

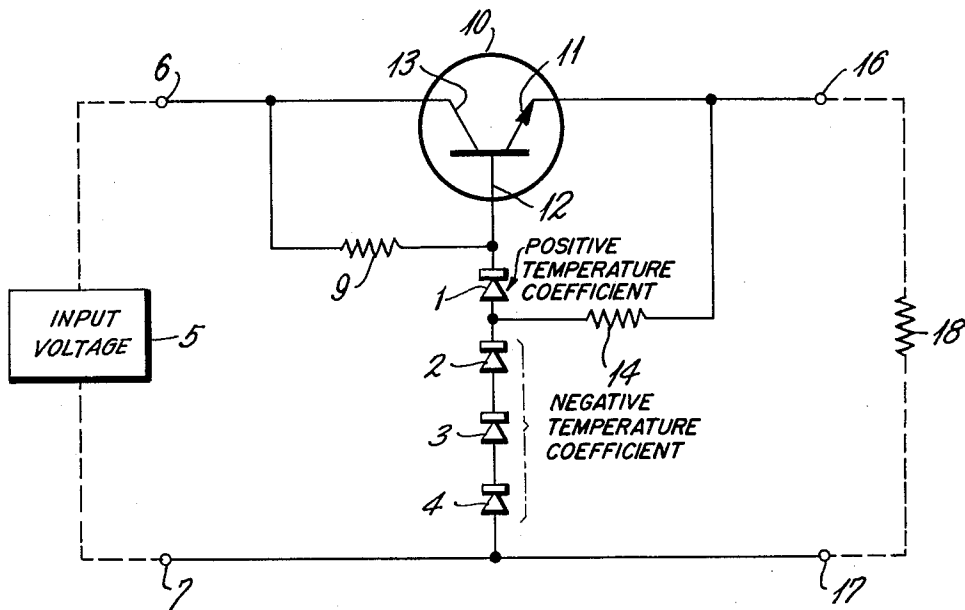
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TRANSISTOR VOLTAGE REGULATOR

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TRANSISTOR VOLTAGE REGULATOR

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This invention relates to transistor voltage regulators, and more particularly to transistor voltage regulators utilizing a novel arrangement of zener diodes interconnected to obtain voltage stabilization over a wide temperature range.

One type of transistor voltage regulator, to which the principles of the invention apply, is known as an emitter-follower transistor voltage regulator. In this type of regulator, the output or emitter voltage will remain nearly constant, provided the base voltage of the transistor remains nearly constant because the output or emitter voltage closely follows the base voltage.

In prior emitter-follower voltage regulators, zener diodes, which have the characteristics of good voltage regulation and low-current requirement, have been utilized in the base of the transistor to maintain the base voltage at a constant or stable reference voltage. The use of a single regulating zener diode in the base of a transistor enables the base voltage to be maintained constant or stable provided the temperature of the zener diode does not vary or change under operating conditions. The voltage drop across the diode will vary, however, with changes in temperature because the regulating diode exhibits a positive temperature coefficient of zener voltage. It is evident then, that under conditions of varying temperature, the base voltage of the transistor will not stay fixed at a constant or stable reference voltage. To offset this difficulty, it has been suggested to place compensating zener diodes, exhibiting a negative temperature coefficient of zener voltage, in series with the zener diode, exhibiting a positive temperature coefficient of zener voltage; the variations produced due to varying temperature will substantially cancel out over a wide range of temperatures. The use of such compensating zener diodes brings about the desired result of maintaining the base voltage of the transistor constant or stable over a wide range of temperatures.

The use of these temperature-compensating zener diodes, however, although solving one difficulty, gives rise to disadvantages and drawbacks. These temperature-compensating zener diodes have the characteristics of poor voltage regulation and high-current requirement. Because of the latter characteristic, the current supplied to these diodes from the input voltage of the transistor regulator is not sufficient to operate these diodes. Thus, the circuitry becomes inoperative as a regulator.

Another disadvantage of prior regulators is the relatively high internal current consumption. When the input voltage of the regulator is varied through the minimum-to-maximum regulating range, there will be a large increase in current drawn from the power source.

A further disadvantage of prior regulators is the relatively high voltage drop across the regulator at minimum input voltage.

It is, therefore, the principal aim of this invention to provide a simple and inexpensive way to overcome the difficulties and disadvantages arising from the use of temperature-compensating zener diodes having high-current requirement. This is accomplished by the present invention by providing a current-path means consisting of a resistor interconnecting the emitter or output terminal and the base of the transistor. Thus, the high current re-

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quired to operate the temperature-compensating zener diodes is supplied from the output side of the regulator. Although these zener diodes have poor voltage regulation, the voltage drop across these diodes is not appreciably susceptible to change when the high current flowing through them varies slightly with changes in input voltage. With the resistor providing a high-current path from the output side of the regulator, changes in input voltage will not cause appreciable current changes in the output side. Accordingly, the unique arrangement of the present invention provides a desirable voltage regulator stable over a wide temperature range of operation.

It is, therefore, the main object of this invention to provide a transistor voltage regulator stable over a wide temperature range of operation which features novel circuit means including a plurality of zener diodes interconnected in a unique manner to stabilize the voltage regulator over a wide temperature range.

Another object of this invention is to provide an improved voltage regulator, which can be easily and inexpensively made stable over a wide operating temperature range.

A further object of this invention is to provide an improved voltage regulator having a relatively low internal current consumption as compared to prior regulators.

A still further object of this invention is to provide an improved voltage regulator having a relatively lower voltage drop across the regulator at minimum input voltage than previously known regulators.

Other objects and advantages of the invention will become apparent from the following detailed description of a preferred embodiment of the invention when taken with the drawing which shows in the sole FIGURE a schematic diagram of the preferred embodiment of the invention.

Referring now to the sole figure, the best mode for carrying out the invention is as follows. There is shown a transistor voltage regulating circuit known as an emitter-follower voltage regulating circuit. The regulating circuit comprises an NPN type silicon transistor 10 having an emitter 11, a base 12 and a collector 13. A shunt resistance 9 is connected between the collector 13 and base 12 of the transistor 10. The regulating circuit has four zener diodes 1, 2, 3 and 4 connected in series with the base 12 of the transistor 10. Zener diode 1, whose cathode is connected to the base 12 of the transistor 10, has the characteristics of low-current requirement and good voltage regulation—its zener voltage does not change appreciably with change in current. It will, however, exhibit a positive temperature coefficient of zener voltage. Another zener diode means, comprising diodes 2, 3 and 4, is selected to have a negative temperature coefficient of zener voltage. Since diodes with negative temperature coefficients of zener voltage come only in small voltages, this diode means is shown as multiple diodes. The temperature-compensating zener diodes 2, 3 and 4, however, exhibit the characteristic of high-current requirement.

To supply these diodes with the required high current, a current-path means is provided for the three temperature-compensating diodes 2, 3 and 4, and consists of a resistor 14, interconnecting the emitter 11 and the common junction between the anode of diode 1 and the cathode of diode 2 in the base circuit of transistor 10. This current path supplies the high current required to operate the temperature-compensating diodes 2, 3 and 4 from the output side of the regulating circuit. Thus, changes in input voltage will not cause appreciable current changes in the output side.

The current flowing through the temperature-compensating diodes 2, 3 and 4 has a range, by way of example, of about 4 to 5 milliamperes. The current flowing

through regulating diode 1 has a range, by way of example, of about 0.1 to 1 milliamperere. A source 5 of input voltage is connected across the input terminals 6 and 7. An impedance load 18, shown as a resistor, is connected across the output terminals 16 and 17. It is appreciated that the impedance load 18 is not restricted to a resistor, but may be an inductor or other suitable circuit element. In one test, the input voltage from source 5 was varied from 25 to 33 volts and the output voltage across the load impedance 18 varied from 20 to 21 volts. The regulator operates over a wide temperature range, such as, by way of example, -20°C . to 83°C .

The operation of the apparatus will now be described. With the input voltage at 25 volts, diode 1 draws 0.1 milliamperere from the input voltage 5 through resistor 9. Since this current is not sufficient to operate diodes 2, 3 and 4, these diodes draw 4 milliamperes through resistor 14 from the output or regulated side of the regulator. The output voltage across the resistive load 18 is 20 volts. As the input voltage varies from 25 volts to 33 volts, there is a current change of approximately 1 milliamperere through the diodes 1, 2, 3 and 4. The current through regulating zener diode 1 changes from 0.1 to 1 milliamperere, and the current through the compensating zener diodes 2, 3 and 4 changes from 4 to 5 milliamperes. Although the current through diode 1 changes considerably, the voltage drop across regulating diode 1 does not change appreciably because the diode 1 has the characteristic of good voltage regulation. Moreover, the voltage drop across the compensating diodes 2, 3 and 4, which have the characteristic of poor voltage regulation, does not change appreciably either because the current change through these diodes is from 4 to 5 milliamperes, which is too small a change to cause any appreciable change in voltage across them.

Since diode 1 draws its small current required from the input voltage through resistor 9, and diodes 2, 3 and 4 draw their large amount of current required through resistor 14 from the regulated side of the regulator, it is evident that there will be little total change in current through all of the diodes when the input voltage varies from 25 to 33 volts. Now, as the temperature varies, the zener voltage of diode 1 varies proportionally and oppositely to the zener voltage of diodes 2, 3 and 4. When this event occurs there is very little over-all change in zener voltage at the base 12 of transistor 10. The base voltage and the emitter or output voltage of the transmitter 10, therefore, are maintained at a desired constant or stable voltage, since the emitter voltage follows the base voltage in the emitter-follower voltage regulator. With the input voltage changing from 25 to 33 volts, the output voltage across the load impedance 18 changes slightly from 20 to 21 volts. In the constructed embodiment, the regulator operated with a minimum of five volt drop at a minimum input voltage of 25 volts, and the output voltage remained nearly constant. However, with other types of transistors and with other diodes, the minimum operating voltage and other circuit characteristics may vary.

Thus, in operation it can be seen that there is very little internal current consumption when the input voltage is varied through the minimum-to-maximum regulating range. Although prior regulators operated with a minimum voltage drop of at least 8 to 10 volts across the regulator per 25 volt input, the regulator of the present invention is designed to operate with a minimum of 5 volt drop at a minimum input voltage of 25 volts.

The total regulator is relatively low cost and requires very few components for its operation—one transistor, four zener diodes and two inexpensive resistors.

This voltage regulator has good regulation over a wide range of temperature and input voltage. The regulator has the ability to regulate within plus or minus 1.3% with an input variation of plus or minus 10% through a temperature range of minus 20°C . to plus 83°C .

This invention is especially useful for silicon transistors, although it can be adapted for use with other semiconductor transistors such as germanium. However, in the case of germanium transistor regulators, it is known that they can be made more easily in other ways because of the lower collector resistance.

It is appreciated that the diode 1 could be picked to have a negative temperature coefficient of zener voltage. In this case, the other diode means would be selected to have an opposite temperature coefficient.

Moreover, although the use of three zener diodes in series has been found expedient because of the inherent limitations in commercially available diodes, if more desirable diodes were available, one might replace the three shown (diodes 2, 3 and 4 in the figure).

The diode 1 has been specified to have a positive temperature coefficient of zener voltage, whereas the diodes 2, 3 and 4 have been specified to have a negative temperature coefficient of zener voltage. The selection of the specific diodes used will be a matter of choice to one skilled in this art. By way of example, an operating circuit may be constructed by employing a commercially available diode identified in the trade as type 1N753 for diode 1 on the drawing; this diode has a positive temperature coefficient of $+0.022\%$ per degree centigrade. The diodes numbered 2, 3 and 4 on the drawing may each be the commercial type 1N751 which has a negative temperature coefficient of -0.008% per degree centigrade. The voltage regulation characteristics of each of these diodes may be had by reference to standard textbooks or to the manufacturer's specification sheet on the diode selected.

Although the present invention has been shown and described in terms of a specific preferred embodiment, changes and modifications which do not depart from the inventive concepts taught herein will suggest themselves to those skilled in the art. Such changes and modifications are deemed to fall within the scope and contemplations of the invention.

What is claimed is:

1. A transistor voltage regulator of the emitter-follower type comprising a transistor having an emitter, a base, and a collector, first zener diode means having one type of temperature coefficient of zener voltage connected to said base, second zener diode means having an opposite type of temperature coefficient of zener voltage connected in series with said first diode means, and means establishing a current path interconnecting said emitter and the common junction of said first and second zener diode means.

2. In a transistor voltage regulator of the emitter-follower type comprising a transistor having an emitter, a base and a collector, first zener diode means having one type of temperature coefficient of zener voltage connected to said base, means establishing a current path connecting said collector and said base to supply a small current to said first zener diode means, second zener diode means having an opposite type of temperature coefficient of zener voltage connected in series with said first zener diode means, and current-path means interconnecting said emitter and the common junction of said first and second zener diode means.

3. A transistor voltage regulator of the emitter-follower type comprising a silicon transistor having an emitter, a base, and a collector, first zener diode means having a positive temperature coefficient of zener voltage connected to said base, second zener diode means having a negative temperature coefficient of zener voltage connected in series with said first diode means, and means establishing a current path interconnecting said emitter and the common junction of said first and second zener diode means.

4. In a transistor voltage regulator of the emitter follower type comprising a silicon transistor having an emitter, a base and a collector, first zener diode means

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having a positive temperature coefficient of zener voltage connected to said base, means establishing a current path connecting said collector and said base to supply a small current to said first zener diode means, second zener diode means having a negative temperature coefficient of zener voltage connected in series with said first zener diode means, and current-path means interconnecting said

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emitter and the common junction of said first and second zener diode means.

References Cited in the file of this patent

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