United States Patent

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[73] Assignee **The Bendix Corporation**

[54] **LIGHT-COUPLED, VOLTAGE-CONTROLLED CONSTANT-POWER SOURCE**
14 Claims, 2 Drawing Figs.

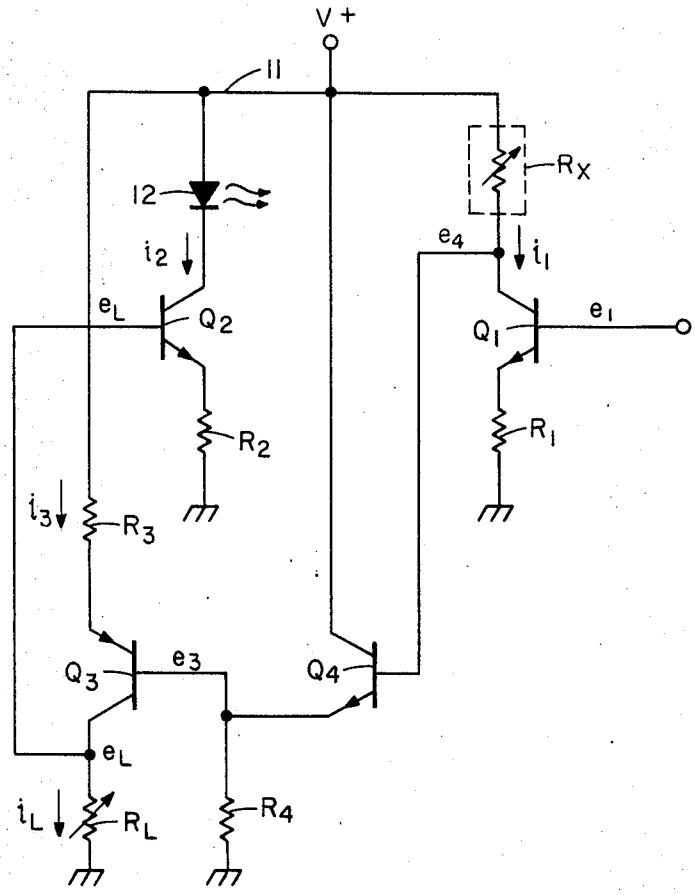
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[51] **Int. Cl.** **G05f 1/56,** G05f 1/66
[50] **Field of Search** ..... 307/117, 311; 315/158; 317/124; 323/4, 21, 22 T

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ABSTRACT: A solid-state circuit for supplying constant power to a varying resistive load in response to a control voltage includes a light source and a photosensitive resistor. Load current is generated by a load current generator operating in response to a control signal. Resultant voltage drop across the load controls a second current generator which is serially connected with a light source. A third current generator, controlled by an independent control voltage, is serially connected with a photosensitive resistor exposed to the light source. Voltage on the photosensitive resistor comprises the control signal which controls the load current generator.



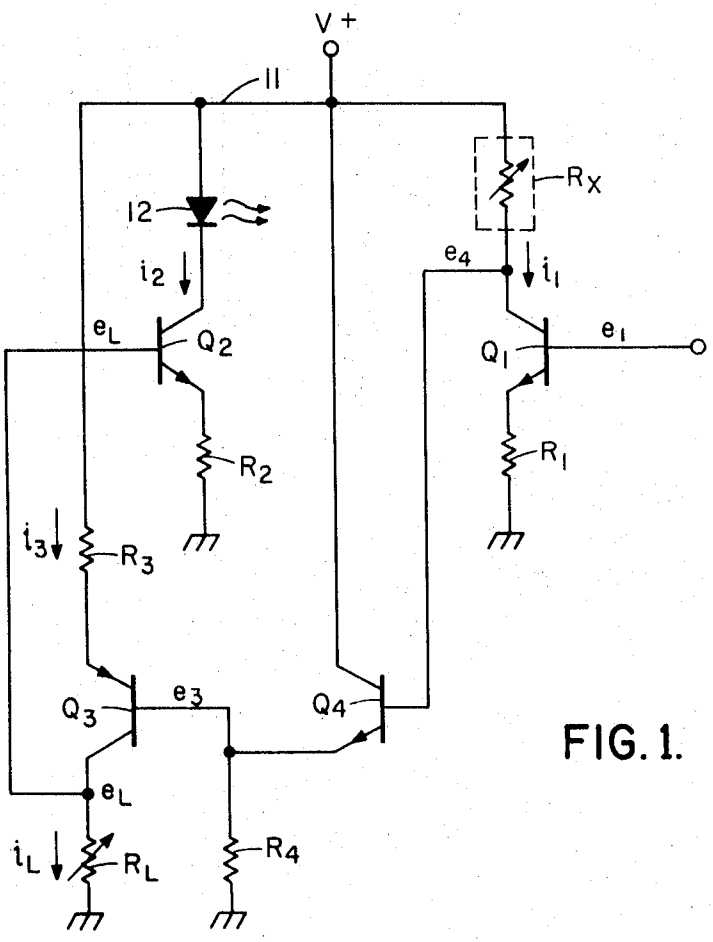


FIG. 1.

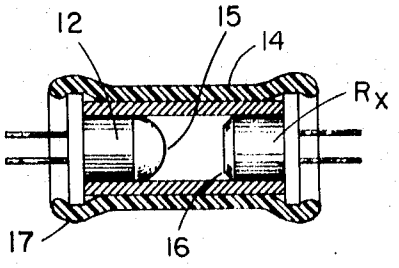


FIG. 2.

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LIGHT-COUPLED, VOLTAGE-CONTROLLED CONSTANT-POWER SOURCE

BACKGROUND OF THE INVENTION

This invention relates to a constant electrical power circuit which maintains constant the electrical power dissipated in a varying resistance load and more particularly to such a power circuit which is constructed of solid-state elements and whose output power can be modulated by a control voltage.

The electrical power dissipated in a resistive element depends upon three variable quantities: resistance of the element; current through the element; and voltage drop across the element. Electrical power sources are normally provided to supply either a constant current or a constant voltage and when such a power source is connected to deliver power to a resistive element whose resistance remains constant, the power dissipated therein will remain constant. However, if the resistance of the element varies, a constant voltage or a constant-current power source alone cannot supply unvarying power to the element. In this case, it is necessary, in order to maintain constant power dissipation in the resistive element, to vary both the current through the resistance and the voltage thereacross.

SUMMARY OF THE INVENTION

A circuit has been devised which delivers constant power to a varying resistor. This is accomplished by sensing the voltage drop across the resistor and, through the use of a novel feedback means, varying the current through the resistor in response to the voltage drop. Briefly, the voltage drop across the resistor is used to modulate a current source, with the modulated current flowing through a radiant energy source, in this particular embodiment a light-emitting diode, whose radiant output is proportional to the current flowing therethrough. A voltage modulator in the form of another current generator has its operating point set by an externally supplied voltage, and additionally comprises a radiant energy sensitive resistor which modulates a control voltage. This control voltage is applied to a load current source which supplies current to the varying resistor thus controlling the current therethrough.

It is thus an object of this invention to provide a constant-power electrical circuit.

It is another object of this invention to provide a constant-power circuit of the type described using radiant energy techniques.

It is another object of this invention to provide constant-power dissipation in a varying resistive load.

It is still another object of this invention to provide a constant-power circuit of the type described which is comprised of semiconductor active elements.

Further objects, features and advantages of the invention will become apparent in the following description and claims when read in view of the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic of the invention.

FIG. 2 shows a means for physically coupling a light-emitting diode to a responsive photosensitive resistor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a resistor R_L whose resistance value varies with respect to time is connected between ground and the collector electrode of the transistor Q_3. A current i_L flows through R_L producing a resultant collector voltage with respect to ground, e_L, which is the voltage drop across resistor R_L. R_L is connected in the serial circuit comprised of the emitter-collector circuit of transistor Q_3 and resistor R_3 between positive voltage bus 11 and ground. A current i_3 flows into the emitter electrode of transistor Q_3. Voltage e_L is sampled at the base electrode of transistor Q_2, whose emitter electrode is connected to ground through R_2 and whose collector electrode is connected to the positive voltage bus 11 through

light-emitting diode 12. Q_2 collector current i_2 excites light-emitting diode 12 to emit radiant energy which excites photosensitive resistor R_X. R_X is connected between the positive voltage bus 11 and the collector electrode of transistor Q_1. A resistor R_1 is connected between the emitter electrode of transistor Q_1 and ground. Control voltage e_1, from a source not shown, is applied to the base electrode of transistor Q_1. Q_1 collector voltage, e_4, is sampled at the base electrode of emitter follower Q_4 whose collector is connected to the positive bus 11 and whose emitter electrode is connected to the base electrode of transistor Q_3. Resistor R_4 is connected between the emitter electrode of transistor Q_4 and ground.

As aforementioned, this circuit operates to maintain the following relationship:

$P_L=e_Li_L=K_1$ where P_L = the power dissipated through resistor R_L and K_1 is a constant. To accomplish this, transistor Q_3 operates as a current generator, regulated in response to base voltage e_3 to generate the resultant collector current i_L which flows through resistor R_L. The resultant voltage drop, e_L, across resistor R_L is applied to the base electrode of transistor Q_2, which also operates as a current generator to generate in response thereto collector current i_2 flowing in the light emitter diode 12.

Light emitter diode 12 is physically disposed in close proximity to photosensitive resistor R_X so that the resistance thereof will vary in accordance with the light emitted by the light-emitting diode, and hence in accordance with the current flow through this diode. It can be seen that the current flow i_L through resistor R_X, assuming, as is the case, that resistor R_1 remains constant, is dependent on control voltage e_1. Q_1 collector voltage e_4, resulting from current i_1 flow through R_X, is applied to emitter follower comprised of transistors Q_4 and resistor R_4 to the base electrode of transistor Q_3. The voltage at the base electrode of transistor Q_3 has been designated as e_3 in the figure and it should be obvious that e_3 is equal to e_4 except for the diode drop across the base emitter diode of emitter follower Q_4. As aforementioned, e_3, and hence e_4, comprises the control for current generator Q_3.

The amount of light emitted by the light-emitting diode 12 is dependent upon the current which passes through it. At the same time the resistance value of photosensitive resistor R_X varies inversely as the amount of light from light-emitting diode 12 which impinges upon it. Hence the relationship:

$$R_X=K_2/i_2 \qquad (1)$$

where K_2 is a coupling constant determined by the characteristics of resistor R_X and the light-emitting diode and the physical coupling therebetween.

Expression (1) can be used as a basis for showing that the power dissipated in resistor R_L is a constant and a function of K_2, the control voltage e_1 and other circuit parameters. In the following mathematical analysis of the circuit diode voltage drops are neglected because they are small relative to the other voltage drops.

Using the expression (1) and the obvious relationship:

$$i_2=e_L/R_2 \text{ and } i_1=e_1/R_1$$

it can be seen that:

$$e_4=V-i_1R_x=V-i_1\frac{K_2}{i_2}=V-\frac{e_1K_2}{R_1i_2}=V-\frac{K_2R_2e_1}{R_1e_L} \qquad (2)$$

Since diode voltage drops can be neglected $e_3=e_4$ so that:

$$i_3=\frac{V-e_4}{R_3}=\frac{V-V+\frac{K_2R_2e_1}{R_1e_L}}{R_3}=\frac{K_2R_2}{R_3R_1}\frac{e_1}{e_L} \qquad (3)$$

$$i_3e_L=\frac{K_2R_2}{R_1R_3}e_1$$

but

$$i_3=i_L \qquad (4)$$

so that:

$$P_{RL}=e_L i_L=\frac{K_2R_2}{R_1R_3}\,e_1 \qquad (5)$$

From equation (5) it can be seen that for every distinct and constant level of control voltage e_1 there is a corresponding constant power dissipated in resistor R_L. In other words, if e_1 is maintained constant, the power dissipated in R_L remains constant, or conversely, the power dissipated in R_L can be modulated by varying control voltage e_1.

Referring now to FIG. 2, there is seen convenient means for physically coupling light-emitting diode 12 to photosensitive resistor R_X when both of these elements are packaged in a conventional transistor can configuration. As shown, the elements are inserted end to end into tube 14 which has an internal diameter equal to the external diameter of the elements and is of such length that the light-emitting face 15 of light-emitting diode 12 is maintained in close proximity to the photosensitive face 16 of photosensitive resistor R_X. The elements are held in place by any convenient means such as by the use of tape 17. The finish of the internal surface of tube 14 is of no consequence, it only being required for constant power dissipation in the load that the coupling factor K_2 between the two elements be constant over their intended range of use.

Having disclosed the above preferred embodiment of our invention, we hereby claim the subject matter including alterations and modifications thereof encompassed by the true scope and spirit of the appended claims.

The invention claimed is:

1. Means for supplying a constant power to a varying resistive element comprising:
- means responsive to the voltage drop across said element for generating a control current which is directly proportional to said voltage drop;
- means responsive to said control current for generating radiant energy;
- a source of a first control voltage;
- means responsive to said first control voltage and said radiant energy for generating a second control voltage; and,
- means responsive to said second control voltage for controlling current through said element.

2. Means as recited in claim 1 wherein said radiant energy generating means comprises a light-emitting diode.

3. Means as recited in claim 2 wherein said means for generating a second control voltage comprises:
- means responsive to said first control voltage for generating a second current; and,
- photosensitive resistive means responsive to said radiant energy and disposed to sample said second current, the voltage drop across said photosensitive resistive means being related to said second control voltage.

4. Means as recited in claim 3 with additionally means for mounting said light-emitting diode in a fixed, predetermined position with respect to said photosensitive resistive means.

5. Means as recited in claim 3 with additionally mounting means for maintaining the radiant energy coupling factor between said light-emitting diode and said photosensitive resistive means constant over the operating range of said constant-power means.

6. A constant-power source for a resistive element comprising:
- means responsive to the voltage across said element for generating radiant energy;
- a source of a first control voltage external to said constant-power source;
- means responsive to said first control voltage and said radiant energy for generating a second control voltage; and,
- means responsive to said second control voltage for controlling current through said element.

7. A constant-power source as recited in claim 6 wherein said second control voltage generating means comprises:
- means responsive to said first control voltage for generating a first control current;
- variable resistance means responsive to said radiant energy and said first control current for generating said second control voltage.

8. A constant-power source as recited in claim 7 wherein said radiant energy generating means comprises means responsive to said voltage across said element for generating a second control current and means responsive to said second control current for generating said radiant energy.

9. A constant-power source as recited in claim 8 wherein said radiant energy generating means comprises a light-emitting diode and said variable resistance means comprises a photosensitive resistor.

10. A constant-power source for a resistive load comprising:
- a load current generator responsive to a first control signal for regulating current through said load, the resultant voltage drop across said load comprising a load voltage;
- means responsive to said load voltage for generating a second current;
- means responsive to said second current for generating a feedback signal;
- a second control signal source external to said constant-power source; and,
- means responsive to said second control signal and said feedback signal for generating said first control signal.

11. A constant-power source as recited in claim 10 wherein said first control signal generating means comprises:
- means responsive to said second control signal for generating a third current; and,
- means responsive to said feedback signal and said third current for generating said first control signal.

12. A constant-power source as recited in claim 11 wherein said means for generating a feedback signal comprises a light-emitting diode, said feedback signal comprising radiant energy generated thereby and arranged to sample said second current; and, wherein said means for generating said first control signal comprises a photosensitive resistor responsive to said radiant energy and arranged to sample said third current, a resultant voltage drop across said photosensitive resistor comprising said first control signal.

13. A constant-power source as recited in claim 12 wherein said light-emitting diode and said photosensitive resistor are physically fixed with respect to one another.

14. A constant-power source for a resistive load comprising:
- a direct current source having first and second terminals, said resistive load having one end connected to said second terminal, and a second end;
- a first resistor having one end connected to said first terminal, and a second end
- a first transistor having a base electrode and a collector-emitter circuit for connecting said first resistor and said resistive load second ends;
- a light-emitting diode having one end connected to said first terminal, and a second end;
- a second resistor having one end connected to said second terminal, and a second end;
- a second transistor having a base terminal connected to said resistive load second end, and a collector-emitter circuit for connecting said light-emitting diode second end with said second resistor second end;
- a photosensitive resistor having one end connected to said first terminal, and a second end;
- a third resistor having one end connected to said second terminal, and a second end;
- a control voltage source;
- a third transistor having a base electrode connected to said control voltage source, and a collector-emitter circuit for connecting said photosensitive resistor second end with said third resistor second end; and,
- means connecting said photosensitive resistor second end to said first transistor base electrode.

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