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Sterns et al.

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[45] **Dec. 4, 1973**

[54] **ELECTROMECHANICAL RELAY**

[76] Inventors: **Ronald Jay Sterns**, 827 Daffodil Way, San Jose, Calif. 95117; **Francis Anthony Sutter**, 7731 Rainbow Dr., San Jose, Calif. 95129

[22] Filed: **May 25, 1972**

[21] Appl. No.: **257,053**

Related U.S. Application Data

[63] Continuation of Ser. No. 82,361, Oct. 20, 1970, abandoned.

[52] **U.S. Cl.** **200/181**, 317/144, 337/109, 337/109

[51] **Int. Cl.** **H01h 59/00**

[58] **Field of Search** 200/181; 317/144

[56] **References Cited**

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Primary Examiner—Herman J. Hohauser
Assistant Examiner—Robert A. Vanderhye
Attorney—Thomas E. Schatzel

[57] **ABSTRACT**

An improved relay incorporating a cantilever comprised of an elongated piezoelectric element joined to an electrical conductive armature with the armature portion of the cantilever positioned about contact means whereby the electrical circuit relationship is responsive to deflections in said piezoelectric element.

5 Claims, 12 Drawing Figures

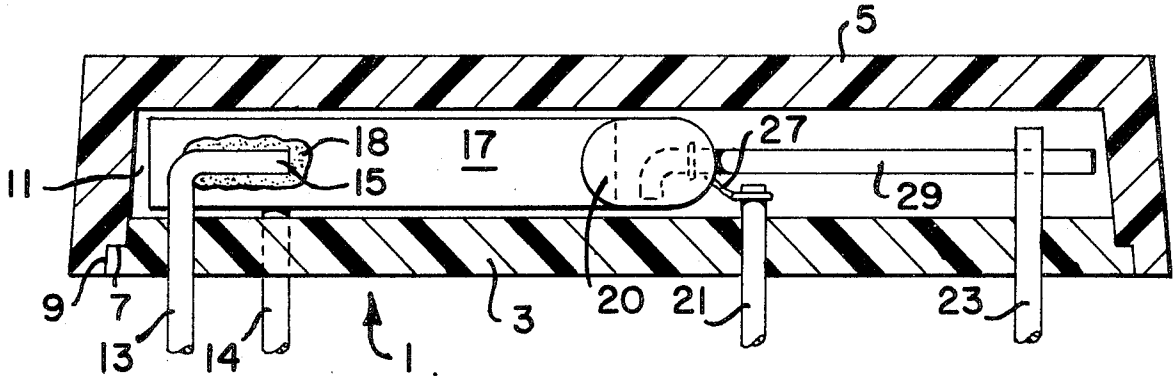


FIG. 1

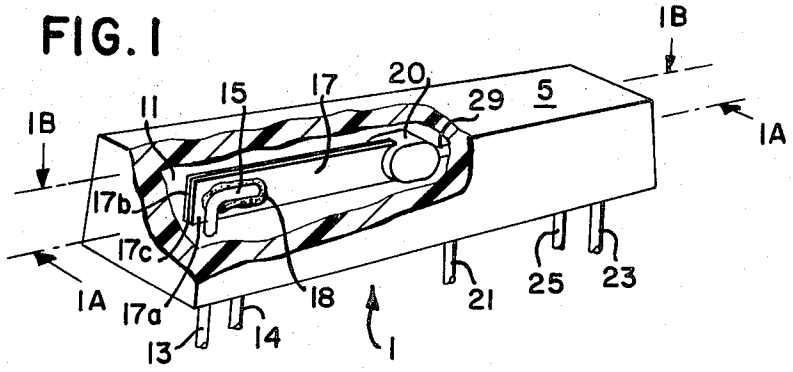


FIG. 1A

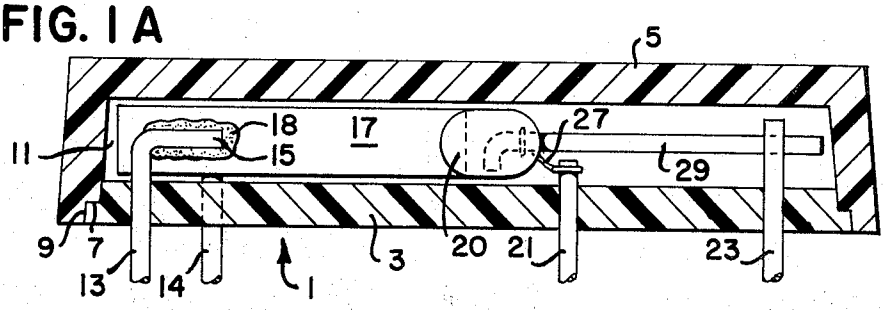
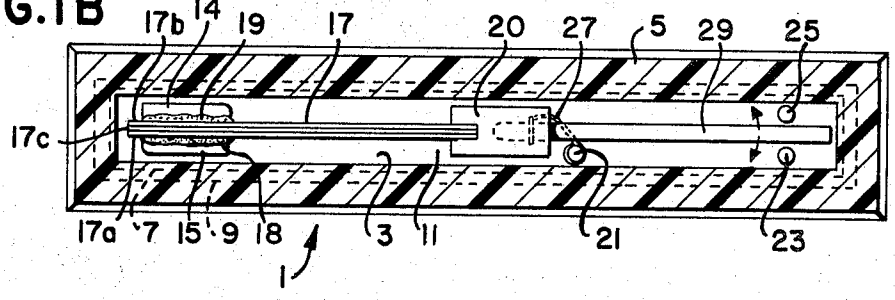


FIG. 1B



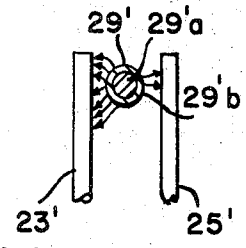


FIG. 1C

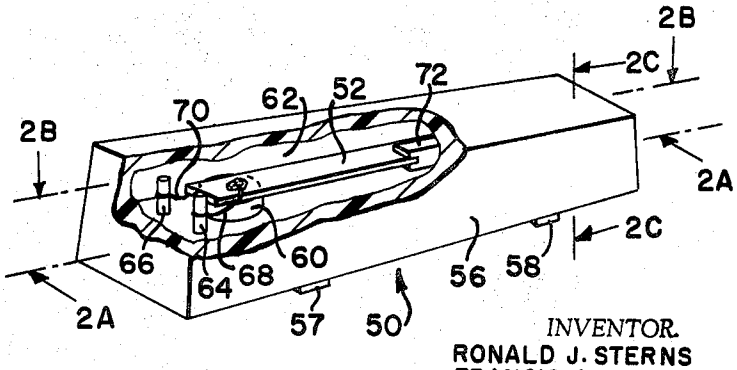


FIG. 2

INVENTOR.
RONALD J. STERNS
FRANCIS A. SUTTER
BY
Thomas E. Schatzel
ATTORNEY

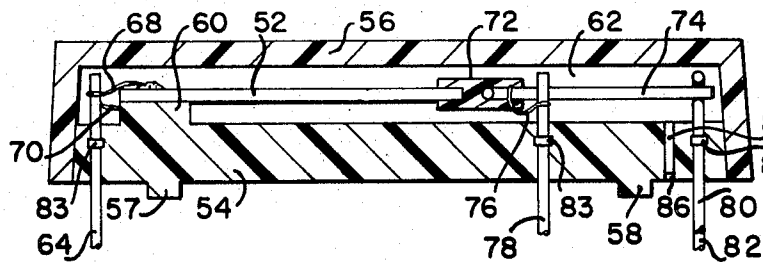


FIG. 2A

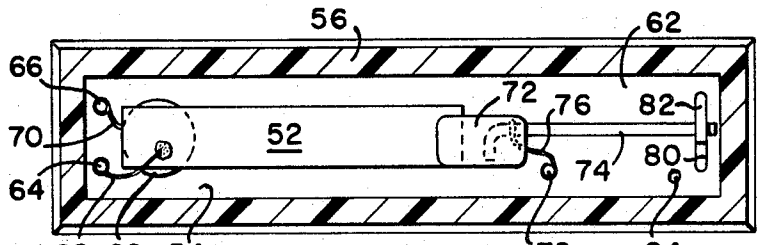


FIG. 2B

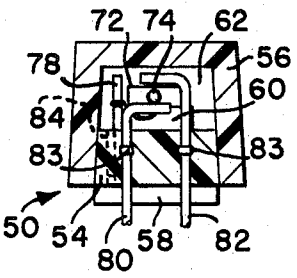


FIG. 2C

FIG. 3

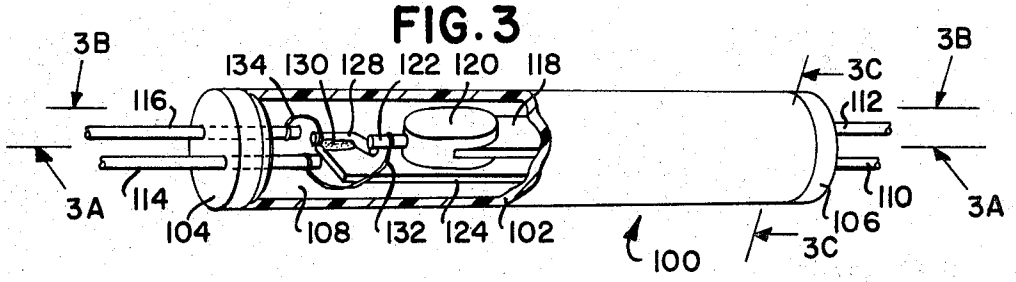


FIG. 3A

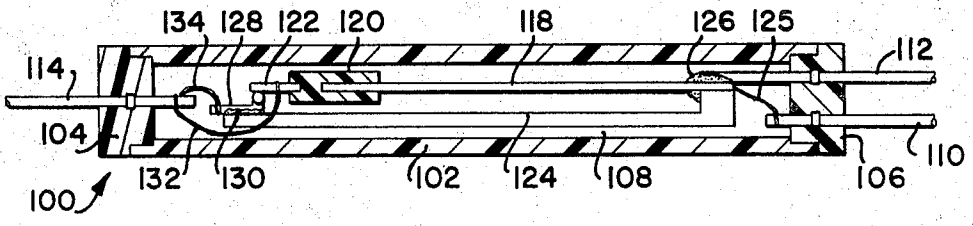
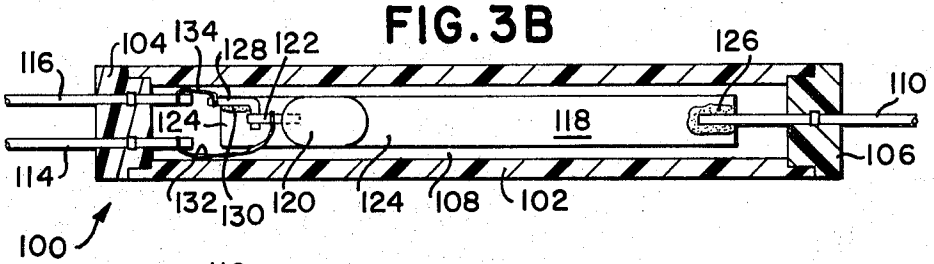


FIG. 3B



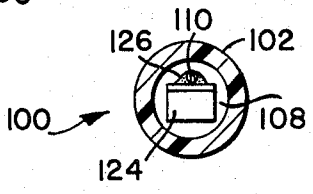


FIG. 3C

INVENTORS.
RONALD J. STERNS
FRANCIS A. SUTTER
BY
ATTORNEY

ELECTROMECHANICAL RELAY

This is a continuation, of application, Ser. No. 82,361 filed Oct. 20, 1970, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to electromechanical relays and more particularly to a relay employing a piezoelectric element. Piezoelectric materials respond physically to the application of a driving voltage and become deformed. An elongated element of piezoelectric material responds by bending. The element is approximately polarized so that application of a suitable voltage to the crystals results in expansion along one axis and contraction along another axis such that the element flexs or bends. Thus, an armature joined to the element may be actuated to pivot relative to a plurality of positioned contacts responsive to physical deflections in the element.

Piezoelectric relays possess a high degree of electromechanical efficiency relevant to that of electromagnetic relays. Piezoelectric relays do not require windings or iron cores. Power requirements for excitation are small. The characteristics of piezoelectric elements are capacitive in nature. Thus, they may be operated by a small drive current building up a charge over a comparatively long period or by a larger current applied over a short period. After the drive potential is removed, the relay will return to its normal position after a time delay. The time delay depends on the time constant of the crystal. The delay can be controlled dependant on the characteristics of the crystal and incorporation of external resistance or shorting bars.

The prior art includes piezoelectric and electrostrictive relays. U.S. Pat. No. 3,292,111 issued to M. B. Cotton discloses an electrostrictive relay including a longitudinal bimorph or multimorph element. U.S. Pat. No. 3,430,020 issued to R. Von Tomkovitch, et al., discloses a piezoelectric relay including a piezoelectric material forming a pair of pressure chambers.

Piezoelectric relays heretofore available are relatively complex in structures. Such structures are costly to manufacture and maintain. Further, the reliability of prior art structures is substantially decreased under adverse atmospheres, for example varying temperatures, vibrations, etc.

SUMMARY OF THE PRESENT INVENTION

The present invention teaches a relay of simplified structure and highly reliable operation.

An exemplary embodiment includes a housing with an elongated cantilever comprised of a piezoelectric element and armature contactor positioned within the chamber formed by the housing. One end of the cantilever is anchored and the other end is suspended. Intermediate the element and contactor is an insulator interlink. Terminal means are positioned adjacent to the armature. The terminals electrically extend to the exterior of the housing. When electrically energized, the element deflects in a bending mode generating lateral movement. The armature in turn responds laterally to the bending or flexure of the crystal and the position of the armature relative to the terminals is in turn controlled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective, partially sectioned view of a relay incorporating the teachings of the present invention;

FIG. 1A is a cross-sectional view of the relay of FIG. 1 taken along the line 1A — 1A;

FIG. 1B is a cross-sectional view of the relay of FIG. 1 taken along the line 1B — 1B of FIG. 1;

FIG. 1C is an end view of an alternative embodiment of an armature incorporated in the relay of FIGS. 1 – 1B;

FIG. 2 is a perspective, partially sectioned view of an alternative embodiment of the present invention;

FIG. 2A is a cross-sectional view of the relay of FIG. 2 taken along the line 2A — 2A;

FIG. 2B is a cross-sectional view of the relay of FIG. 2 taken along the line 2B — 2B;

FIG. 2C is a cross-sectional view of the relay of FIG. 2 taken along the line 2C —2C;

FIG. 3 is a perspective, partially sectioned view of an alternate embodiment of the present invention;

FIG. 3A is a cross-sectional view of the relay of FIG. 3 taken along the line 3A — 3A;

FIG. 3B is a cross-sectional view of the relay of FIG. 3 taken along the line 3B — 3B; and

FIG. 3C is a cross-sectional view of the relay of FIG. 3 taken along the line 3C — 3C.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIGS. 1, 1A and 1B illustrate a relay, referred to by the general reference character 1 and incorporating the teachings of the present invention. The relay is comprised of a non-conductive dielectric housing having a mechanically rigid base support member 3 and a cover 5. The base support member 3 is in the shape of a flat rectangular member having a ridge 7 extending about the periphery. The cover 5, in cross-section, is of inverted U-shape with a ridge 9 adapted to compliment the ridge 7 of the base support. Accordingly, with the cover 5 positioned about the base support 3 with the ridges 7 and 9 in engagement, an internal chamber 11 is formed. The base support 3 and cover 5 are comprised of an insulative material. Dielectric materials comprised of a glass filled thermo plastic or thermoset material have proven desirable.

Protruding through the base support member 3 are a pair of input electrical power terminals 13 and 14. The terminals 13 and 14 are anchored within the base support member and protrude to the exterior to receive input electrical drive signals. Within the interior the terminals 13 and 14 are each bent at an approximate 90° angle to establish an arm 15 and 16 respectively having an axis substantially parallel with the longitudinal axis of the chamber 11. Within the chamber 11 the arms 15 and 16 are secured to opposing surfaces of an elongated flat rectangular piezoelectric bimorph crystal 17. The crystal 17 is mounted as a cantilever 17 and mechanically supported about one terminal end by the input terminals 13 and 14 while the opposite terminal end is suspended. The power terminal 13 and arm 15 are secured to one surface of the crystal by means of a silver solder 18 while the terminal 14 and arm 16 are secured to the opposing surface of the crystal by means of a silver solder 19. The crystal 17 is secured at its opposite end to an insulative interlink 20. The interlink 20 and end of the crystal 17 are thus suspended. The insu-

lative interlink **20** is of oblong shape and of a thickness exceeding that of the crystal.

The base support **3** anchors a plurality of output signal contact posts **21, 23** and **25.** The post **21** is positioned adjacent to the interlink **20.** The posts **23** and **25** are longitudinally displaced relative to the terminal **21** within the chamber. The posts **23** and **25** are positioned laterally relative to one another and in the travel path of the armature.

An armature wire **27** is secured about the post **21** by means of a solder or weld. The wire extends to an elongated armature contactor **29.** The armature **29** extends longitudinally parallel to the longitudinal axis within the chamber **11** and the crystal **17.** One terminal end of the armature **29** is embedded within the insulative interlink **20** and is in electrical engagement with the contactor **29** by means of the wire **27** which may be soldered or welded thereto. The opposing terminal end of the armature **29** extends beyond the terminal posts **23** and **25** intermediate thereof.

The crystal element **17** of the relay **1** is in the form of a piezoelectri bimorph element. The dimensions of the element may be in the order of approximately 0.020 inches (20 mils) in depth; 0.100 inch in width and 0.5 inches in length. The element **17** may include two flat crystal segments **17***a* and **17***b* of barium titanate with a shim plate **17***c* of brass sandwiched intermediate. Intermediate the crystal plates and the brass plates is layer of nickel spheres embedded in epoxy (not shown). The power terminals **13** and **14** are connected across the two crystal plates **17***a* and **17***b* as illustrated in FIG. **1B** to form a series connection of the crystals. Though not shown, electrical connection of the terminal **13** to the brass shim **17c** and electrical connection of the terminal **14** to both of the crystals provides a parallel connection of the piezoelectric element. When electrical signals are applied across the power input terminals **13** and **14** the element **17** becomes electrically energized. As shown, the element **17** s serially energized with the active plates oppositely polarized. The drive signals give rise to oppositely directed transverse strains in the piezoelectric element which gives rise to bending or deflecting of the free end of the element. The element **17** tends to pivot about the terminal ends of the arms **15** and **16.** The insulative interlink **19** also pivots responsive to the element **17.** The armature contactor **29** acts as an extension of the element **17** through the interlink **19.** Consequently, the movement of the armature **29** is an amplification of the movement of the crystal as a result of the longer moment arm established by the interlink and armature contactor.

The armature may be in the form of a 20 mil diameter cylinder. The terminal posts may be in the order of 20–25 mils in diameter and spaced apart to leave approximately one mil spacing between the normally open post and armature when the relay is not activated.

When the piezoelectirc element **17** is at rest, the armature **29** rests against the electrical contact **23** to provide a normally closed condition between the terminals **21** and **23.** When the element **17** is energized, it flexs laterally relative to the base **3.** The flexure causes the armature **29** to move away from the terminal **23** towards the terminal **25.** The rotational velocity of the armature imparts a mechanical force to the armature such that when it comes into physical contact with the terminal **25,** good electrical contact is made to complete the circuit between the terminals **21** and **25.** This action is of a form "C" set of relay contacts. A form "A" set of contacts may be made by eliminating the terminal **23.**

FIG. **1C** illustrates an alternative embodiment of the relay **1** in which an auxiliary permanent magnetic field is incorporated. Such a structure may be used in environments where it is not essential that the relay be nonresponsive to impinging magnetic fields or free of generating magnetic fields. For example, the structure **1** of FIGS. **1–1B** may be modified to incorporate an armature **29'** having a polarized permanent magnet **29'***a* embedded within a magnetic cylinder **29'***b.* The magnetic field of the magnet **29'***a* tends to increase the force on the armature **29'** in the direction of the closest contact pole piece **23'** or **25'**, which are also of a magnetic material. The magnetic attraction tends to increase the contact pressure and thereby increase the current handling capacity of the contact. Preferably, the force due to the magnetic field is set to less than the relaxation force of the crystal once the drive signal is removed from the crystal. This will permit the armature to return to the normal position.

FIGS. **2, 2A, 2B** and **2C** represent an alternative embodiment of the present invention, referred to by the general reference character **50.** The relay **50** include a bimorph piezoelectric element **52** similar to the element **17,** positioned horizontally within a housing such that it flexes in a vertical plane. The housing includes a molded base support **54** and a molded cover **56.** The base support member **54** is in the shape of a flat rectangular member with a pair of exterior clearing ridges **57** and **58** and an interior attachment shoulder **60.** The cover **56,** in cross-section, is of an inverted U-shape and receives the base support **54** about the interior surface of the outer edge. Accordingly, with the cover **56** positioned about the base support **54** an internal chamber **62** is formed. The base support **54** and cover **56** are comprised of an insulative material, e.g. dielectric material comprised of a glass filled thermoplastic or thermoset material.

Protruding through the base support member **54** are a pair of input power terminals **64** and **66** in the form of terminal posts extending from within the chamber to the exterior. Within the chamber **62** the posts **64** and **66** are joined to a lead wire **68** and **70,** respectively, soldered or welded to opposite crystals of the element **52.** The element **52** is anchored to the attachment shoulder **60.** The opposite end of the element **52** is engaged to an insulative interlink **72** similar to the interlink **19** of the relay **1.**

The interlink **72** is also secured to an armature contactor **74** which acts as an extension of the element. The armature **74** is electrically engaged to a lead wire **76** embedded within the interlink **72.** The opposite end of the lead wire **76** is secured to a terminal post **78** extending to the exterior.

About the end of the armature **74** are a pair of L-shaped contact posts **80** and **82** with the post **82** overlapping the post **80.** Intermediate the overlaps is a spacing through which the armature **74** extends. The posts **80** and **82** extend to the exterior of the housing for connection to external circuitry. As illustrated, the posts **64, 66, 78, 80** and **82** may each carry a shoulder **83** embedded within the base **54** to provide physical support of the terminals.

Accordingly, upon application of an input power signal across the input terminals **64** and **66**, the element **52** flexes in a vertical plane such that the armature **74** is moved in a vertical path intermediate the overlap portions of the posts **80** and **82**. The housing carries an evacuation portal **84** which may be sealed by means of a seal **86** after the chamber **62** is evacuated and filled with a dry gas. During construction, after the relay **50** is assembled with the cover **56** and base **54** sealed in place, the chamber **62** may be evacuated through the portal **84** to rid the chamber of contaminants and moisture. The chamber **62** may then be filled with a dry gas, e.g. nitrogen, and the portal **62** sealed with the sealant **86**. The dry gas tends to eliminate further moisture from entering the chamber which may otherwise tend to condense on the interior surface.

FIGS. 3–3C illustrate a further embodiment of the present invention, referred to by the general reference character **100**. The relay includes a cylindrical housing **102** comprised of an insulative dielectric material. A pair of end caps **104** and **106** are secured about opposite terminal ends of cylinder **102** to form an internal chamber **108**. Protruding from the chamber **108** to the exterior through the cap **106** are a pair of power input terminal posts **110** and **112**. The posts **110** and **112** are embedded within the cap **106**. Protruding from the chamber **108** to the exterior through the cap **104** are a pair of signal output lead terminal posts **114** and **116**. The posts **114** and **116** are embedded within the cap **104**.

The power input post **112** is secured to one end of a flat rectangular bimorph piezoelectric element **118** so as to provide structural support for said crystal. The post **112** simultaneously makes electrical engagement with the outer surface of the crystal **118**. The element **118** extends longitudinally within the chamber **108** and is secured about its opposite end to an insulative interlink **120**. The interlink **120** in turn is engaged to an armature contactor **122** so as to establish a crystal-interlink-armature cantilever within the chamber **108**. The piezoelectric element **118** is engaged to a L-shaped insulative support **124** with one leg extending longitudinally within the chamber and in parallel with the element **118** and armature **122**. The other leg of the support **124** is adhered to the element **124** by means of a weld **126** such that the element **118** is sandwiched intermediate the post **112** and the support **124**. The element **118** is electrically engaged to power terminal **110** by means of a lead wire **125**. The terminal end of the long leg of the support **124** is engaged to a contact **128** positioned laterally opposite to the armature **122**. The contact **128** is secured to said support **124** by means of a weld **130**. A lead wire **132** is soldered to the armature contactor **122** and to the terminal post **114**. Also, the contact **128** is soldered to a lead wire **134** engaged to the terminal post **116**.

In operation, application of a power signal across the input posts **110** and **112** results in flexure of the piezoelectric element **118** in a vertical path such that the crystal-interlink-armature flexes vertically. Thus, the contactor **122** is moved in and out of contact with the terminal contact **128** thereby controlling the electrical circuit intermediate the signal posts **114** and **116**. It may be noted in the structure **100** that the support structure **124** and contact **128** are suspended as is the crystal-interlink-armature chain. Thus, the support **124** and chain are equally subjected to vibration and shocks. Accordingly, the electrical operation of the relay **100** is relatively stable in vibrating atmospheres.

Relay structures incorporating the teachings of the present invention require low actuating energy to operate. The actuating energy may be in the order of one microJoule per contact set. The input inpedance may be in the order of 1,000 megohms shunted by approximately 10^{-9} farads. The turnoff time is dependant upon the time constant of the piezoelectric and any resistance added about the input power terminals. Accordingly, the turnoff time delay may be controlled according to the specific application of the relay. If during operation, input power is momentarily lost, the switches may hold their position for a time duration dependant upon the time constant. The relay may be made of extremely small size. The relay does not generate any substantial heat and may be made relatively free of the effects of impinging magnetic fields. Relays according to the present invention have wide application in environments where low power switching is required; in environments with space limitations, such as in portable and battery operated equipment; and in environments where isolation between input and controlled circuitry is desired.

We claim:

1. An electromechanical relay comprising, in combination:

a housing forming an enclosed internal chamber, the housing having two endwalls and sidewalls, said sidewalls extending longitudinally of and interconnecting said endwalls to form said enclosed internal chamber;

an elongated rectangular-shaped piezo-electric element positioned internally within the enclosed chamber and extending longitudinally within said chamber substantially parallel to said sidewalls, the element being flexible laterally intermediate said sidewalls responsive to electrical power applied to the element;

support means for anchoring a first longitudinal terminal end of the element to the housing within the internal chamber and adjacent to one of said endwalls, the other longitudinal terminal end of the element being suspended within the enclosed internal chamber;

input terminal means embedded within the housing walls and protruding through the housing to within said internal chamber and externally to the exterior of the housing, the input terminal means being positioned externally to receive input electrical power from an external source, the input terminal means being electrically connected internally to the element adjacent to said first longitudinal terminal end;

an elongated electrically insulative interlink having a thickness greater than the thickness of the element, the interlink being anchored about one of its longitudinal terminal ends to said other longitudinal terminal end of the element, the interlink extending longitudinally within the chamber in tandem longitudinal alignment with said element and substantially parallel with said sidewalls, the interlink establishing an elongated moment arm with the element;

an elongated electrically conductive armature contactor having one longitudinal terminal end anchored within and adjacent the other longitudinal

end of the insulative interlink, extending longitudinally in tandem longitudinal alignment with the interlink substantially parallel with said sidewalls, the interlink electrically insulating the element from the armature contactor, the armature contactor establishing an elongated moment arm with the interlink and the element; and

a plurality of contact terminals embedded within said housing walls and protruding through said housing walls to within said internal chamber and externally of the housing, the contact terminals projecting internally to a position laterally adjacent to the armature contactor, at least two of said contact terminals being offset relative to one another within the chamber, a flexible conductive wire connected to one of said contact terminals within the chamber and about its other end to said conductive armature contactor.

2. The relay of claim **1**, further including an elongated insulative support within the chamber and substantially parallel with the element, one terminal end of said support being suspended within the chamber and positioned adjacent to said armature contactor, and a contact member engaged to said support about the suspended end of said support adjacent to the armature contactor.

3. The relay of claim **1** in which

the insulative support is L-shaped with the terminus of one leg joined to the element and the terminus of the other leg being suspending and engaged to said contact.

4. The relay of claim **1** further including permanent magnetic field means embedded within the armature contactor for establishing a magnetic field intermediate the armature contactor and the contact means.

5. The relay of claim **4** in which

the armature contactor and the contact terminal means comprise a magnetic material.

* * * * *