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TRANSISTOR CURRENT REGULATOR

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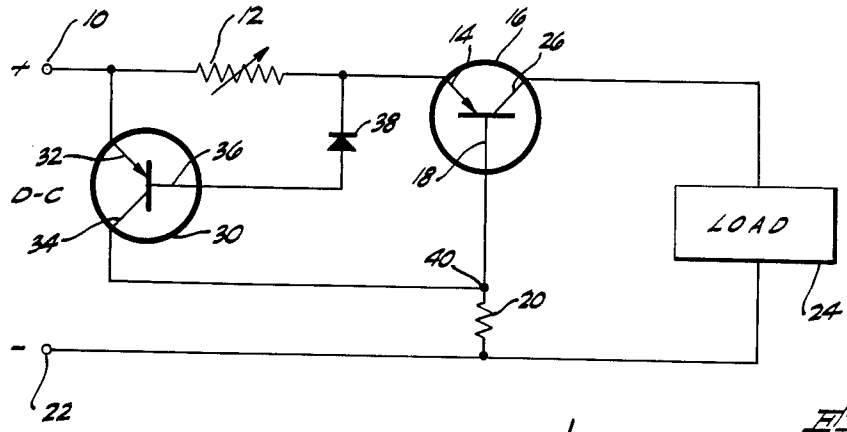


FIG. 1.

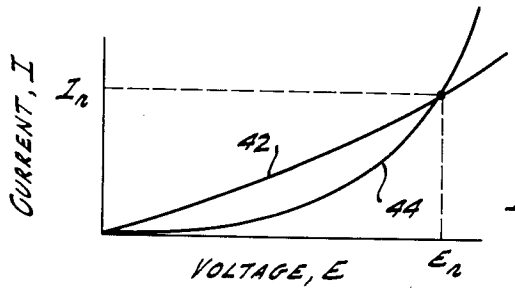


FIG. 2.

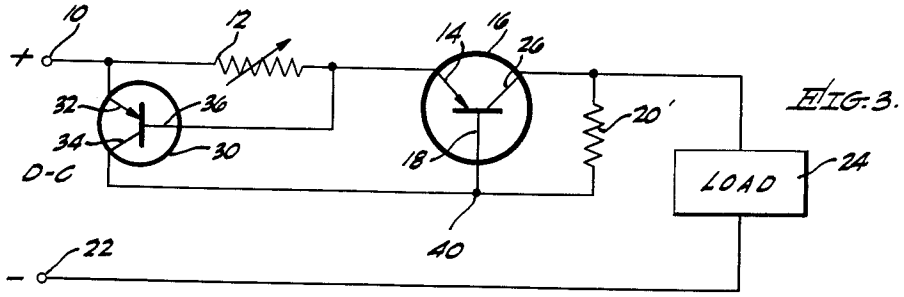


FIG. 3.

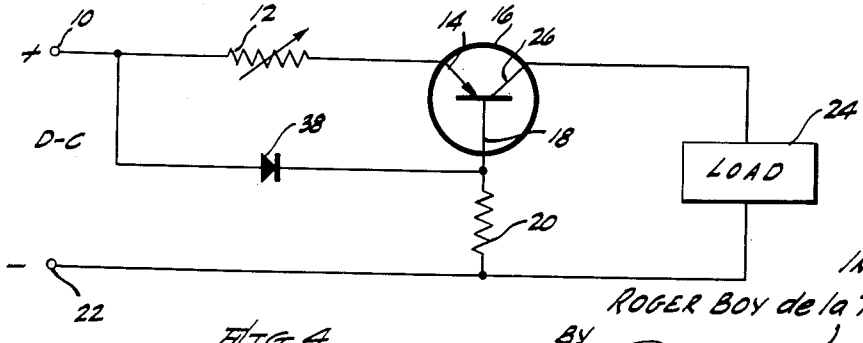


FIG. 4.

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TRANSISTOR CURRENT REGULATOR

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2 Claims. (Cl. 323—4)

This invention relates to current regulating devices, and more particularly to an improved current regulator circuit employing semiconductors.

In many situations, such as in aircraft, electronic equipment assumes such size and complexity as to place severe limitations on volume and weight requirements. As a consequence, emphasis has been placed upon miniaturization, including the development of simple but reliable circuits utilizing semiconductors to replace bulky and complex circuits which employ vacuum tubes. However, the internal impedance of many semiconductors such as transistors vary markedly with changes in ambient temperature. This characteristic is reflected in changes in the output or collector current of a transistor, and presents an obstacle to the use of transistors for current regulation.

It is an object of this invention to provide a unique current regulator circuit employing semiconductors, wherein output current is maintained constant despite of changes in internal impedance of semiconductors with variations in temperature.

It is a further object of this invention to provide a transistor current regulator comprising a minimum number of component parts of simple design, which is suitable for use where space and weight are at a premium.

The above and other objects and advantages of this invention will be apparent from the following description, taken in conjunction with the accompanying drawings, in which a preferred embodiment of the invention is illustrated by way of example. The scope of the invention is pointed out in the appended claims.

Referring to the drawing,

Fig. 1 is a schematic diagram of an improved current regulator employing a pair of transistors, in accordance with this invention,

Fig. 2 is a graph of current-voltage characteristics to aid in explaining the operation of the circuit of Fig. 1,

Fig. 3 is a schematic diagram of a modification of the current regulator of Fig. 1, further in accordance with this invention, and

Fig. 4 is a schematic diagram of a current regulator employing a single transistor, also in accordance with this invention.

Briefly, this invention comprises a current regulator utilizing a transistor having its emitter-to-collector current path in series with a source of D.-C. voltage and a load, and having a resistor connected between the positive terminal of the D.-C. source and the emitter electrode of such transistor. Means are provided for utilizing the voltage drop across the resistor as a reference to maintain a constant output current regardless of fluctuations in the voltage of the source or variations in the load.

Referring to Fig. 1, the positive terminal 10 of a D.-C. source (not shown) is connected through a resistor 12 to the emitter electrode 14 of a transistor 16, the base electrode 18 of which is resistively connected, as through

a resistor 20, to the negative terminal 22 of the source. Transistor 16 preferably is a power transistor. A load 24 is connected between the collector electrode 26 of transistor 16 and the negative terminal 22.

A transistor 30 has its emitter electrode 32 connected to positive terminal 10 and collector electrode 34 connected to the base 18 of transistor 16. The base electrode 36 of transistor 30 is shown coupled through a diode 38 to the emitter 14 of transistor 16. Diode 38 is used as a non-linear resistance element, as will now be more fully explained.

The operation of the above circuit will be described with reference to Fig. 2, which illustrates the current-voltage relations for the diode 38 and resistor 12. The constant slope line 42 represents the linear current-voltage relation for resistor 12, and curve 44 illustrates the non-linear portion or "knee," of the diode current-voltage characteristic. Resistor 12 is preferably a variable resistor to permit its adjustment so that its current-voltage characteristic 42 intercepts that of diode 38 in its non-linear region; this point is determined by the voltage E_r across resistor 12, and the current I_r through it, which is necessary to insure the desired load current at the rated voltage of the D.-C. source. At such rated voltage, a small emitter-to-collector current flows through transistor 30, and the resistances of resistor 12 and transistor 30 are such that emitter 14 is sufficiently positive, relative to base 18, to provide the desired current flow through load 24.

When the voltage of the source increases, whereby the voltage drop across resistor 12 tends to increase, an inspection of curve 44 shows that a greater current will tend to flow through diode 38. Such current also represents a larger base current of transistor 30, which effects a lower internal impedance of transistor 30. Accordingly, the potential difference between emitter 14 and base 18 of transistor 16 decreases, whereupon the current through resistor 12, the voltage drop across it, and the current through load 24 remain constant.

Similarly, if the source voltage decreases, thereby tending to decrease the voltage drop across resistor 12, it will be seen from curve 44 that the current through diode 38 will tend to decrease. Under these conditions, the internal impedance of transistor 30 tends to increase, resulting in a smaller collector current therefrom. Since the potential of junction 40 is less than that of terminal 10 by the amount of this impedance, the net effect is an increase in potential difference between emitter 14 and base 18 to maintain the current through resistor 12, and also the load current, constant.

If the load changes and tends to draw more or less current, there is a resulting tendency to draw more correspondingly more or less current through resistor 12, thereby to change the voltage drop across it. The same operation discussed above takes place to change the emitter-to-base potential difference for transistor 16, thereby maintaining the load current constant.

Although diode 38 is shown as a forward diode, it is pointed out that a backward diode may be suitable, e.g., a Zener diode working at the Zener voltage.

The foregoing operation has the distinct advantage that current flow through transistor 16 cannot be altered by changes in ambient temperature. If the temperature increases, thereby tending to lower the internal impedance of transistor 16 to effect greater current flow, the circuit of this invention functions as above explained to counteract this tendency and to keep the current constant.

In one example of a current regulator as above described, utilizing resistors 12, 20 of 30 and 5000 ohms, respectively, load current was observed for loads of 1,000

ohms and 500 ohms for variations in source voltage from 18 volts to 60 volts. The following results were obtained:

Source Voltage	18	25	30	40	50	60
Load Current, ma. (1,000-ohm load)	17	17.5	18	19	19.5	20
Load Current, ma. (500-ohm load)	17	17.5	18	18.5	19	20

As will be observed, the current regulation is very good, even for quite wide voltage variations. In actual practice, the voltage of a D.-C. source would not vary over such a range. For example, a 24-volt battery as used in aircraft may have a terminal voltage varying between 22 volts and 30 volts. With a current regulator as above described, the load current is held to within 0.5 ma. of a desired load current of 17.5 ma., i.e., less than a 3% change occurs in load current. To further illustrate the current regulating qualities of the above circuit, a load fed by a 24-volt battery was short-circuited. A measurement at a terminal battery voltage of 30 volts showed the current through the short-circuit connection was 18 ma.

Fig. 3 illustrates a modification of the current regulator of Fig. 1, wherein diode **38** is eliminated and the base **36** of transistor **30** is connected directly to the emitter **14** of transistor **16**. Also, resistor **20** is eliminated and a resistor **20'** connected between the base **18** and collector **26** of transistor **16**. So far as resistor **20** of Fig. 1 and resistor **20'** of Fig. 3 are concerned, it is noted that these represent alternate arrangements to complete voltage divider connections from terminal **10** to a point of lower potential. Further, such resistors serve to prevent transistor **16** from being made non-conductive. In the absence of a resistor, the impedance of transistor **30** may decrease sufficiently upon an increase in voltage drop across resistor **12** to cause base **18** to be positive with respect to emitter **14**. Transistor **30** would thus be cut off, whereupon emitter **14** would be placed at the potential of terminal **10** and conduction renewed, i.e., an oscillatory condition could result unless resistors **20**, **20'** were employed.

As is well known, the emitter and base electrodes of a transistor form a diode. The circuit of Fig. 3 makes use of this fact, and in this connection, curve **44** of Fig. 2 illustrates the non-linear portion of the current-voltage relations of the diode formed by emitter **32** and base **36** of transistor **30**. However, the non-linear characteristic here exists at much smaller currents than required for a conventional diode. Accordingly, it would be necessary to adjust resistor **12** for a low enough resistance to permit its linear characteristic to intercept the non-linear characteristic at an appropriate point. Beyond this, the operation of the circuit of Fig. 3 is identical to that of Fig. 1.

Fig. 4 illustrates still a further modification, wherein transistor **30** of Figs. 1 and 3 is eliminated and diode **38** is connected between terminal **10** and the junction **40** of base **18** and resistor **20**. Since the voltage drop between emitter **14** and base **18** is quite small, diode **38** in this version is effectively connected across resistor **12**, and also serves as a variable resistance connection between terminal **10** and base **18**. The operation of the circuit of Fig. 4 differs from that of the circuits of Figs. 1 and 3 by the current amplification characteristic of transistor **30**. Thus, in Fig. 4, changes in base potential with changes in the potential of terminal **10** are not as pronounced as in the circuits of Figs. 1 and 3, and circuit operation is correspondingly less rapid when changes in source voltage or load impedance occur. As with the circuits of Figs. 1 and 3, this circuit functions to counteract the effects of temperature change upon transistor **16**.

The circuits of Figs. 1 and 4 have been illustrated and described as using p-n-p junction transistors. It is noted that n-p-n junction transistors could also be used, in which case all polarities shown are reversed.

From the foregoing, it will be apparent that there has been described an improved current regulator utilizing semiconductors, wherein a resistor and the emitter-collector path of a transistor are connected in series between a source of D.-C. voltage and a load impedance, wherein voltage responsive means connected across such resistor operate upon changes in source voltage or load impedance to vary the emitter-base potential difference to maintain substantially constant the voltage drop across the resistor and the current through the load impedance.

What is claimed is:

1. A current regulator device comprising a source of D.-C. voltage having output terminals, said source having a rated voltage output, a transistor having emitter, base and collector electrodes, a resistor connected between one of said output terminals and said emitter electrode, a load impedance connected between the other of said output terminals and said collector electrode, means operable at the rated voltage to establish a voltage drop across said resistor and a potential difference between said base electrode and said emitter electrode to establish a predetermined current through said load impedance, said last-named means including a second transistor having an emitter-collector path connected between said one output terminal and said base electrode, a resistor connected between said base electrode and a point of potential different from the potential at said one output terminal, a diode, said second transistor having a base electrode, and said diode being connected between the base electrode of said second transistor and said emitter electrode of said first transistor.

2. A current regulator having a pair of input terminals for connection to a D.-C. voltage source having a rated output voltage, a pair of output terminals for connection to a load impedance, a transistor having emitter, base and collector electrodes, a resistor connected between one input terminal and said emitter electrode, said collector electrode being connected to one output terminal, a direct connection between the remaining input and output terminals, means establishing a potential difference between said emitter and base electrodes at the rated voltage of the source to provide a predetermined collector current through the load impedance, said last-named means including a diode, a transistor having an emitter electrode connected to said one input terminal, a collector electrode connected to the base electrode of the first-mentioned transistor, and a base electrode coupled through said diode to the emitter electrode of said first-mentioned transistor.

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