to the collector voltage of the transistor Q_1 is made constant by the Zener diode Z. The base voltage of the transistor Q_2 follows the variation in the collector voltage of the transistor Q_1. The circuit **2** is a voltage source circuit which comprises an AC source **3**, a switch **4**, and a conventional rectifying circuit **5** for rectifying the AC signal from the source **3** and supplying the rectified DC voltage to the input terminals i_1–i_2 of the regulating circuit. The circuit **8** represents a load connected between the output terminals O_1–O_2. R_5 is a thermistor having a positive resistance-temperature coefficient, one end of which is connected to the base of transistor Q_1 and the other end of which is connected to the reference potential line l_c. The voltage-current characteristics of this thermistor R_5 at a constant ambient temperature are shown in FIG. **4** in which the thermistor R_5 has a low resistance at a lower applied voltage while a high resistance at a higher voltage. As the thermistor R_5, well-known thermistors having a positive resistance-temperature coefficient can be used.

In this circuit, let us consider the transient state when the switch **4** is turned on. Initially, when the switch **4** is turned on, the thermistor R_5 is not yet heated and hence has a low resistivity. Accordingly, a current is supplied to the base of the transistor Q_1 through the thermistor R_5. Then, the transistor Q_1 is made conductive and transmits the voltage V_i at the input terminal i_1 to the output terminal O_1 as a voltage V_o. With the application of o **0** to the voltage detecting circuit **1** the output voltage V_o is regulated to a potential determined preliminarily by the resistors R_1 and R_2, the reference voltage V_z of the Zener diode Z and the amplification factor of the transistor Q_2 by the action of the positive feedback of transistor Q_2. At this moment, since a voltage higher than the critical voltage V_m shown in FIG. **4** is applied to the thermistor R_5, it comes to the high resistivity state by the current flowing therethrough, whereby the normal operation of the transistors Q_1 and Q_2 is not interfered.

Therefore, according to this invention, at the starting moment when the switch **4** is turned on, the starting current of the regulating transistor Q_1 is given through the thermistor R_5 which is in the low resistivity state. In the normal operating state of the regulating circuit, the thermistor R_5 has a high resistance sufficient to isolate the base of the regulating transistor Q_1 from the common reference potential line l_c.

Therefore, the voltage regulator according to this invention can attain the voltage regulating action even for a light load, and the effective operation region ΔI is widened, as shown in FIG. **2**.

As described above, this invention is characterized by the use of a thermistor having a positive resistance-temperature coefficient. A voltage regulator with a widened effective operation region and with a low electric power consumption can be obtained by relatively simple means. Various modifications of this invention may be done without departing from the spirit of this invention.

What is claimed is:

1. A voltage regulator for use between a power source and a load comprising:

regulator transistor having an emitter, a base and a collector for controlling the voltage to be supplied to the load, said emitter being adapted to be connected to the power source;

an output terminal connected to the collector and being adapted to be connected to said load;

a voltage detecting means connected to the collector of said transistor for detecting a regulating signal proportional to the potential difference between the potential at said output terminal and a predetermined reference potential;

an amplifier means connected between the base of said regulating transistor and said voltage detecting means for amplifying the regulating signal from said voltage detecting means and supplying the amplified regulating signal to said base as a controlling signal, whereby the conductance of said regulating transistor is controlled by said controlling signal; and

a thermistor having a positive resistance-temperature coefficient connected between the base of said regulating transistor and a common reference potential, said thermistor having a low resistance in the starting moment of said regulating transistor and supplying a starting current to said transistor while having a high resistance sufficient to isolate said thermistor from the base of the regulator transistor in the normal operation of said regulator transistor.

2. In a voltage regulator for use between a power source and a load, including

a regulator transistor having an emitter, a base and a collector for controlling the voltage to be supplied to the load, said emitter being adapted to be connected to the power source;

an output terminal connected to the collector and being adapted to be connected to said load;

first means connected to the collector of said transistor for detecting a regulating signal proportional to the potential difference between the potential at said output terminal and a predetermined reference potential;

second means connected between the base of said regulating transistor and said voltage detecting means for amplifying the regulating signal from said voltage detecting means and supplying the amplified regulating signal to said base as a control signal, whereby the conductance of said regulating transistor is controlled by said controlling signal, the improvement comprising:

third means comprising a thermistor, having a positive resistance-temperature coefficient, connected between the base of said regulator transistor and said predetermined reference potential, responsive to the transient flow of current through said regulator transistor, for supplying a starting current thereto when load current begins to flow and for providing a high resistance sufficient to isolate the base of said regulator transistor from said common reference potential during steady state load voltage at said output terminal.

3. A voltage regulator according to claim 2, wherein said first means comprises first and second voltage divider circuits connected in parallel across said load, said second means being connected to each of said first and second voltage divider elements.

4. A voltage regulator according to claim 3, wherein said first voltage divider circuit comprises a Zener diode in series with a first resistor, and said second voltage divider circuit comprises second and third resistors connected in series, said first means being connected to the common connection point of said Zener diode with said first resistor and the common connection point of said second and third resistors, respectively.

5. A voltage regulator according to claim 4, wherein said second means comprises an amplifying transistor having its electrodes respectively connected to the base of said regulator transistor and said common connection points of said first and second voltage dividers.

6. A voltage regulator according to claim 5, wherein said amplifying transistor has its base connected to the common connection point of said second and third resistors, its emitter connected to the common connection point of said Zener diode and said first resistor and its collector connected to the base of said regulator transistor.

* * * * *