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SURGE CURRENT CONTROL

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FIG. 1

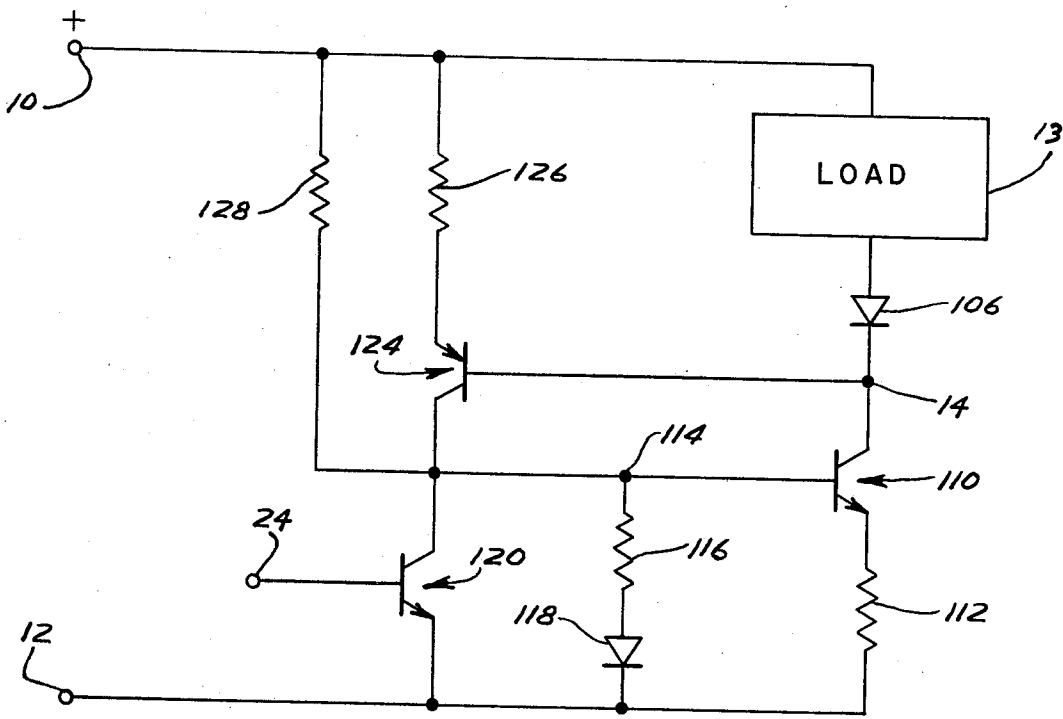
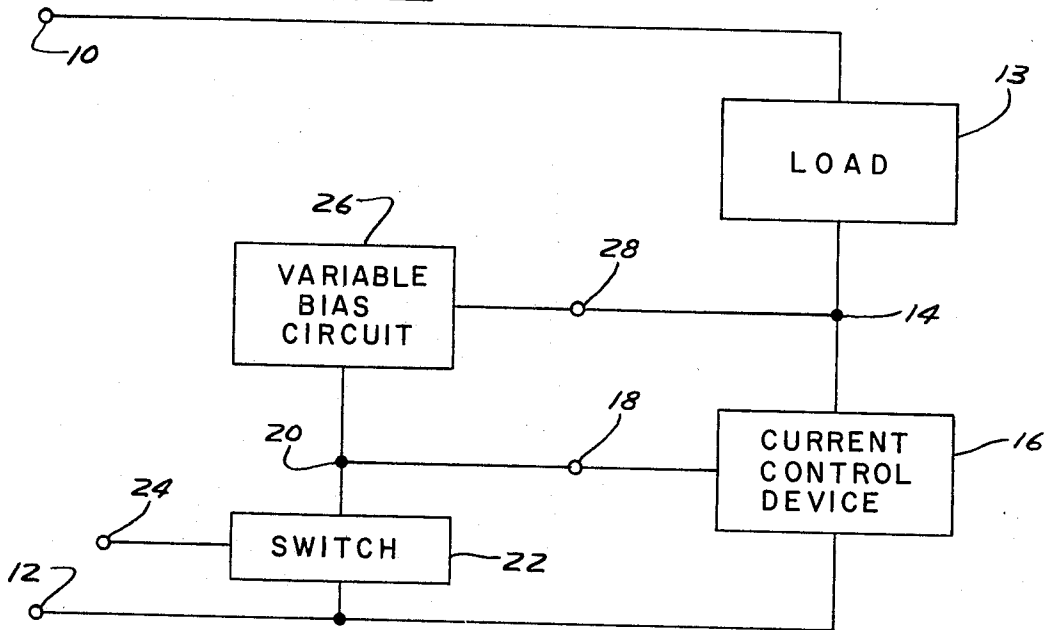


FIG. 2

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SURGE CURRENT CONTROL

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4 Claims

ABSTRACT OF THE DISCLOSURE

An electrical circuit for preventing surge currents in an electrical load is disclosed. A current control device, in series with a load, allows load current to increase in relation to a signal at its input. The signal is indicative of the condition of the load. As the condition of the load more closely approximate a steady state condition, the signal derived from the load causes the current control device to allow more current to flow in the load until the steady state level of current is reached.

BACKGROUND

Surge currents, a problem in electrical loads, occur because most electrical loads have an initial condition which is greatly different from their final or steady state condition. In most cases the initial condition presents a lower impedance to the driving source, and therefore, the load draws more current initially. This initial overcurrent is called a surge current. One example of a load causing a surge current is a load with a large associated parallel capacitance. A voltage source driving this load must charge the capacitance, appearing as a low impedance in parallel with the actual load, before steady state conditions can be reached. The charging causes a surge current. Another example of a load causing a surge current is a lamp whose resistance increases as the lamp filament reaches its operating temperature. Since the initial resistance of the lamp filament is lower than its final resistance, a surge current is drawn until the operating temperature is reached.

Various solutions have been tried to overcome the surge current problem. For example, a direct approach is to use a switch that can carry the surge current and not try to eliminate it. The disadvantages of this technique are the large size of the switch necessary, the limited life of the switch, and the interference with other circuits on the same power supply line caused by the surge currents.

Keep-on circuits which allow a small holding current to flow in the load at all times have also been tried. This technique partially aids a lamp circuit by keeping the filament slightly warm. Power is wasted using this technique, however, and the surge currents are not totally eliminated.

Inserting a series resistor to maintain a minimum resistance in the circuit has also been tried. This technique has the disadvantages of wasting large amounts of power during steady state operating conditions and needing higher voltage supplies to eventually reach equilibrium operating voltage at the load. Nor does it totally eliminate surge current.

The present invention prevents the entire surge by allowing the current to slowly build in the load as the condition of the load dictates. Using a lamp as an example again, the condition of the load or the signal used to control the current in the lamp is sensed from the voltage across the lamp. The voltage is dependent upon the instantaneous current in the lamp and the instantaneous resistance of the lamp. These two factors indicate the degree to which the lamp has reached steady state conditions. By using the voltage across the lamp to control

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the allowable current in the lamp, the surge is totally eliminated.

DESCRIPTION

It is an object of the present invention to advance the art of eliminating surge currents in an electrical load.

Further objects and advantages may be ascertained from an understanding of the description of the illustrative embodiment of the invention and from the appended claims.

The invention may be best described by reference to the drawings where:

FIG. 1 shows a block diagram of an electrical circuit using the teachings of the present invention;

FIG. 2 shows one possible transistorized embodiment of the block diagram of FIG. 1.

In FIG. 1, input terminal means 10 and 12 are adapted to be connected to a source of electrical energy, for example a voltage supply. A load 13 is connected between terminal 10 and a junction point 14. A current control device or current amplifier means 16 is connected between junction point 14 and terminal 12. Current control device 16 has an input terminal means 18 which is connected to a junction point 20. Apparatus initiating means or a switch 22 is connected between junction point 20 and terminal 12. Switch 22 also has an input terminal means 24. A variable bias device 26 is also connected to junction point 20. Variable bias device 26 includes a control terminal means 28 which is connected to junction point 14.

FIG. 2 also shows apparatus input terminal means 10 and 12. Terminal 10 forms the positive input terminal, and terminal 12 forms the negative input terminal. One end of a load 13 is connected to terminal 10. The other end of load 13 is connected to the anode of a diode 106. The cathode of diode 106 is connected to a junction point 14. A transistor 110 has its collector connected to junction point 14, its emitter connected to terminal 12 through an emitter degeneration resistor 112, and its base connected to a junction point 114. A resistor 116 has one end connected to junction point 114 and the other end connected to the anode of a diode 118. The cathode of diode 118 is connected to terminal 12. A transistor 120 has its collector connected to junction point 114 and its emitter connected to terminal 12. The base of transistor 120 forms an input terminal means 24. A transistor 124 has its collector connected to junction point 114, its base connected to junction point 14, and its emitter connected to terminal 10 through an emitter degeneration resistor 126. A resistor 128 is connected between terminal 10 and junction point 114.

OPERATION

In FIG. 1, current control device 16 allows current to flow through load 13 in proportion to a bias signal appearing at input 18. The bias signal is applied by variable bias device 26. Variable bias device 26 forms this bias signal according to the condition of the load as indicated by the signal provided by the connection of control input 28 of variable bias device 26 to junction point 14.

For the purpose of this specification, "load impedance" or "impedance of the load" includes DC or AC resistance, capacitive reactance caused by the charging of the capacitor, and inductive reactance in a motor caused by armature rotation. The actual impedance, being a ratio and usually not directly measured, is determined by reference to some parameter associated with the load. In a lamp circuit, the impedance would be indicated by the voltage across the lamp. If load 13 is a motor, the impedance of the load might be indicated by the speed of that motor. It is not considered necessary that variable bias device 26 be directly connected to the load as shown, as is understood from the last example. Any means of

sensing the impedance of the load will suffice whether directly connected to the load or not.

Switch 22 is used merely as an On-Off switch. When switch 22 prevents any signal from variable bias device 26 from reaching input 18 of current control device 16, no current is allowed to flow in the load.

In FIG. 2 transistor 110 and resistor 112 function as current control device 16 of FIG. 1 because a voltage applied across the base emitter junction and emitter degeneration resistor of a transistor operating in a common emitter configuration results in that transistor providing a collector current which is approximately equal to the input voltage divided by the emitter degeneration resistor—as is well known to those skilled in the art.

Transistor 124, resistor 126, resistor 128, resistor 116, and diode 118 function as variable bias device 26 of FIGURE 1. Resistor 128, resistor 116, and diode 118, form a fixed bias circuit in the form of a voltage divider which sets an initial value upon the voltage at junction point 114. Transistor 124 and resistor 126 form a current source in the same manner as transistor 110 and resistor 112. Transistor 124 and resistor 126 act as a controlled bias circuit. The collector current provided by transistor 124 will be approximately equal to the voltage between junction point 14 and terminal 10 divided by the value of emitter degeneration resistor 126. Initial bias is provided by the voltage divider and additional bias is provided by the collector current of transistor 124 in relation to the voltage across load 13.

Transistor 120 functions as switch 22 of FIG. 1. A signal impressed between input 24 and terminal 12 will render transistor 120 conducting or non-conducting. If transistor 120 is conducting, it shunts the bias to transistor 110 to ground. Without bias, transistor 110 will provide no collector current, and no load current will flow. If transistor 120 is non-conducting, bias may be provided to transistor 110 and load current may flow.

The operation of FIG. 2 may now be explained with reference to the functioning of all component parts just explained. For this explanation, assume load 13 is a lamp filament, and the filament resistance is low initially and increases to its steady state value, as previously explained. A source of power such as a voltage generator will be connected between terminals 10 and 12. When it is desired to provide current to load 13, a signal at input 24 to transistor 120 renders transistor 120 non-conducting. The current which was previously flowing from terminal 10 through resistor 128, through the collector-emitter junction of transistor 120, and to terminal 12 is now conducted through resistor 128, resistor 116, and diode 118 to terminal 12. This current causes a voltage between junction point 114 and terminal 12. This voltage provides an initial bias to transistor 110 and load current begins to flow from terminal 10, through load 13, through diode 106, through the collector-emitter junction of transistor 110, through resistor 112, and to terminal 12. This load current passing through the load impedance causes a voltage between junction point 14 and terminal 10. This voltage causes a collector current to flow from transistor 124 as previously explained. The collector current from transistor 124 increases the voltage between junction point 114 and terminal 12. This increase in voltage causes additional current to flow through transistor 110. The additional current flowing through transistor 110 and the load impedance causes an increase in voltage between junction point 14 and terminal 10. This increase in voltage causes additional collector current to flow from transistor 124 which again causes transistor 110 to allow additional load current to flow. If load 13 were equal to its steady state value, the circuit would recycle in this fashion until full load current was achieved. Since the circuit operation to this point is very rapid, however, load 13 has not achieved its steady state value. In fact, since load 13 was assumed to be a lamp filament, its impedance at this point is much lower than its steady state value.

Since the impedance of load 13 is much lower than its steady state value, the voltage between junction point 14 and terminal 10 is much lower than steady state. This voltage allows less than steady state collector current flow from transistor 124. Less than steady state collector current from transistor 124 causes less bias to be applied to transistor 110. If transistor 110 does not have full bias, less than full collector current is allowed to flow. Without the present invention, the initial current in the lamp circuit is greater than its steady state value. Using the present invention, it is now seen that the initial current is less than its steady state value, and the current increases to steady state value as the condition of the load allows.

The initial low value of current established in the load then begins to warm the lamp filament causing its impedance to increase. The increase in impedance causes an increase in voltage between junction point 14 and terminal 10. This increase in voltage causes an increase in collector current from transistor 124 which in turn increases the voltage between junction point 114 and terminal 12. This increase in voltage causes additional current to flow through transistor 110. The additional current through transistor 110 aids the heating of the lamp filament. As the lamp filament continues to heat, the voltage between junction point 14 and terminal 10 continues to approach its steady state value. As this voltage approaches its steady state value, a steady state bias is provided to transistor 110 which allows steady state load current to flow.

It is now apparent that the load current is allowed to build only in relation to condition of the load. In the lamp example, if the increase in resistance were slow, the voltage across the load would increase slowly and the current through the load would be constrained to increase slowly. If the resistance of the load increased to approach its steady state value rapidly, the voltage across the load would increase more rapidly and the current through the load would be allowed to increase more rapidly. Thus, the current through the load increases at a rate determined by the rate the load approaches its steady state value.

Diodes 118 and 106 are not necessary in all embodiments and are inserted to eliminate the emitter-base voltage offset of transistors 110 and 124. If these diodes were not present, their respective transistors would require an additional input bias voltage equal to the emitter-base voltage of the transistor.

The value of resistor 112 is chosen assuming that, under steady state conditions, the collector to emitter saturation voltage of transistor 110 and the small diode drop across diode 106 may be neglected. Thus the only voltage drops in the circuit are across load 13 and resistor 112. Resistor 112 is then chosen to be small in relation to the steady state resistance of load 13 so that resistor 112 does not cause an excessive power loss.

After resistor 112 is chosen, the steady state voltage between junction point 14 and terminal 10 is known. Resistor 126 is chosen small enough to provide sufficient bias from transistor 124 to saturate transistor 110.

Resistors 128 and 116 must at least provide an initial bias large enough to cause some initial load current and must conform to the biasing requirements of the transistors used.

It will be obvious to those skilled in the art that many variations may be made within the teachings of the present invention. For example switch 22 of FIG. 1 may be inserted in series with input 18 of current control device 16, in series with input terminal 10, or in series with input terminal 12 and yet perform the same function.

Also, variable bias circuit 26 of FIG. 1 may be connected to the same source of power as load 13, as illustrated in FIG. 2, or to a different source of power.

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Additionally many active devices will perform the functions necessary. Transistors are shown for illustrative purposes only.

Again, the present invention may be used to eliminate transients after a steady state is reached. It is not limited to eliminating initial surges.

The description of the present invention is for illustrative purposes only and is not intended as a limitation. Many alternates and variations will be obvious to one skilled in the art. It is desired that the present invention be limited only by the appended claims in which it is intended to cover the full scope and spirit of the present invention.

I claim:

1. Apparatus for controlling surge currents in an electrical load caused by variation in the load impedance, comprising:

(a) current control means for controlling load current, said current control means having a control terminal for receiving an input signal and a controllable impedance connected between two output terminals, said controllable impedance coupled in series relationship between the electrical load and a power source, and having controllable impedance values responsive to signals applied to said control terminal;

(b) variable bias means for applying signals to said control terminal, said variable bias means having an input device coupled to said electrical load and responsive to the impedance of said electrical load to generate signals for applying to said control terminal to cause impedance of said current control means to vary in an inverse relationship with load impedance,

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2. The apparatus of claim 1 wherein the variable bias means input device further comprises voltage sensing means connected across said electrical load.

3. The apparatus of claim 1 wherein an electric motor comprises said load and wherein said variable bias means input device further comprises motor speed sensing means.

4. Apparatus for controlling surge currents in an electrical load caused by variations in the load impedance, comprising

(a) first amplifying means for supplying power to the load, including an input terminal for receiving the signal to be amplified and

(b) second amplifying means including an input device coupled to said electrical load and responsive to the impedance of said load, said second amplifying means generating signals applied to said input terminal to cause output power of said first amplifying means to increase with increasing load impedance and decrease with decreasing load impedance.

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