United States Patent [19]

Clarke

[11] **3,872,415**

[45] **Mar. 18, 1975**

[54] **RELAY**

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[73] Assignee: **Texas Instruments Incorporated,** Dallas, Tex.

[22] Filed: **Apr. 16, 1973**

[21] Appl. No.: **351,750**

[52] **U.S. Cl.** **337/140,** 337/131, 337/395

[51] **Int. Cl.** **H01h 61/06**

[58] **Field of Search** 337/140, 145, 41, 123, 337/124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 135, 136, 138, 139, 140, 382, 393, 394, 395, 390

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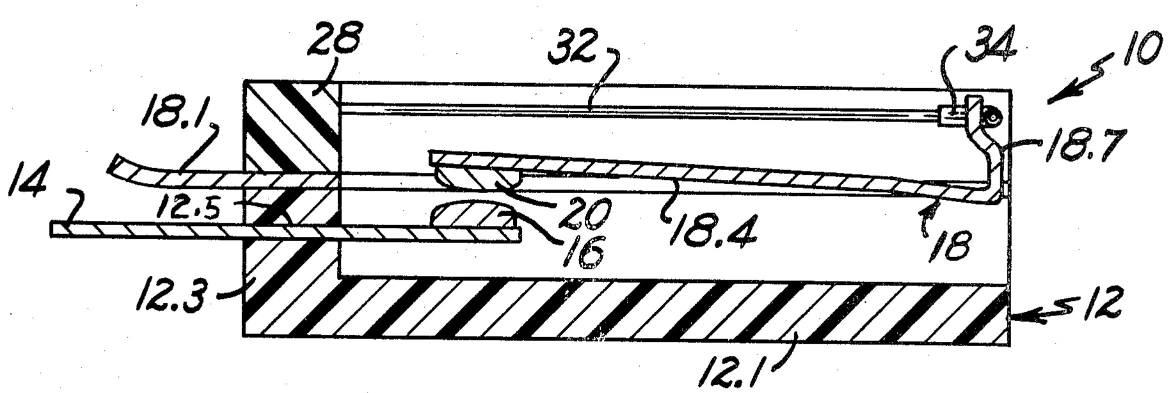
[57] **ABSTRACT**

A relay which is operable at very low power levels and which is highly versatile in its applications is shown to be characterized by high gain and high reliability and by simplicity of structure. The relay comprises a first terminal mounted on a base of electrically insulating material and a second electrically conductive member having a terminal portion secured to the base, having a contact arm movable between an open circuit position spaced from the first terminal and a closed circuit position engaging the first terminal, and having integral spring portions connecting the contact arm and terminal portion of the second member for normally biasing the contact arm to one of the noted circuit positions. The relay also includes an actuator wire secured between the base and the contact arm of the second member. The actuator wire is formed of a nickel-titanium alloy and is adapted to be deformed from an original length to a second length as the contact arm is moved to the one circuit position in response to the noted spring bias while the wire material displays a relatively low modulus of elasticity below a transition temperature. The actuator wire is also adapted to abruptly return to its original length and to display a relatively higher modulus of elasticity to move the contact arm to the other circuit position against the spring bias when the wire material is heated above its transition temperature. Means are provided for electrically self-heating the actuator wire to its transition temperature when relay operation is desired.

7 Claims, 8 Drawing Figures



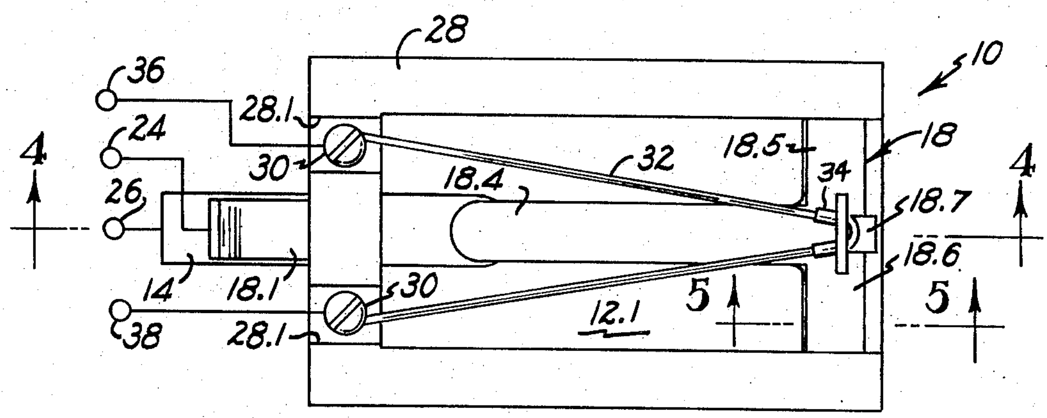


Fig. 1.

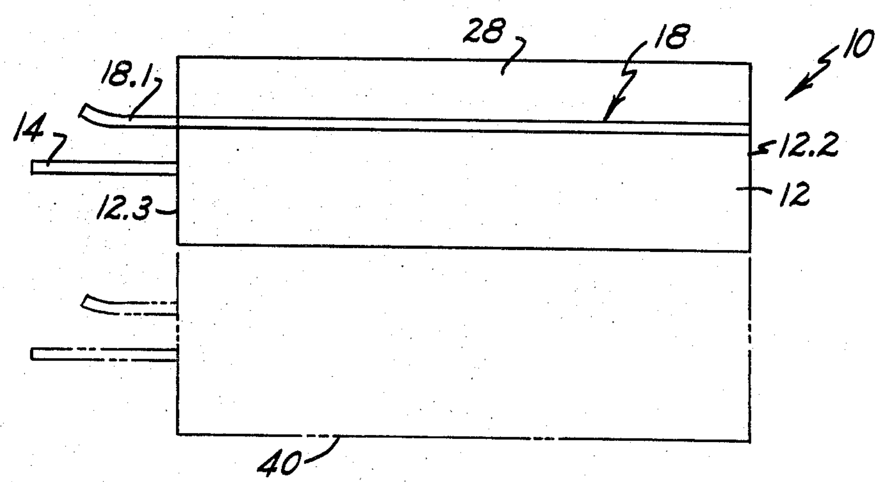


Fig. 2.

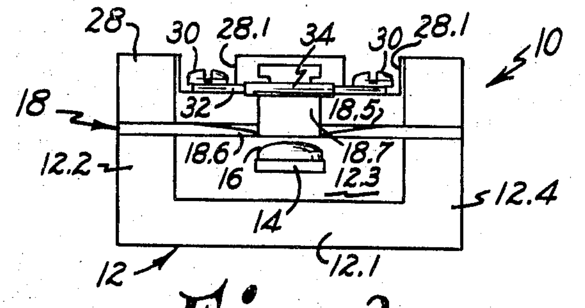


Fig. 3.

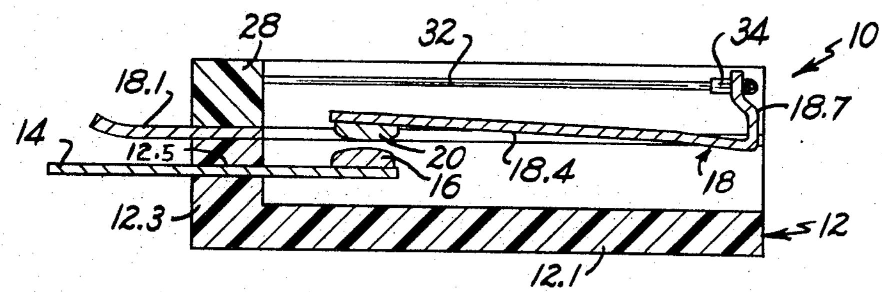


Fig. 4.

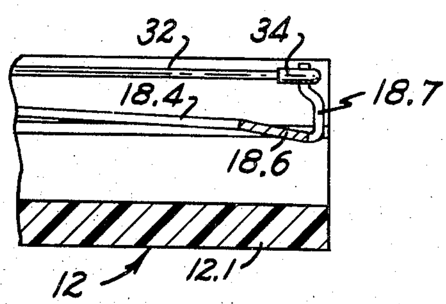


Fig. 5.

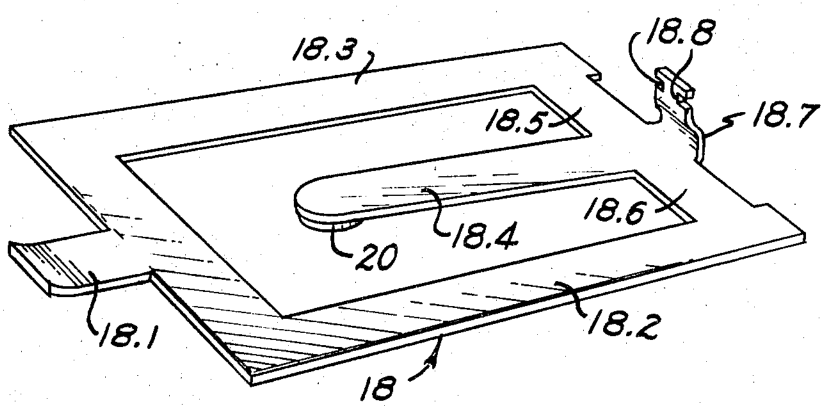


Fig. 6.

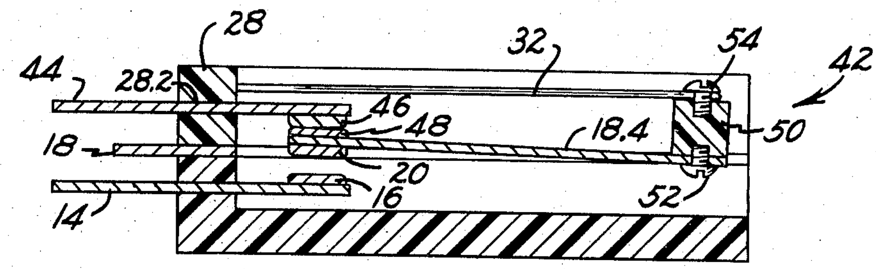

28
32
54
42
44
28.2
46
48
50
18
18.4
20
52
16
14

Fig. 7.

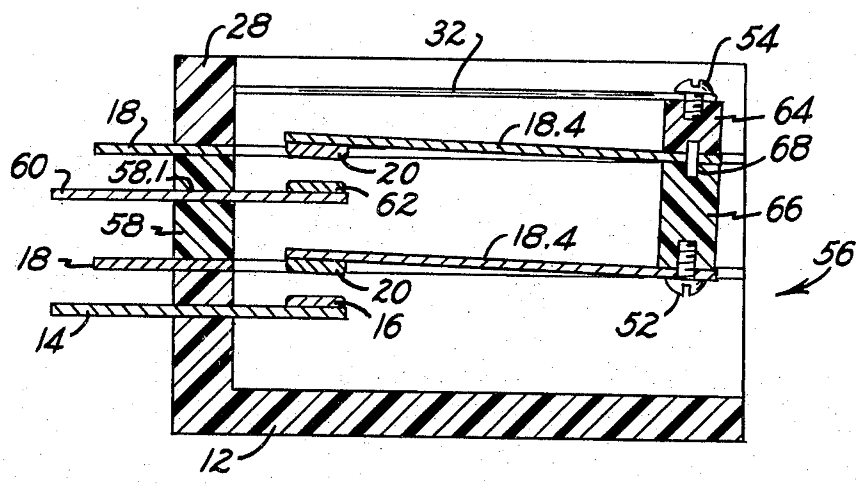

28
32
54
64
18
18.4
68
60
58.1
20
62
66
58
18.4
56
18
20
52
16
14
12

Fig. 8.

RELAY

With the development of increasingly more compact and inexpensive control systems which are operable at very low power levels, it becomes possible to incorporate an increasing number of control functions within the control system while still retaining reasonable system costs. However, for these control system advantages to be achieved in practice, the systems must be utilized with improved relays which are capable of operating at low power levels, which provide the high gain necessary for performing various individual control functions, and which are of compact, reliable and inexpensive construction.

It is an object of this invention to provide novel and improved electrical relays; to provide such relays which are operable at very low power levels; to provide such relays which display very high gain; and to provide such relays which are of compact, reliable, versatile and inexpensive construction.

Other objects and advantages of the novel and improved relays of this invention appear in the following detailed description of preferred embodiments of this invention, the detailed description referring to the drawings in which:

FIG. 1 is a plan view of a preferred embodiment of the relay of this invention;

FIG. 2 is a front elevation view of the relay shown in FIG. 1;

FIG. 3 is an end elevation view of the relay shown in FIG. 1;

FIG. 4 is a section view along line 4—4 of FIG. 1;

FIG. 5 is a partial section view to enlarged scale along line 5—5 of FIG. 1;

FIG. 6 is a perspective view of a component of the relay of FIG. 1;

FIG. 7 is a section view similar to FIG. 4 illustrating an alternate embodiment of the relay of this invention; and

FIG. 8 is a section view similar to FIG. 4 illustrating another alternate embodiment of the relay of this invention.

Referring to FIGS. 1–5 of the drawing, **10** indicates a preferred embodiment of the relay of this invention which is shown to include a base member **12** of a strong, rigid, electrically insulating material such as a phenolic resin. Preferably, as shown, the base has a flat, bottom portion **12.1** and a generally U-shaped wall portion formed by upstanding walls **12.2, 12.3** and **12.4**, the end wall **12.3** preferably having an aperture **12.5** therein receiving an electrically conductive output terminal member **14.** The terminal **14** is secured in the aperture **12.5** by a press fit or in other conventional manner and extends in cantilever relation over the base bottom to support a first, stationary, output electrical contact **16.**

In accordance with this invention, the relay **10** also includes a second electrically conductive member **18**, best shown in FIG. **6**, which integrally incorporates an output terminal portion **18.1** including two leg portions **18.2** and **18.3**, a contact arm portion **18.4**, and a pair of spring portions **18.5** and **18.6** which connect the contact arm **18.4** to the respective legs **18.2** and **18.3** of the terminal portion of the second conductive member. In a particularly inexpensive embodiment of this invention, the second conductive member **18** also includes an integral tang portion **18.7** upstanding from

the contact arm, the tang preferably having reentrant surfaces thereon as indicated at **18.8** in FIG. **6.**

In accordance with this invention, the second conductive member **18** is formed of beryllium copper or phosphor bronze or other electrically conductive spring material and carries a second output contact **20** at the distal end of the contact arm **18.4.** The conductive member **18** is secured to the base **12** by cementing or in other conventional manner for disposing the contact **20** over the contact **16** as is best shown in FIG. **4.** In this arrangement, the tang **18.7** and the contact arm **18.4** form a bell-crank element which is pivotably movable around an axis (indicated by the broken line **22** in FIG. **1**) formed by the spring portions **18.5** and **18.6** of the conductive member. The contact arm **18.4** is normally disposed out of the general plane of the second conductive member **18** by deforming of the spring portions **18.5** and **18.6** as is best illustrated in FIG. **5.** Accordingly, the contact arm **18.4** is normally biased to the open circuit position illustrated in FIG. **4** so that the contact **20** carried by the contact arm is normally separated or disengaged from the mating output contact **16.** However, the contact arm **18.4** is adapted to be moved to a closed circuit position wherein the contact **20** engages the contact **16** with selected contact pressure. In this regard, where the tang **18.7** of the second conductive member is relatively shorter than the contact arm **18.4,** rotational movement of the bell-crank element formed by the tang and arm around the axis **22** requires relatively limited linear movement of the tang to provide fairly substantial movement of the movable output contact **20.** As will be understood, the terminal **14** and the terminal portion **18.1** of the second conductive member are adapted to be connected to a device diagrammatically indicated in FIG. **1** by the terminals **24** and **26** so that the device is energized when the output circuit formed by the terminal **14** and the conductive member **18** is closed by engagement of the contacts **16** and **20.**

In a preferred embodiment of this invention, a second base component **28,** also preferably formed of phenolic resin or other electrically insulating material and also of generally U-shaped configuration, is then secured to the other side of the conductive member **18.** Two relay control terminals **30,** preferably comprising screws threadedly engaged with the base component **28,** are then preferably recessed into grooves **28.1** in the second base component. An actuator wire **32** is then secured in electrically conductive relation between the control terminals **30** to extend around the tang **18.7** of the second conductive member **18.** Preferably a length of electrically insulating tubing **34** is fitted over the actuator wire **32** as shown for electrically insulating the actuator wire from the second conductive member. In this way, the control terminals **30** are adapted to be connected to a control system, indicated in FIG. **1** by the terminals **36** and **38,** for selectively directing electrical current through the metal actuator wire **32** when desired.

In accordance with this invention, the actuator wire **32** is preferably formed of a selected nickel-titanium alloy commonly called Nitinol having a composition, by weight, of from about **54** to **56** percent nickel and the balance titanium. As this metal alloy is well known, the alloy is not further described herein and it will be understood that the alloy is adapted to display a relatively low modulus of elasticity below a characteristic transition temperature and to display a relatively much higher modulus of elasticity when the wire material is heated above the noted transition temperature, this change in properties being reversible as the wire material is cooled below the transition temperature. When properly conditioned in well known manner, the noted alloy is also adapted to display remarkable shape memory properties. That is, when the material of the wire **32** is deformed while below its transition temperature as by stretching the wire to increase the wire length up to about **8** percent, the wire is adapted to shorten abruptly and to return to its original length when the wire is heated above its transition temperature. After cooling, the wire is again adapted to be deformed to again prepare the wire for displaying its shape memory. Typically, for example, the wire **32** is formed of a nickel-titanium alloy comprising about 55 percent nickel, by weight, and the balance titanium, this alloy having a transition temperature at about 60°C. and having other physical properties as follows:

Ultimate tensile strength	— 125,000 psi
Density	— 6.5 g./cc.
Heat capacity	— 0.077 cal./degree C./g.
Resistivity	— 80×10^{-6} ohm-centimeters
Young's Modulus (below transition temperature)	— 3×10^{-6} psi
Young's Modulus (above transition temperature)	— 12×10^{-6} psi

alternately, the wire **32** is formed of other known metal alloys capable of displaying similar shape memory and modulus of elasticity properties.

In the relay **10** of this invention, the spring properties of the conductive member **18** are selected so that, with the material of the actuator wire **32** below its transition temperature, the spring portions **18.5** and **18.6** of the second conductive member apply sufficient force to the wire **32** to deform the wire to increase the wire length, preferably by at least about **4** percent, and to normally bias the contact arm **18.4** to the open circuit position shown in FIG. 4 to hold the contact **20** disengaged from the contact **16.** However, when electrical current is selectively directed through the wire **32** between the relay control terminals **30** for electrically self-heating the material of the wire above its transition temperature, the wire is sharply or abruptly shortened in length returning to its original configuration and is sharply increased in modulus of elasticity for moving the contact arm **18.4** to its closed circuit position against the bias of the spring portions **18.5** and **18.6** to engage the contact **20** with its mating contact **16** for closing the output circuit of the relay. When the wire **32** is thereafter permitted to cool below its transition temperature, whereby the modulus of elasticity of the wire material returns to its low initial level, the spring portions **18.5** and **18.6** again deform the wire to increase its length and again return the contact arm **18.4** to its open circuit position. As will be understood, the spring portion **18.5** and **18.6** of the second conductive member are initially deformed to a selected extent as illustrated in FIG. 5 for adjusting the tension the spring portions apply to the wire **32** and for adjusting the contact pressure between the contacts **20** and **16** when the relay is in closed circuit position.

In the relay of this invention, the wire **32** is found to display high strength when the wire is above its transition temperature. Accordingly, the wire used in the relay is of very small diameter or cross-sectional area. Preferably the wire has a cross-sectional area less than about 1.5×10^{-5} square inches and typically the wire has a diameter of about 0.002 inches and a length of about 2 inches. As a result, the wire is adapted to be heated from room temperature to its transition temperature with very low input of electrical energy at low current levels but is adapted to provide significant movement of the contact arm **18.4** and to apply substantial contact pressure between the contacts **20** and **16** so that the relay can switch substantial currents. Thus, the relay is operable at very low power levels but provides very high gain. Typically, for example, where the wire has a diameter of 0.002 inches and a length of 2 inches, the relay **10** is operable at a power level below 2 watts and preferably below 0.5 watts but displays a very high gain, preferably greater than about 500 to 1 and preferably on the order of 10,000 to 1, and can switch 50 amperes at 120 volts across the contacts **20** and **16.** The relay **10** is also of compact, reliable and very inexpensive construction. In addition, the relay is very versatile in its applications. Note that, as illustrated by the broken lines **40** in FIG. **2,** a plurality of the relays **10** are adapted to be stacked together in a very compact package.

Further, various alternate embodiments of the relay **10** are also included within the scope of this invention as is illustrated in FIGS. **7** and **8.** That is, referring to FIG. **7** wherein components of the relay **42** shown therein which are comparable to components of the relay **10** ae identified with corresponding reference numerals, the relay **42** is shown to include a base **12** supporting a first output terminal **14** to carry a contact **16** as in the relay **10.** In addition, however, the second base element **28** is also provided with an aperture **28.2** and a second output terminal **44** is mounted in this aperture to support another output contact **46.** The second conductive member **18** is then provided with an additional contact **48** as shown. Preferably, the tang **18.7** of the conductive member **18** previously described, is also replaced by a bell-crank arm member **50** of electrically insulating material which is secured to the contact arm **18.4** by a screw **52** or the like and which carries a boss **54,** also preferably comprising a screw threadedly engaged with the bell-crank arm **50,** around which the actuator wire **32** extends. In the relay **42,** the contacts **46** and **48** are normally engaged for closing a first output circuit of the relay while the contacts **20** and **16** are disengaged leaving a second output circuit of the relay open. However, when the actuator wire **32** is heated above its transition temperature by directing electrical current through the wire, the contact arm **18.4** moves as in the relay **10** to engage the contacts **16** and **20** for closing the second output circuit and to open the first output circuit of the relay.

Referring now to FIG. **8,** wherein corresponding reference numerals are again used, the relay **56** illustrated in this drawing figure as shown to include a base member **12** supporting a first output terminal **14** carrying a contact **16.** A first conductive member **18** is then secured to the base **12** as in relay **10.** Another base element **58** having an aperture **58.1** receiving a second output terminal **60** carrying a contact **62** is then mounted on the conductive member **18,** the contact **62** being oriented upwardly as shown in FIG. **8.** An additional conductive member **18** is then mounted on the second base element **58** for disposing its contact **20** to be engaged with the output contact **62.** A base element

28 is then secured on top of this additional conductive member **18** as shown in FIG. **8.** Neither of the conductive members **18** embodied in the relay **56** is provided with a tang **18.7** but bell-crank arm elements **64** and **66** are secured to the conductive members **18** by a screw **52** and by a pin **68** so that the two contact arms **18.4** are arranged to move together. The actuator wire **32** is then extended around a screw boss **54** as in the relay **42.** In this arrangement, two relay output circuits are normally open. However, when the actuator wire **32** is heated above its transition temperature, the wire shortens in length to move both contact arms **18.4** to engage one of the contacts **20** with the contact **16** and to engage the other circuit **20** with the contact **62** for closing two output circuits of the relay.

Of course other modifications and equivalents of the described relays **10, 42** and **56** are also within the scope of this invention. For example, the terminal **14,** the conductive member **18** and the control terminals **30** of the relay **10** could all be mounted on a single base element having the general configuration of the end wall **12.3** of the base described with reference to relay **10** for significantly reducing the size and weight of the relay. Other such modifications would be recognized by persons skilled in the art. It should be understood that this invention includes all modifications and equivalents of the disclosed embodiments falling within the scope of the appended claims.

I claim:

1. A relay comprising electrically insulating base means, a first conductive member mounted on said base means, a second conductive member formed of a single sheet of electrically conductive sheet material having a pair of spaced first portions secured to said base means, having a contact arm portion extending in cantilever relation from the remainder of said second member between said first portions of said second member and movable at its distal end between an open circuit position spaced from said first conductive member and a closed circuit position engaging said first conductive member, and having spring means integrally formed in said sheet material respectively connecting said first member portions with an opposite end of said contact arm portion of said second conductive member and normally biasing said contact arm portion to one of said circuit positions, and an actuator wire element secured between said opposite end of said contact arm portion and said base means, said actuator element being formed of a metal alloy adapted to be deformed from an original configuration to a second configuration as said contact arm portion is moved to said one circuit position by said spring bias while said metal alloy displays a relatively low modulus of elasticity below a transition temperature and to abruptly return to said original configuration and to display a relatively higher of elasticity to move said contact arm portion to the other of said circuit positions against said spring bias when said metal alloy is heated above said transition temperature.

2. A relay as set forth in claim **1** wherein said actuator element is formed of a nickel-titanium alloy.

3. A relay as set forth in claim **2** wherein said nickel-titanium alloy has a composition, by weight, of from about 54 to 56 percent nickel and the balance titanium.

4. A relay as set forth in claim **3** wherein said actuator element comprises a wire of said nickel-titanium alloy having a cross-sectional area of less than about 1.5×10^{-5} square inches.

5. A relay comprising a base means of electrically insulating material having a bottom and having a pair of upstanding side walls and an end wall forming a base wall portion of generally U-shaped configuration, a first electrically conductive terminal member cantilever mounted on said end wall and mounting a first electrical contact at the distal end thereof over said bottom of said base means, a second member formed of a single sheet of electrically conductive spring material having a terminal portion including two leg portions thereof secured to said side walls of said base means, having a contact arm portion extending in cantilever relation from the remainder of said second member and mounting a second electrical contact means thereon at the distal end of said contact arm portion for movement between an open circuit position spaced from said first contact and a closed circuit position engaging said first contact, and having spring portions integrally formed from said sheet material extending between respective leg portions and an opposite end of said contact arm portion of said second conductive member over said bottom of said base means and normally biasing said contact arm portion to said open circuit position, a bell-crank arm secured to said opposite end of said contact arm portion and rotatable with said contact arm portion around an axis extending through said spring portions, control terminals secured to said base means, and a metal actuator wire connected between said control terminals and secured in electrically conductive relation to said bell-crank arm, said wire being formed of a nickel-titanium alloy adapted to be deformed from an original length to a greater length as said contact arm portion is moved to said open circuit position in response to said spring bias while said alloy displays a relatively low modulus of elasticity below a transition temperature and to abruptly return to its original length and to display a relatively higher modulus of elasticity to rotate said contact arm and bell-crank arm on said axis to move said contact arm portion to said closed circuit position against said spring bias when said alloy is heated above said transition temperature by directing electrical current through said wire between said control terminals.

6. A relay as set forth in claim **5** having an additional electrically conductive terminal member cantilever mounted on said base means and mounting an additional electrical contact at the distal end thereof to normally engage said second contact means and to be disengaged from said second means when said actuator wire is heated to said transition temperature.

7. A relay as set forth in claim **5** having a plurality of said conductive terminal members mounting respective electrical contacts and mounted on said base means, having a plurality of said members of electrically conductive spring material mounted on said base means and having respective contacts mounted on the contact arm portions thereof, and having means for connecting said contact arm portions of said spring members together for common movement to engage respective spring member contacts with respective contacts mounted on said terminal members.

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