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[72] Inventor **Ernest O. Lee, Jr.**
Fairport, N.Y.
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[73] Assignee **Stromberg-Carlson Corporation**
Rochester, N.Y.

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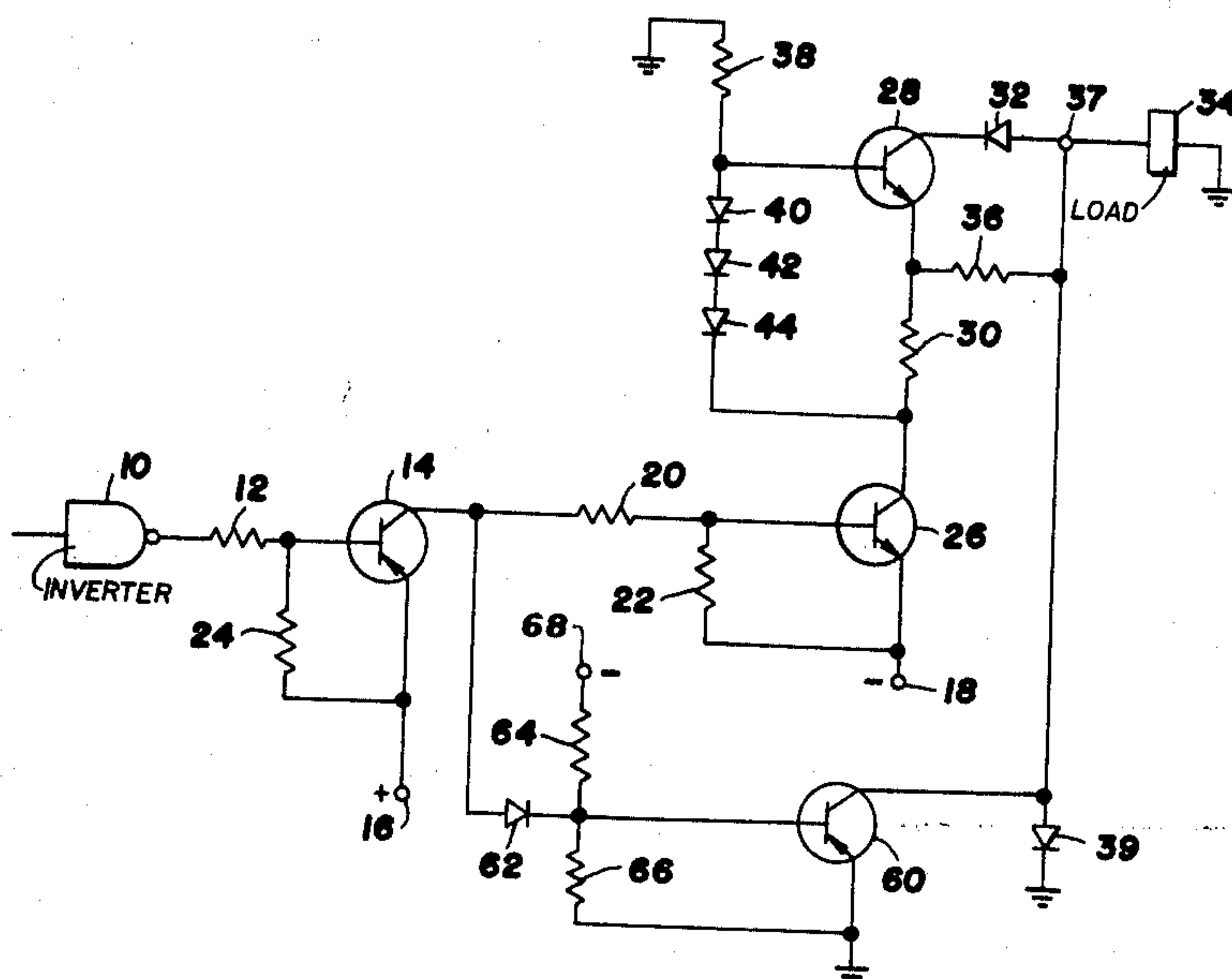
Primary Examiner—A. D. Pellinen
Attorney—Charles C. Krawczyk

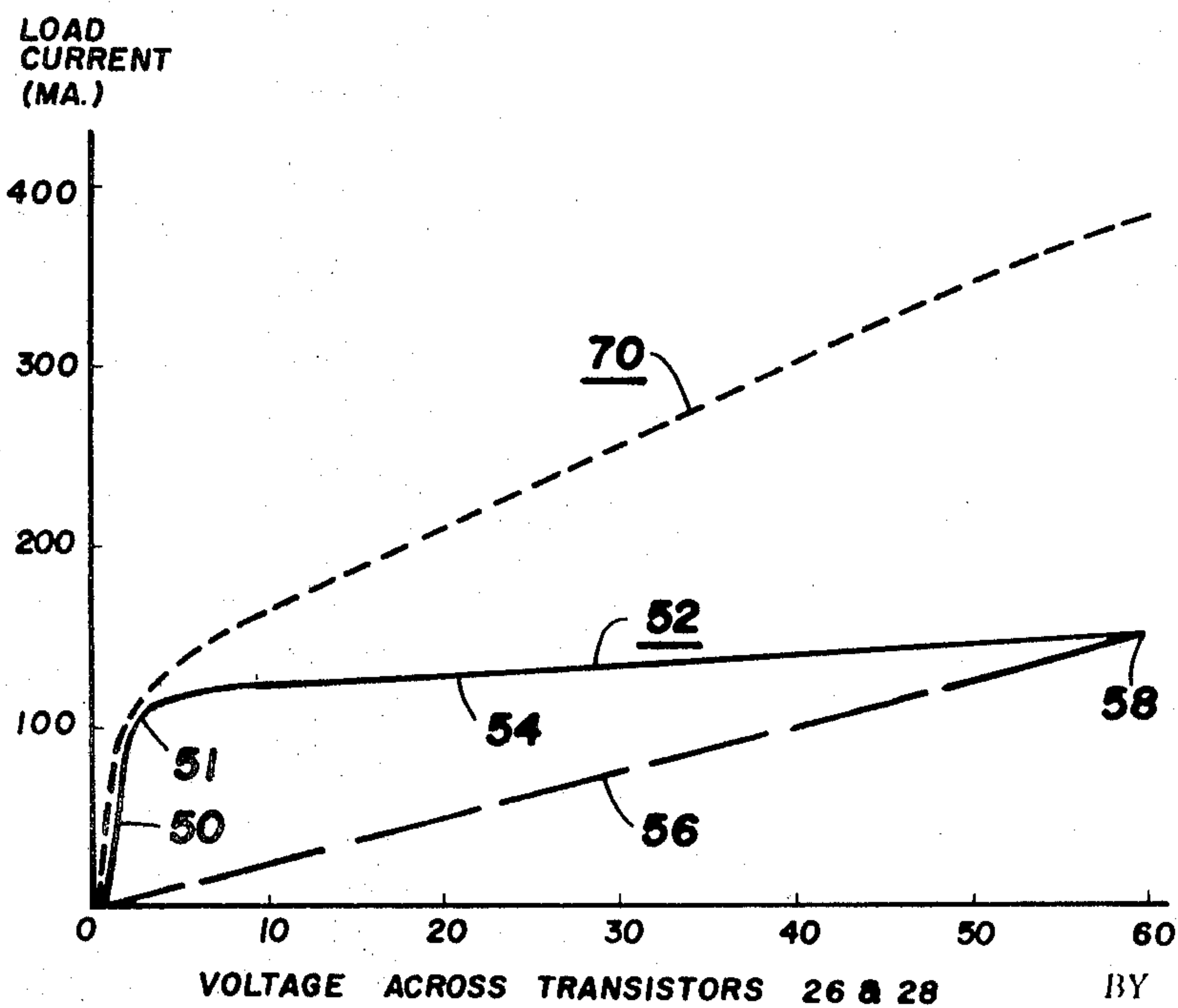
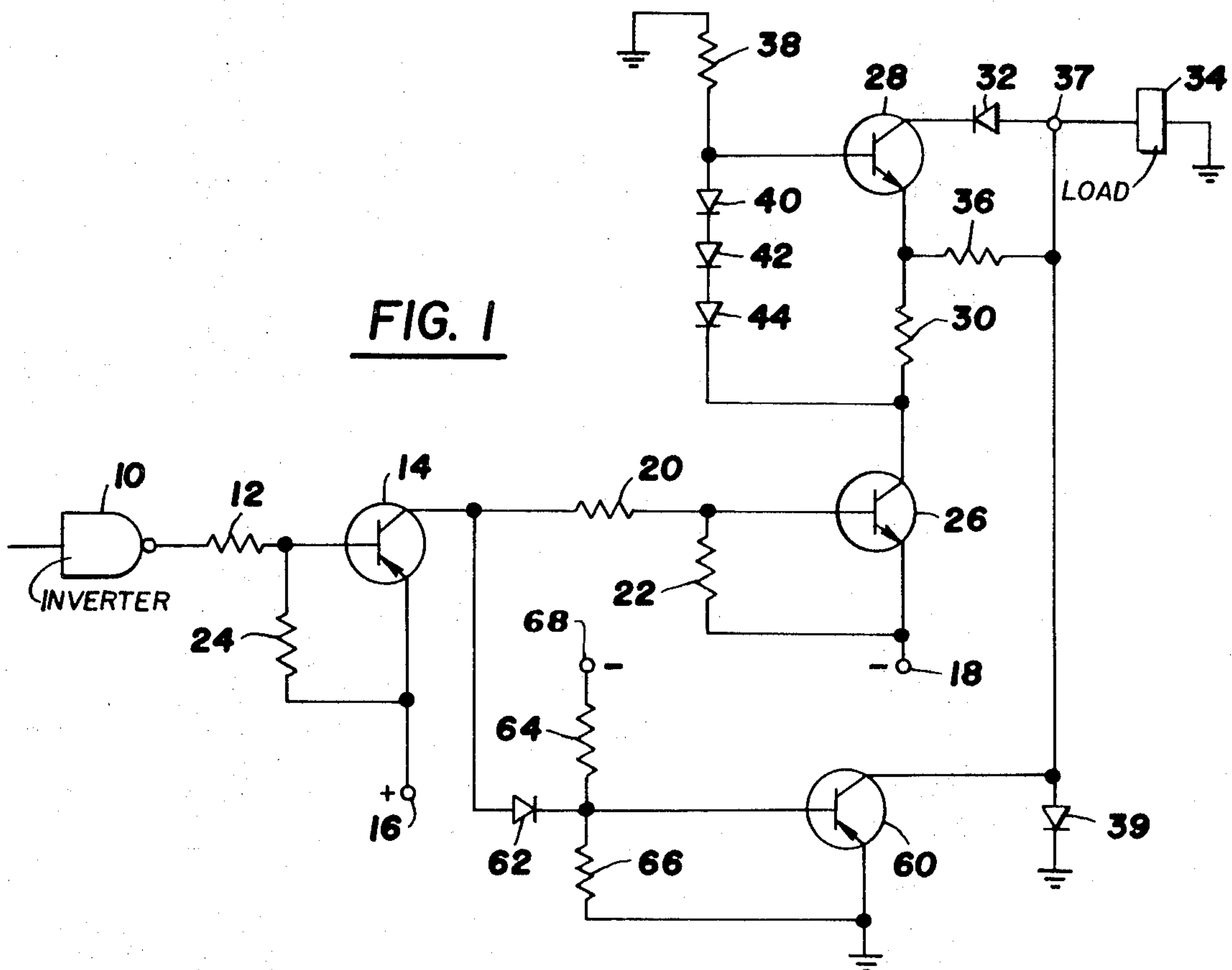
[54] **CURRENT LIMITING SWITCHING CIRCUIT**
10 Claims, 2 Drawing Figs.

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ABSTRACT: First and second transistors are connected in a series circuit with a load circuit. Switching signals are applied to the first transistor to render both transistors conductive simultaneously. A constant bias potential is applied to the second transistor so that said transistor is switched into saturation for a normal range of current. A resistor is connected in the series circuit between the transistors so that in the event of overload conditions the current flow through the resistor overcomes the constant bias and the circuit functions as a constant current source. A third transistor can be connected to apply ground to the load circuit when the first and second transistors are cut off to provide battery-to-ground signalling.





ERNEST O. LEE, JR.
INVENTOR.

BY *Charles C. Hrawczyk*

ATTORNEY

CURRENT LIMITING SWITCHING CIRCUIT

BACKGROUND OF THE INVENTION

This invention pertains to switching circuits in general and more particularly to switching circuits that have current limiting capabilities in the event of overload conditions.

In various control-type systems, such as for example, computers and telephone exchanges, it is necessary to transmit switching signals to a large variety of controlled devices, often at varying distances, and often presenting different load impedances. Furthermore, the controlled device, or the connections thereto, may fail and present undesirable high loading on the system output circuit. Hence, it is desirable to provide an interface-type circuit that assures proper transmission of signals to a large range of external load impedances and also provides an overload protection in the event of a fault in the external load.

In telephone trunk switching circuits wherein signalling and supervisory control is exercised on a separate line (other than that transmitting the voice signals), a low resistance battery is applied to the line to indicate the presence of a signal, and an open circuit, or ground, indicates the absence of a signal. In order to insure that external faults on this lead do not damage the trunk circuit, or blow a fuse, some sort of current limiting is generally included in the trunk circuit. In the past this has normally been done by the use of a ballast lamp connected in series with the signal lead, or sometimes by merely connecting a resistor in series with the lead. The characteristic of the ballast lamp is such that at low currents it presents a relatively low resistance. However, when the current increases the lamp filament becomes hotter and its resistance increases, thus tending to limit the current flow to the circuit. While the ballast lamp is more effective as a current limiter than a simple resistor, it still presents certain disadvantages. The ballast lamp filaments inherent have a limited life and therefore lamp replacement is necessary from time to time. The ballast lamp is bulky and is difficult to fit into densely packaged equipment. In operation, the ballast lamp presents a very low resistance to current flow to a specified level. Beyond the specified level, the ballast lamp functions as a high resistance providing only a crude approximation of an ideal current limiting characteristic.

It is therefore an object of this invention to provide a new and improved switching circuit with substantially constant current limiting capabilities in the event of overload conditions.

It is also an object of this invention to provide a new and improved switching circuit that functions as a low impedance for a normal range of load current and a substantially constant current source for a range of load current greater than normal.

It is still a further object of this invention to provide a new and improved compact semiconductor switching circuit with current limiting capabilities for overload conditions that is responsive to low level logic signals.

It is also an object of this invention to provide a new and improved switching circuit with current limiting capabilities for overload conditions that can provide battery-to-open, or battery-to-ground signalling.

BRIEF DESCRIPTION OF THE INVENTION

The switching circuit of the invention includes current limiting capabilities in the event of overload conditions. A semiconductor device is connected in series with a load circuit and a switching circuit that renders the device conductive and nonconductive. A constant bias signal is applied to the control terminal of the device. Resistive means is connected in the series circuit so that for a normal range of current the device is saturated when rendered conductive, and for overload conditions the signal developed by said resistive means counteracts the constant bias signal and said device, when rendered conductive, functions as a substantially constant current source.

A further feature of the invention includes a second semiconductor device connected between the load circuit and

ground and controlled by said switching circuit so that when the other device is cut off, the second device is conductive, and vice versa, thereby providing battery-to-ground signalling.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a schematic diagram of a switching circuit including the invention.

Fig. 2 is a graph illustrating a comparison between the current limiting characteristics of the circuit of FIG. 1 and that of the ballast lamps used in the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the embodiment of the invention in FIG. 1, low level switching signals are applied through an inverter circuit 10 and a current limiting resistor 12 to the base of a first switching transistor 14. The emitter of the transistor 14 is connected to a positive power supply terminal 16 while the collector is connected to a negative power supply terminal 18 through the series resistors 20 and 22. The transistor 14 is biased by a resistor 24 so that when a positive signal (in the order of 5 volts) is applied by the inverter 10 the transistor 14 is nonconductive, and when a low signal (ground) is applied, the transistor 14 is saturated.

The junction of the resistors 20 and 22 is connected to the base of a second switching transistor 26. The emitter of the transistor 26 is connected to the negative power supply terminal 18 while the collector is connected through a current control resistor 30 to the emitter of a transistor 28. The collector of the transistor 28 is connected through a diode 32 and an output terminal 37 to an external load 34, illustrated as a relay winding. A diode 39 is connected between the terminal 37 and ground to reduce inductive spikes. A bypass resistor 36 is connected between the emitter of transistor 28 and the terminal 37. The biasing circuit for the transistor 28 includes a resistor 38 and the silicon diodes 40, 42 and 44 connected in series between ground and the collector of transistor 26. The junction of the resistor 38 and the diode 40 is connected to the base of the transistor 28.

When a positive signal from the inverter 10 is present, the transistors 14, 26 and 28 are cut off presenting an open circuit to the external load 34. When a ground signal is present, the transistors 14, 26 and 28 are conductive to energize the load 34. Transistors 14 and 26 function as switching circuits, either in a saturated or cut off state. The transistor 28 generally functions as a low impedance switching circuit that is switched between saturation and cut off for a normal range of load currents. However, in the event of an overload fault in the external load, or connection thereto, the transistor functions as a substantially constant current switching circuit limiting the amount of current to the faulty load to a predetermined level.

The resistor 38 and the diodes 40, 42 and 44 function to supply a substantially constant reference potential to the base of the transistor 28. The base-emitter junction of transistor 28 compares the biasing potential at the base to the voltage drop across the current control resistor 30. Since the resistor 30 is connected in series with the transistors 26 and 28 and the external load 34, the voltage drop across the resistor 30 is proportional to the current flow to the external load. The circuit values are selected so that under a normal range of resistive values of the external load 34, the transistor 28 is a saturable switch and operates in the portion 50 of the curve 52 of FIG. 2. In the event of an overload condition, the transistor 28 operates as a constant current switch in the portion 54 of curve 52.

The curve 52 of FIG. 2 is a plot of the total current flow through the external load 34 versus the voltage drop across the transistors 26 and 28. The transistors 26 and 28 are saturated while operating below the knee of the curve 52 (portion 50) so that the output circuit flow is determined by the resistance value of resistor 30 and the load 34. If the resistance of the load should decrease, the current flow will increase proportionally until a limiting point of the circuit is reached (por-

tion 51) wherein the voltage drop across the resistor 30 reaches a magnitude that reduces the bias on the base-emitter junction of transistor 28 to a point to prevent the transistor 28 from being saturated. This increases the voltage drop across the transistor 28 and limits the current to the load. Any further reductions in the resistance of the load 34 will operate the circuit beyond the knee 51 and into the limiting portion 54 thereby presenting a substantially constant current flow to the load 34 with additional reduction in the load resistance.

The resistor 36 is connected in parallel with the collector and emitter current path of the transistor 28 to reduce the power dissipation of the transistor and allows the use of a smaller and less expensive transistor. Since the resistor 36 is connected to the emitter of the transistor 28, the current flow through the resistor 36 is reflected as a voltage drop across the resistor 30 and thus the current limiting action is not effected by the distribution of current between transistor 28 and the resistor 36 up to a point wherein the transistor 28 is cut off, at which time the entire current flow is through the resistor 36.

Hence, for operation below the knee 51 of the curve 52 the transistor 28 (when conductive) is saturated and presents essentially no limitation to current flow. This is the region for normal operation. With the foregoing circuit values and voltage level, the current limit value is approximately 120 milliamperes:

Terminal 18=50 volts

Resistor 22=10 ohms

Resistor 36=400 ohms

Resistor 38=6,800 ohms

The value of the current limit may be varied by changing the bias voltage at the base of the transistor 28 or by changing the value of the resistor 30. The current flow through the resistor 36 is illustrated in FIG. 2 by the curve 56. Beyond the point 58 (when the limiting action cuts off the transistor 28) current limiting ceases and the current will increase linearly with decreasing resistance of the external load 34. The value of the resistor 36 is chosen such that this point is beyond the maximum supply voltage (potential at terminal 18) which would be normally applied to the circuit.

If there is a requirement for battery-to-ground signalling rather than battery-to-open signalling a fourth transistor 60 is added to the circuit. The base of the transistor 60 is connected through a diode 62 to the collector of the transistor 14. A biasing circuit, including a pair of resistors 64 and 66, connected between ground and a negative supply terminal 68, provides a biasing potential to the base of the transistor 60. The arrangement is such that when the transistors 14, 26 and 28 are cut off, the transistor 60 is saturated to connect the terminal 37 to ground and thereby provide battery-to-ground signalling. The curve 70 of FIG. 2 illustrates the typical characteristic of a ballast lamp. At low currents the ballast lamp provides a relatively low resistance. At higher currents the conductivity of the ballast lamp decreases to limit the amount of current available to the external source. However, it should be noted that the current continues to increase at a relatively high rate and the limiting effect of the ballast tube is only partially effective. As illustrated by the curve 52, the operation of the circuit of the invention provides a very low resistance current for a normal range of external loads, corresponding to the curve portion 50, and in the event of an overload condition in the external load 34, the circuit functions as a substantially constant current high impedance source. Hence, once the external load exceeds the normal range, the amount of current flow to the external load 34 is highly limited.

The transistors of the circuit of the invention operate in a cut off or a saturated condition during normal load conditions so that a minimum amount of power dissipation is required by the transistors. In the event of an overload condition in the external load, the transistor 28 and the resistor 36 share the load current. The arrangement is such that as the external load increases, the amount of current flow through the resistor 36 increases while the current flow through the transistor 28 decreases, thereby reducing the power dissipation require-

ments of the transistor 28. In addition to the foregoing, the circuit can be simply modified to provide either battery-to-open or battery-to-ground signalling. The circuit of the invention also has the advantage of being able to be responsive to low-level logic signals generally employed with semiconductor circuitry.

What is claimed is:

1. A switching circuit comprising:

a semiconductor device including first and second terminals defining a controllable current path therebetween, and a control terminal for controlling the current flow therethrough;

circuit means for connecting said first terminal to a load circuit;

circuit means for applying a constant bias signal to said control terminal;

switching means responsive to a control signal for providing a circuit that is switched between high and low impedance states;

resistive means, and

circuit means connecting said resistive means in a series circuit between said second terminal and said switching means so that for a first range of current through said resistive means said device is saturated when said switching means is in said low-impedance state and is cut off when said switching circuit is in said high-impedance state, and for a second range of current through said resistive means, greater than said first range, said resistive means generates a signal that offsets said constant bias signal wherein said device functions as a substantially constant current source providing a present level of current and said device is conductive at said present level when said switching circuit is in said low-impedance state and is cut off when said switching circuit is in said high-impedance state.

2. A switching circuit comprising:

first and second transistors;

resistive means;

circuit means connecting said first and second transistors in a series circuit, with said resistive means connected between the collector of said first transistor and the emitter of said second transistor;

circuit means for connecting said second transistor collector to an output circuit;

biasing circuit means for applying a substantially constant bias potential to the base of said second transistor, and

switching circuit means coupled to the base of said first transistor for switching said first and second transistor between conductive and nonconductive states.

3. A switching circuit as defined in claim 2 including:

a third transistor;

circuit means connecting said third transistor between the collector of said second transistor and ground, and

circuit means connecting the base of said third transistor to said switching means so that said third transistor is rendered conductive when said first and second transistors are rendered nonconductive, and vice versa.

4. A switching circuit as defined in claim 2 wherein said biasing circuit means includes a plurality of diodes in series with a second resistive means connected to apply a substantially constant reference potential to the base of said second transistor.

5. A switching circuit as defined in claim 4 wherein said switching means switches said first transistor between cut off and saturated states of operation.

6. A switching circuit as defined in claim 5 including third resistive means connected between said output circuit and the emitter of said second transistor.

7. A switching circuit comprising:

first and second power terminals for connection to a unidirectional source of energizing potential;

first and second semiconductor devices, each including first and second terminals defining a controllable current path

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therebetween and a control terminal for controlling the current flow therethrough;
 an output terminal for connection to a load circuit connected to said first power terminal;
 switching circuit means connected to the control terminal of said first semiconductor device for switching said first device between saturated and nonconductive states;
 biasing means connected to the control terminal of said second semiconductor device for applying a substantially constant biasing control potential thereto;
 circuit means connecting the first and second terminals of said first and second semiconductor devices in a series circuit between said second power terminal and said output terminal so that second device is conductive when said first device is conductive;
 resistive means, and
 circuit means connecting said resistive means in said series circuit between said first and second devices so that a current flow through said series circuit develops a potential across said resistive means having a polarity to counteract the biasing potential applied to said second device, the arrangement being such that for a first range of current through said resistive means said second device is switched between a saturated state and cut off, and for a second range of current through said resistive means, greater than said first range, the potential drop across said

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resistive means reduces the conductivity of said second device to provide a substantially constant current switching circuit.

8. A switching circuit as defined in claim 7 including:
 a third semiconductor device having first and second terminals defining a controllable current path therebetween and a control terminal for controlling the current flow therethrough;

circuit means connecting the first and second terminal of said third device between said output terminal and said first power terminal, and

circuit means connecting the control terminal of said third device to said switching means so that said third device is rendered conductive when said first device is cut off.

9. A switching circuit as defined in claim 8 wherein said biasing circuit means includes second resistive means connected in series with a plurality of diodes between said first power terminal and the connection of said other resistive means with said first device, and circuit means connecting said second resistive means to the control terminal of said second device.

10. A switching circuit as defined in claim 9 including third resistive means connected across the first and second terminals of said second device.

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