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[54] CIRCUIT FOR GENERATING A REPEATABLE VOLTAGE AS A FUNCTION OF TEMPERATURE

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[58] Field of Search.....**323/16, 18, 22 T, 22 Z, 68, 323/69; 307/310; 331/109; 330/143**

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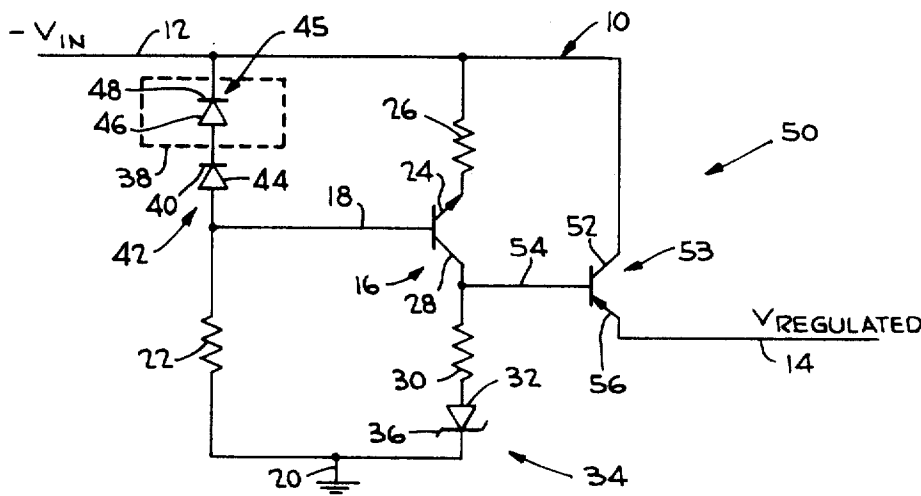
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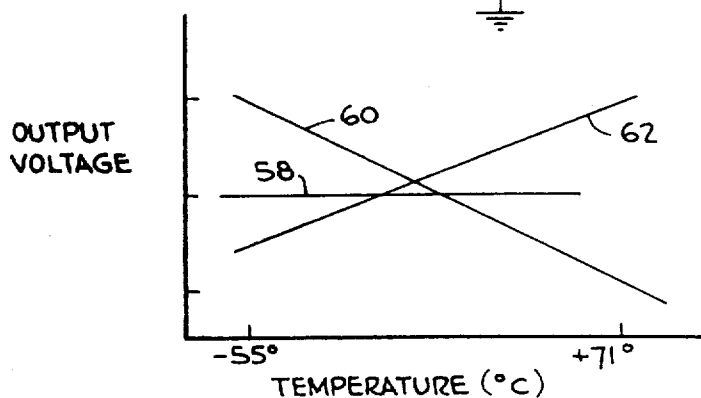
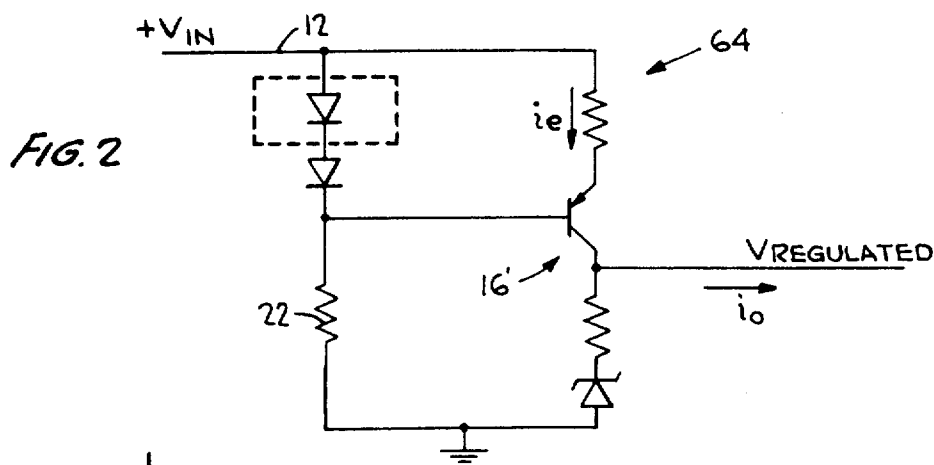
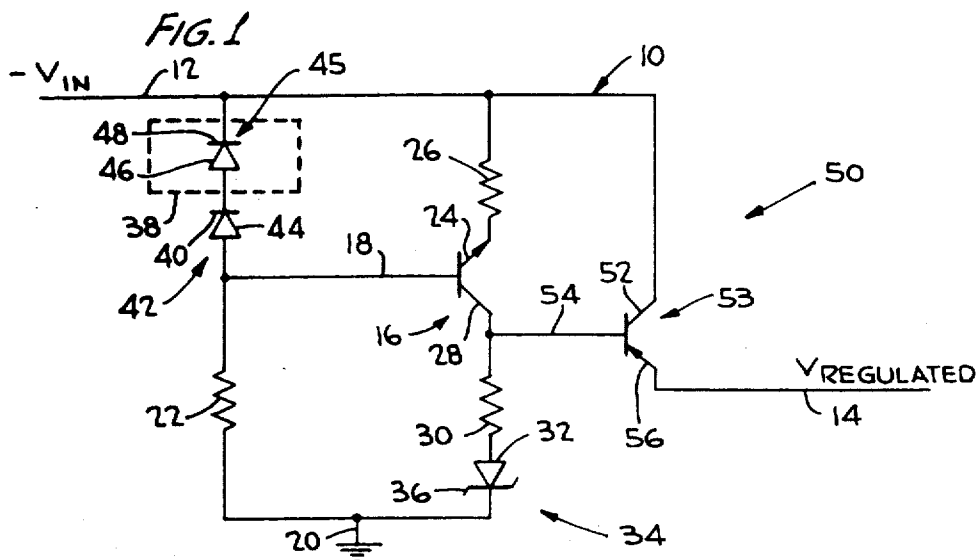
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[57] ABSTRACT

A circuit for producing a repeatable predetermined voltage as a function of temperature and includes a component having a known temperature coefficient characteristic. A transistor stage connected to the component multiplies the temperature coefficient. Linear as well as non-linear temperature characteristics can be multiplied by the circuit.

10 Claims, 3 Drawing Figures





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CIRCUIT FOR GENERATING A REPEATABLE VOLTAGE AS A FUNCTION OF TEMPERATURE

The invention described herein may be manufactured, used and licensed by and for the U.S. Government for governmental purposes without the payment to us of any royalty thereon.

FIELD OF THE INVENTION

The present invention relates to voltage regulators and more particularly to a regulator which is capable of producing a repeatable predetermined voltage as a function of temperature. It is to be emphasized that the present circuitry does not maintain a constant regulated voltage but rather, can produce the same output voltage as a function of temperature, with a broad variation of input voltage. Thus, use of the word "regulator" herein does not refer to a constant voltage circuit but rather, refers to a circuit capable of a predetermined output voltage which varies in accordance with temperature.

THE PRIOR ART

The present regulator design resulted from a need for a regulated voltage with a negative temperature coefficient (TC) in the order of 20 millivolts/degree C. Usually, a negative TC can be realized by placing a number of diodes in series with an appropriate Zener diode. Typically a diode has a negative TC approximating 2 millivolts/degree C. A Zener diode of 5 volts or more has a positive TC. Thus, in order to realize a TC = 20 millivolts/degree C would require at least 10 diodes connected in series with the Zener diode. This arrangement, needless to say, is quite expensive and the TC slope can be adjusted only in increments of about 2 millivolts/degree C. If a positive TC greater than the TC offered by a Zener diode is required, diodes cannot be used thereby making the solution quite difficult.

SUMMARY OF THE INVENTION

The temperature responsive regulator disclosed in the present invention is quite versatile in that the sign of the TC of the output voltage, as well as the slope thereof can easily be adjusted. The disclosed design concept is to use a single temperature sensitive component which possesses a TC with the desired sign. By connecting this component to the input of a transistor stage, the TC can be multiplied to achieve a desired slope. The TC can be controlled precisely by adjusting the gain of the transistor stage which is connected in the circuit in a common emitter configuration. By employing the design considerations of the present invention, desired circuit operation can be obtained from both positive and negative supply voltages. As will be seen hereinafter, with a minimum number of components, the circuit can provide a voltage with a zero, positive, or non-linear temperature coefficient.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned objects and advantages of the present invention will be more clearly understood when considered in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic circuit illustrating one form of the present invention having an output driver stage.

FIG. 2 is a schematic circuit illustration of a second form of the invention which is lacking a final current driving stage.

FIG. 3 is a graphical illustration of the temperature coefficient characteristics that can be achieved by the circuitry of the present invention as compared with the usual output voltage plot of a voltage regulator.

Referring to the drawings and more particularly FIG. 1, reference numeral 10 generally denotes the circuitry involved in one form of the invention which includes a final current driver stage.

Input line 12 provides an input potential to the circuitry. An output line 14 makes available an output voltage which is "regulated." By "regulated" we mean that the circuit is capable of producing a repeatable predetermined voltage as a function of temperature. As will be appreciated, this is in marked contrast to a temperature compensated regulating circuit which maintains a constant voltage over a given temperature range.

The circuitry illustrated in FIG. 1 includes a single transistor 16 having its base terminal 18 connected to ground 20 through a base resistor 22. As will be seen hereinafter, the base resistor 22 is chosen to establish the base current required by the transistor so that the effect of the transistor beta change with temperature is negligible.

The emitter 24 is connected to the input voltage line 12 through an emitter resistor 26.

The collector terminal 28 of transistor 16 is connected to one end of a collector resistor 30 while the opposite end of this resistor is directly connected to the anode 32 of Zener diode 34. The cathode 36 of the Zener diode is grounded at 20. An output voltage is produced across the collector resistor 30 and Zener diode 34, this voltage providing an input to a following current driving stage.

The component with the temperature coefficient (TC) to be multiplied by the circuit is represented by the dashed box 38 which has its upper terminal connected to the input voltage line 12 while the lower terminal is connected to the cathode 40 of a diode 42. The anode 44 of the diode 42 is directly connected to the base lead 18 of transistor 16.

The main concept of the present invention is to use one temperature sensitive component which possesses a temperature coefficient (TC) with the desired sign and then multiplying this TC to achieve another TC characteristic. Referring to FIG. 1, the component with the TC to be multiplied replaces the dashed box 38. As an example, a diode 45 is used as the special component.

The cathode 48 of the diode 45 is connected to the input voltage line 12 while the anode 46 of diode 45 is directly connected to the cathode 40 of diode 42. The primary function of diode 42 is to compensate for the temperature varying voltage drop across the base-emitter junction of transistor 16. The emitter resistor 26 is chosen so that equal current flows through diode 44 and the base-emitter junction of transistor 16. Under these circuit conditions, the voltage drops across diode 42 and the base-emitter junction of transistor 16 are the same, and in effect, the emitter resistor 26 is in parallel with diode 45. The voltage drop across the emitter resistor 26 makes this resistor an equivalent

current source which supplies current for the collector resistor 30 and the Zener diode 34. As the voltage across diode 45 changes with temperature, the current through the emitter resistor 26 changes which results in a change of the voltage drop across the collector resistor 30.

Inasmuch as the voltage drop across diode 42 compensates for the voltage drop across the base-emitter junction of transistor 16, the change in voltage across the collector resistor 30 is the change in the voltage across diode 45 multiplied by the voltage gain of transistor 16. For example, if the ratio of the collector resistance plus the Zener diode resistance to the sum of the emitter resistance and the intrinsic resistance of the transistor is equal to 10, the resulting TC at the collector terminal 28 of transistor 16 is approximately -20 millivolts/degree C minus the temperature characteristic of the Zener diode. The Zener diode voltage drop is used to place the voltage at the collector terminal 28 to the required level. In certain instances where a high gain is required, the Zener diode may not be needed. If the Zener is used, its TC must be considered in adjusting the voltage gain. More particularly, a Zener diode having a 5 volt rating has nearly a zero temperature coefficient. However, when using a Zener rated above 5 volts, one must take into consideration a positive TC of the Zener diode. Thus, with various Zener diodes, the gain must be adjusted to obtain a desired slope in the TC characteristic of the output voltage.

An emitter follower stage 50 is added to the described circuitry to give current gain. Specifically, as will be seen in FIG. 1, the collector 52 of the PNP transistor 53 is directly connected to the input voltage line 12 while the base terminal 54 of the transistor 53 is connected to the collector 28 of transistor 16. The emitter terminal 56 of the output transistor 53 provides the "regulated" voltage on output line 14, to be applied to a utilization device. The TC of the base-emitter junction of output transistor 53 must be considered when adjusting the voltage gain of transistor 16.

Referring to FIG. 3, a plot 58 of a usual temperature compensated regulated voltage is shown. The ordinate axis represents output voltage, while the abscissa axis represents variations in temperature. The plot indicated by reference numeral 60 represents the output characteristics of the invention when using a component 38 having a negative TC. As previously explained, diode 45 would create a linear plot such as 60. On the other hand, if a Zener diode were used as the special component 38, a plot having a positive TC could be produced as indicated by 62.

As will be apparent from FIG. 3, plots 60 and 62 both have a DC offset which depends upon the rating of the Zener diode 34.

It is to be emphasized that the plots 60 and 62 in FIG. 3 are repeatable for a wide range of input voltage variations. In a typical application, these voltage variations may be produced from a battery power supply which varies due to temperature changes, age, etc. The TC characteristics obtainable with the present circuitry are independent of input voltage over a broad voltage range. It is this operational quality of the circuit which leads one to consider the circuit as a "regulator" of sorts.

It should be mentioned that when using a special component 38 having a negative TC, a positive TC can be finally realized if a stage is added to invert the phase of transistor 16.

In order to achieve relative independence of input voltage, the voltage drop across the emitter resistor 26 must remain constant with changes in the input voltage on line 12. This condition is realized if either a Zener diode or a regular diode is used as the special component. As previously mentioned, a Zener diode having a positive TC will enable the generation of an output plot 62 (FIG. 3) that is linear and has a positive slope. Use of a regular diode as special component 38 will enable generation of plot 60 (FIG. 3) which is characterized by a linear TC of negative slope. It is to be noted at this point, that the preceding discussion involves an unregulated input voltage on line 12. However, if voltage regulation is provided prior to the TC compensating circuit, then any component could be used in the dashed box 38. As an example, a component with a non-linear TC could be used. For example, utilization of a thermistor as special component 38 would cause the generation, at the output 14, of a non-linear TC which has been multiplied and added to the TC characteristic of the Zener diode 34. Any component can be used as the special component 38 if the input voltage is regulated because the circuit need no longer rely upon the saturation characteristic of diode 45 which produces substantially the same voltage drop thereacross regardless of the extent of forward bias.

One of the unique features of this circuit is that the voltage gain can be adjusted to compensate for the transistor parameters which vary with temperature.

Referring to FIG. 2, it will be observed that the circuit illustrated in this figure includes all of the components shown in FIG. 1, with the exception of transistor 53. Otherwise stated, the variation illustrated in FIG. 2 accomplishes the basic circuit operation as previously discussed without an output current driving stage.

The circuitry illustrated in FIG. 1 uses a negative supply for input voltage. As will be appreciated, a positive supply voltage can be accommodated by reversing the direction of the diodes 42, 45 and the Zener diode 34. In addition, a PNP transistor must be used instead of a NPN transistor 16. Likewise, a NPN transistor must be used in place of the illustrated PNP transistor 53. These changes will become evident when viewing the circuit of FIG. 2 which has been designed to accommodate a positive supply voltage.

In the second variation of the present invention, as shown in FIG. 2, there is no final current driver stage 50 as was present in the previously described circuit embodiment. In the former embodiment the current driving stage provides a relatively unlimited supply of current depending upon the capacity of the input voltage which serves as the supply. If the current driver stage is removed, current delivery is limited because current must be drawn through transistor 16 and the emitter resistor 26. For a fixed emitter resistor and a given voltage drop across diode 45, which for example may be one half volt, with the emitter resistor being 1,000 ohms the circuit can only draw a maximum of one half milliamp through the transistor 16. Thus, if a particular circuit application requires a relatively high current delivery, the driver stage 50 must be supplied.

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The circuitry illustrated in FIG. 2 is sensitive to the output current and voltage.

The output current i_o is sensed to detect load circuit change and the output voltage is changed to keep the circuit at a constant current voltage product relationship.

It should be understood that the invention is not limited to the exact details of construction shown and described herein for obvious modifications will occur to persons skilled in the art.

We claim:

1. A circuit for producing a repeatable predetermined voltage as function of temperature comprising a component having a known temperature coefficient characteristic; circuit means connected to the component for multiplying the component temperature coefficient to form a different temperature coefficient characteristic; and connection means for connecting an input voltage to the component, the circuit means including a transistor having its emitter connected to an input voltage, a branch circuit path including said component in addition to means for compensating temperature changes in the emitter-base junction of the transistor, means connecting the branch circuit path between the input voltage and the transistor base, and collector resistance means connected between the transistor collector and a reference potential, whereby the change in voltage across the collector resistance means is the change in the voltage across the component multiplied by the voltage gain of the transistor.

2. The subject matter set forth in claim 1 wherein the connection between the transistor emitter and the input voltage includes a series emitter resistor which serves as a current source for the collector resistor.

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3. The structure set forth in claim 1 wherein the component is a solid state device having a linear temperature coefficient.

4. The circuitry distinguished in claim 1 wherein the component is a solid state device having a non-linear temperature coefficient.

5. The subject matter as set forth in claim 2 wherein the base of the transistor is connected to the referenced potential through a base resistor chosen so that the current through said component is at least a factor of 10 greater than the base current of the transistor thereby making negligible the transistor beta change with temperature.

6. The circuitry as defined in claim 1 wherein output voltage and current are derived at the transistor collector, the circuit being sensitive to output current whereby an increase in output current is accompanied by a commensurate decrease in output voltage, and vice-versa.

7. The structure set forth in claim 1 wherein a driver stage is coupled between the input voltage terminal and the transistor collector to furnish an output current of increased capacity dependent upon input voltage.

8. The structure defined in claim 1 wherein a Zener diode is connected in series with the collector resistance means for adding a voltage offset to the temperature varying voltage characteristic.

9. The circuitry defined in claim 3 wherein the device is a diode.

10. The circuitry distinguished in claim 1 wherein the component can be any temperature sensitive electrical component if the input voltage is already regulated.

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