REDUCED ACTUATION TIME THERMAL RELAY SYSTEM

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Abstract

A reduced actuation time thermal relay system for controlling energization of a load by a power supply. The system comprises a thermal relay having a resistive control element and a pair of mating contacts movable between closed circuit and open circuit positions in response to the temperature of the control element rising above a predetermined level and falling substantially therebelow. The system also includes means for electrically energizing the resistive control element initially to apply a first voltage thereby to cause rapid heating of the element and thereafter to apply a second and reduced voltage to the element, the reduced voltage being of sufficient magnitude to prevent the temperature of the element from falling substantially below the predetermined level whereby the actuation time of the thermal relay is substantially reduced without damaging the resistive control element.

14 Claims, 6 Drawing Figures
FIG. 5

FIG. 6

CONTACT MAKE

CONTACT ARM POSITION (Z)

ACTUATION TIME
REDUCED ACTUATION TIME THERMAL RELAY SYSTEM

BACKGROUND OF THE INVENTION

This invention relates generally to relay systems and more particularly to a reduced actuation time thermal relay system.

The use of conventional electromagnetic relays as an interface between integrated circuit controls and relatively high current electrical loads has not been generally satisfactory and practical. A recently developed thermal actuator appears to be quite useful as an interface between the low power outputs of such integrated circuit controls and electrical loads having substantial current requirements. Such a thermal actuator utilizes a wire of a martensitic memory alloy which will, when heated to a transition temperature by the passage of electric current, change its length and actuate electrical contacts capable of handling substantial currents.

Thus these thermal actuators have a very high gain so that they may be energized by low power sources such as integrated circuits and control the energization of substantial loads. However, the time required between the initiation of energization of the control wire of such actuators and the actual actuation of the contacts is in some applications, e.g., the operation of the brake lights and horn in automotive vehicle applications, greater than desired. This inherent time delay of such thermal actuators, which involves a “thermal wind-up” from ambient temperatures to the transition temperature of the wire, is typically in the order of 0.1 to 0.5 seconds.

SUMMARY OF THE INVENTION

Among the several objects of the invention may be noted the provision of an improved thermal relay system; the provision of such a system which will greatly reduce the actuation time of the thermal relay without damage to the relay; the provision of such a system which has a decreased transfer time of the contacts between their open circuit and closed circuit positions and greatly reduce the possibility of contact welds; and the provision of such a system which is reliable in operation and is simple and economical to manufacture. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, a reduced actuation time thermal relay system of this invention comprises a thermal relay having a resistive control element and a pair of mating contacts movable between closed circuit and open circuit positions in response to the temperature of the control element rising above a predetermined level and falling substantially therebelow. The system also includes means for electrically energizing the resistive control element initially to apply a first voltage thereby to cause rapid heating of the element and thereafter to apply a second and reduced voltage to the element. The reduced voltage is of sufficient magnitude to prevent the temperature of the element from falling substantially below the predetermined level whereby the actuation time of the thermal relay is substantially reduced without damaging the resistive control element.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan of a thermal actuator such as is utilized in a thermal relay system of this invention;

FIG. 2 is a section generally on line 2—2 of FIG. 1 with certain components shown in elevation;

FIG. 3 is a schematic diagram of a reduced actuation time thermal relay system of the present invention;

FIG. 4 is a graph illustrating the reduction in actuation time of a system of the present invention as compared to that of a thermal actuator such as shown in FIGS. 1 and 2;

FIG. 5 is a schematic diagram of an alternate embodiment of the present invention which reduces contact transfer time as well as thermal windup time; and

FIG. 6 is a graph illustrating the improved response time of the alternate embodiment as compared to that of a thermal actuator such as shown in FIGS. 1 and 2.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. 1 and 2, a thermal relay or actuator is indicated generally by 1. This relay comprises a frame, preferably molded from a thermosetting synthetic resin material, having a pair of spaced parallel sidewalks 2 with three bridging support portions 3, 4 and 5. Bridging portion 3 has a threaded bore 6 receiving a machine screw 7 to secure thereto one end of a switch arm 8 and a terminal lug 9. Bridging support 4 is provided with a doubly counterbored bore 10 which receives a shank of a machine screw 11, the tip of which is threaded into a terminal lug 12 carrying a contact 13 on an inner end thereof while the outer end serves as a normally closed (NC) terminal for the actuator or relay. Another terminal lug 14 is secured to the undersurface of support 4 by a retainer 16 against which the head of screw 11 bears. The inner cantilevered end of lug 14 carries another fixed contact 15 and the outer end of lug 14 constitutes a normally open (NO) terminal for relay 1. A double-faced contact 16 is mounted on the free end of switch arm 8 which is biased upwardly into engagement with contact 13 by a coil spring 17 seated in a well 18 of bridging support 5.

A bell crank 19 of electrical insulation material is mounted for pivotal movement about a pin 20 within the recess formed between sidewalks 2. A nose 21 constituting one end of the bell crank bears against the switch arm 8 on the surface opposite that against which the end of spring 17 acts. The other end of crank 19 has two integrally formed spaced tongues 22 projecting therefrom, while a similar tongue 23 is formed on the upper surface of support 3. Mounted on support 3 are two similar spaced terminal members 24 and 25 having upper arms, the outer end of which serve as terminal posts 26 and 27, and legs 24a and 25a extending downwardly and secured to support 3. Members 24 and 25 have outwardly projecting ends 29 and 29a forming terminals for connection to a low level power source.

A thin wire 28 of a martensitic memory alloy, such as that formed of a selected nickel-titanium alloy referred to as Nitinol, has its opposite ends secured to terminal posts 26 and 27 and is trained around tongues 22 and 23 and four reaches. This wire, tensioned by spring 17 acting against the nose of crank 19 to rotate it counterclockwise, is a resistive control element, which when heated above a transition temperature by the passage
of low level current, will quickly shorten because of a sudden change in its modulus of elasticity and overcome the biasing action of spring 17 to move switch arm 8 and cause contact 16 to engage contact 15. When the actuator or terminal relay wire 28 is electrically deenergized, it cools below its transition temperature and will revert to its original modulus of elasticity and thereby lengthen so as to permit contact 16 to disengage contact 15 and return to engagement with contact 13.

This thermal actuator is particularly useful in that it has a high gain and can be directly operated by the very low power level provided by integrated circuit chips. However, the time required for actuation of the relay to move contact 16 from one to the other of its positions, although typically in the order of 0.1 to 0.5 seconds, is too long for some applications of this actuator.

A reduced actuation time thermal relay system of this invention is shown in FIG. 3. In addition to thermal actuator 1 the system includes means for electrically energizing resistive control element 28 initially to apply a first voltage corresponding to V1 (hereafter referred to as V1) to cause rapid heating of the element and thereafter to apply a second and reduced voltage corresponding to V2 (hereafter referred to as V2) to the element to prevent the temperature of the control element from falling substantially below its transition temperature. An electrical load 30 is connected to the NO relay terminal carrying contact 15 while the NC terminal and its contact 13 are interconnected to V2 via a diode D1 and terminal 29 of control wire 28. The other terminal 29a of control element 28 is connected to ground through the collector-emitter circuit of a transistor Q1. The base of Q1 is connected through a current limiting resistor R1 to an input terminal 31.

With no control signal applied to input terminal 31 and the base of transistor Q1, Q1 does not conduct and control element 28 remains at ambient temperatures with the relay contacts as shown in FIG. 3. When a control signal is applied to the base of transistor Q1, it conducts and control element 28 is energized by V1 via normally closed contacts 13, 16. Since the cathode of diode D1 is at a higher potential than its anode, D1 is back biased preventing energization of element 28 by voltage source V2. The potential of V1 is so high that it causes very rapid heating of resistance control wire 28 to its transition temperature whereupon contact arm 8 will start to move contact 16 away from contact 13. V1 is of such a magnitude that if it were applied to control wire 28 for a substantial period of time the wire could be damaged. However, as soon as contact 16 disengages contact 13, the circuit from V1 to wire 28 is broken and diode D1 becomes forward biased so that wire 28 is then energized by the lower potential voltage source V2. The magnitude of V2 is sufficient to maintain the temperature of element 28 preferably somewhat above the predetermined transition temperature of wire 28 or in any event to prevent this temperature from falling substantially below transition temperature. The application of V1 and then V2 voltage to wire 28 thus reduces the actuation time of contact arm 8 in moving contact 16 into engagement with contact 15 thereby to energize load 30. Diode D1 serves as a means for preventing application of the second and reduced voltage to the control element until after initial contact movement and contact 13 in conjunction with contact 16 constitutes means for terminating application of the first voltage to the control element after initial contact movement.

When the control signal to the base of transistor Q1 is removed, Q1 ceases to conduct and control element 28 is thus deenergized. As the temperature of element 28 falls substantially below its transition temperature, the contact 16 will move away from contact 15 and deenergize load 30.

If the desired control function of the relay system is to maintain the load 30 energized while the control wire 28 remains deenergized and to deenergize the load in response to heating of element 28 above its transition temperature, this is accomplished by a simple modification of the circuit of FIG. 3. Load 30 is simply disconnected from contact 13 and connected to contact 15, with no other circuit changes necessary. The load continues to be energized by V1 and control element 28 remains unheated as long as no signal is applied to the base of Q1 which therefore remains nonconducting. When a signal is applied to the base of Q1, it will conduct thereby simultaneously applying the overdriving V1 voltage to control wire 28 to effect accelerated heating thereof and causing contact arm 8 to move contact 16 away from contact 13 thereby deenergizing load 30. After this accelerated opening of contacts 16 and 13, control wire 28 is energized at the lower voltage level of V2 and it remains so until the control signal is removed.

FIG. 4 illustrates the reduction in the actuation time of thermal actuator 1 as effected by the system of this invention shown in FIG. 3. Actuation time is plotted along the abscissa and the ordinate represents the distance the contact 16 of contact arm 8 moves during actuation of the relay or actuator. Actuation time is the sum of the thermal windup time (tw) and the contact transfer time (tt). The former is the time required for the control element to heat to its transition temperature from ambient from the instant of electrical energization thereof. The latter is the time required to move the contact from its normal or rest position to its contact make or alternate actuated position after the transition temperature is reached. Curve B illustrates both the thermal windup and transfer times of relay 1 energized by a voltage source of the usual potential applied to relay 1, i.e., typically the voltage level V2. Curve A illustrates the reduced actuation time of the relay system of FIG. 3, wherein the thermal windup time (tw) is greatly reduced by the application of the overvoltage V1 during initial energization. The transfer times are essentially the same for relay 1 and the system of FIG. 3 inasmuch as the same voltage, V2, is applied to the control element during the transfer periods. The short dashed extensions of curves A and B following contact make represent the overtravel of the contact arm between initial contact make and the contact's final actuated position, and indicate increasing contact pressures. With this system of FIG. 3, the advantageous reduced thermal windup time is accomplished without risk of damage to the control element due to extended application of an overvoltage because the system utilizes the separation of contacts 13 and 16 to terminate the overvoltage. In other words, the system is self-protecting.

A reduced actuation time thermal relay system is shown in FIG. 5 which provides not only reduced thermal windup time but also substantially reduced contact
transfer time. While similar to the FIG. 3 system, it differs in several respects. In FIG. 5 one side of thermal element 28 is connected directly to the positive polarity terminal of V1 and the other terminal thereof is connected via the collector-emitter circuit of Q1 to the junction between two diode anodes D2 and D3 connected back-to-back. The cathode of D2 is connected to contact 15 and output load 30. The cathode of D3 is connected to the positive polarity terminal of a voltage source V3, the negative terminal of which is grounded. The potential of V3 is considerably lower than that of V1.

Operation of the FIG. 5 system is as follows:
With no control signal applied to the base of transistor Q1, it does not conduct and control element 28 remains deenergized and at ambient temperatures. Load 30 is also not energized because contact 16 is not in engagement with contact 15 and diode D3 prevents energization of the load from V3. When a control signal, preferably from an integrated circuit or solid state control, is applied to the base of the transistor, it conducts so that current will flow from power source V1 to control element 28 and load 30. Since substantially the entire voltage drop is across the control element, it will rapidly heat to its predetermined transition temperature. When element 28 reaches that temperature, contact 16 will move away from contact 13 toward contact 15.

In contrast to the previous embodiment, however, the higher voltage is applied until contact 16 engages contact 15. When these contacts close, load 30 becomes fully energized since it is directly connected across V1. Also since the cathode of diode D2 is at a higher potential than its anode, the diode is back biased isolating control element 28 from load 30. A second and reduced voltage is applied to control element 28 as it, the collector-emitter circuit of transistor Q1, and diode D3 are series connected from the positive side of V1 to the positive side of the lower potential voltage source V3. The magnitude of this reduced voltage applied to the control element is equal to the d.c. level of V1 minus the d.c. level of V3. Thus diodes D2, D3 comprise means responsive to completion of contact movement to simultaneously terminate application of the first voltage (V1) to the control element and to apply a second and reduced voltage (V1–V3) thereto. This second reduced voltage is again of sufficient magnitude to prevent the temperature of control element 28 from falling substantially below its predetermined transition temperature thereby maintaining the contacts 15, 16 in their closed position. The system of FIG. 5 is now in its steady state operating condition.

When the control signal is removed from the base of transistor Q1, it stops conducting causing deenergization of control element 28 and permits the temperature of the element to fall substantially below its predetermined transition temperature thereby to open contacts 16,15 and deenergize load 30.

FIG. 6 compares the actuation time of the FIG. 5 system with that of thermal relay 1 used alone. Curve C represents the former while dashed curve B again represents the latter. As is indicated, both the thermal windup time (tw) and the transfer time (t) of the system of FIG. 5 are greatly reduced because the overvoltage is applied to the control element from the moment of initial energization of the element until contact 16 has substantially completed its movement from its initial position engaging contact 13 to its actuated position engaging contact 15. Again, the system is self-protecting in that damage to control element 28 because of prolonged overvoltage energization thereof is avoided because closure of contact 16 against contact 15 automatically effects reduction of the voltage applied across element 28 by V1–V3. It is also to be noted that because of the reduced transfer time of this system contact sticking or welds is minimized.

The degree of reduction of actuation time of the reduced actuation time thermal relay system is a function of the magnitude and duration of the overvoltage applied to the control element. Thermal relay 1, when energized at normal rated voltage has a typical actuation time of 100 milliseconds (ms) comprising a 70 ms thermal windup time and a 30 ms contact transfer time. The reduced actuation time thermal relay system of FIG. 3 by reducing the thermal windup time to an exemplary 7 ms reduces the total actuation time to 37 ms. By also reducing the transfer time to an exemplary 3 ms, the system of FIG. 5 reduces the total actuation time of relay 1 from 100 ms to 10 ms, i.e., by a whole order of magnitude. An actuation time of 10 ms is comparable to that of a conventional electromagnetic-type high current relay.

It is to be noted that both of the previously described embodiments are well suited to inclusion in an integrated circuit control since resistor R1, transistor Q1, and the various diodes can be included within an integrated circuit chip.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:
1. A reduced actuation time thermal relay system for controlling energization of a load by a power supply, said system comprising:
a thermal relay having a resistive control element and a pair of mating contacts movable between closed circuit and open circuit positions in response to the temperature of said control element rising above a predetermined level and falling substantially therebelow;

and

means for electrically energizing said resistive control element initially to apply a first voltage thereby to cause rapid heating of the element and thereafter to apply a second and reduced voltage to said element, said reduced voltage being of sufficient magnitude to prevent the temperature of said element from falling substantially below said predetermined level whereby the actuation time of said thermal relay is substantially reduced without damaging said resistive control element.

2. A relay system as set forth in claim 1 wherein said resistive control element comprises a wire of a martensitic memory alloy.

3. A relay system as set forth in claim 2 in which the energizing means includes means for reducing the first voltage in response to initial movement of the contacts from one position to the other.
4. A relay system as set forth in claim 3 wherein the voltage reducing means includes means for preventing application of said second and reduced voltage to said control element until after initial movement of said contacts and means for terminating application of said first voltage to said control element after initial movement of said contacts.

5. A relay system as set forth in claim 4 in which said means for preventing application of the reduced voltage comprises a diode.

6. A relay system as set forth in claim 4 wherein said terminating means includes another contact of said relay adapted to be disengaged after initial movement of the said pair of contacts.

7. A relay system as set forth in claim 4 in which said energizing means further includes means for energizing said control element in response to the presence of a control signal and for deenergizing the control element when said control signal is absent.

8. A relay system as set forth in claim 7 wherein the means responsive to the control signal includes a transistor having its collector-emitter circuit serially connected with said control element across said first voltage and the control signal is applied to the base thereof.

9. A relay system as set forth in claim 2 in which the energization means includes means for reducing the first voltage in response to completion of contact movement from one position to the other.

10. A relay system as set forth in claim 9 wherein the voltage reduction means comprises means for simultaneously terminating application of the first voltage to the control element and applying said second voltage there to upon completion of contact movement.

11. A relay system as set forth in claim 10 wherein said means terminating application of said first voltage comprises first and second diodes.

12. A relay system as set forth in claim 9 in which said energizing means further includes means for energizing said control element in response to the presence of a control signal and for deenergizing the control element in the absence thereof.

13. A relay system as set forth in claim 12 wherein the means responsive to the control signal includes a transistor having its collector-emitter circuit serially connected with said control element and the control signal is applied to the base thereof.

14. In a thermal relay system for controlling energization of a load by a power supply, said system including a thermal relay having a resistive control element and a pair of mating contacts movable between closed circuit and open circuit positions in response to the temperature of said control element rising above a predetermined level and falling substantially therebelow; the improvement comprising means for electrically energizing said resistive control element initially to apply a first voltage thereby to cause rapid heating of the element and thereafter to apply a second and reduced voltage to said element, said reduced voltage being of sufficient magnitude to prevent the temperature of said element from falling substantially below said predetermined level whereby the actuation time of said thermal relay is substantially reduced without damaging said resistive control element.

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