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3,194,986

ELECTROMECHANICAL SWITCH EMPLOYING SEMICONDUCTIVE DIODES FORMED
AT THE CONTACTS TO SIMULTANEOUSLY CONTROL DIRECTION
OF PLURAL SIGNALS

Filed Nov. 28, 1962

2 Sheets-Sheet 1

FIG. 1

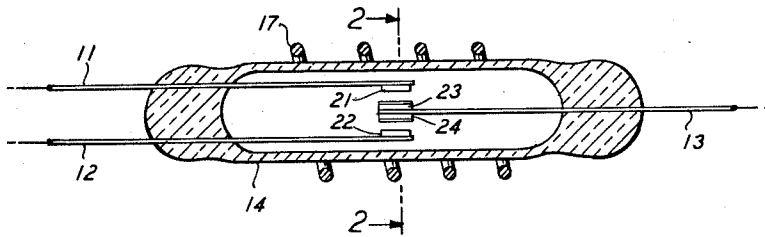


FIG. 2

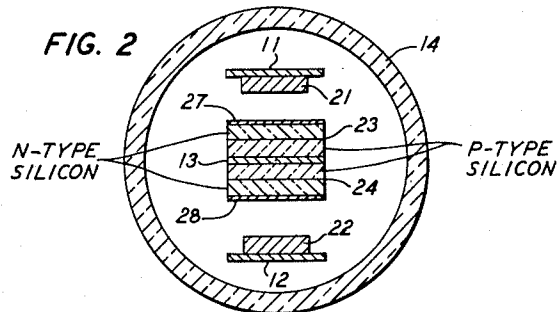


FIG. 3

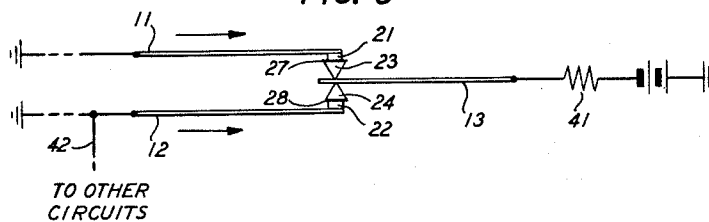
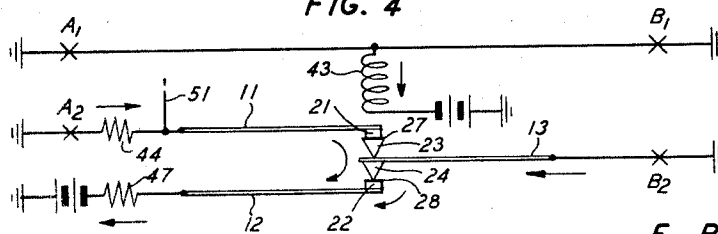


FIG. 4



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FIG. 5

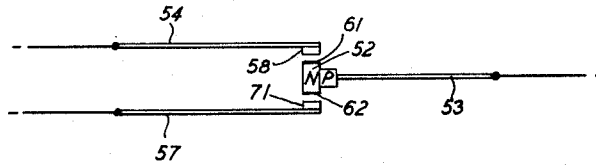


FIG. 6

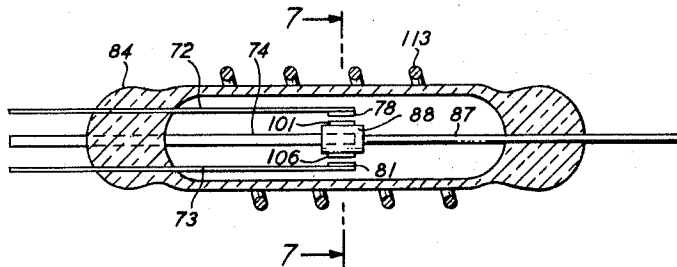
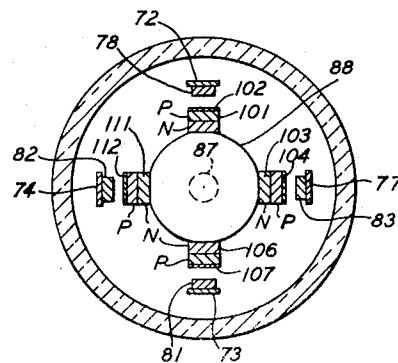


FIG. 7



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ELECTROMECHANICAL SWITCH EMPLOYING SEMICONDUCTIVE DIODES FORMED AT THE CONTACTS TO SIMULTANEOUSLY CONTROL DIRECTION OF PLURAL SIGNALS

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7 Claims. (Cl. 307—88.5)

This invention relates to electrically controlled switching devices and more particularly to such a device utilizing a magnetic field to effect movement of switch contacts.

For many years an important, indeed an essential, element of telephone systems and other communication systems has been the electromechanical switch or relay. These devices have proven through the years to be economical and reliable means for interconnecting circuits. However, such devices as known heretofore function only as means for interrupting or completing current paths, and do not have the ability to segregate current flow on the basis of polarity or bias.

Notable improvements in communication systems are constantly being made, particularly with regard to speed and perfection of transmission, and these changes have, of course, been accompanied by some increase in complexity of the various circuits involved. This has, in turn, resulted in increasing demands on the relays utilized, particularly with regard to their speed of operation and ability to control a multiplicity of circuits without undue increase in size.

Accordingly, it is an object of our invention to improve the performance of an electromechanical relay or switch.

Another specific object of the invention is to accomplish simultaneous control of a plurality of separately biased circuit paths by a single relay operation thereby materially increasing the effective over-all operating speed of the relay.

A still further object of the invention is to control the direction of current flow through closed relay contacts.

In the above and subsequent description the terms "relay" and "switch" are used interchangeably.

In accordance with one specific embodiment of our invention a reed switching device is provided with asymmetric conductors, such as diode elements, built into the reed contacts. Three reed springs are provided, two outer springs projecting from one end of the enclosing vessel or tube, and a common central spring projecting from the opposite end of the enclosing tube with its free, or contact, end positioned between the free ends of the respective outer springs. The diode elements are positioned at both contact surfaces of the common central spring, and, when the three springs are pulled together through normal operation of the switch, particular combinations or isolations of the circuits connected to the respective reeds are attained depending upon the particular polarization of the respective diodes with regard to the opposed outer reed. Since a single circuit closure of the device can control a plurality of differently biased or polarized current paths, it is obvious that the structure embodies inherent advantages both from the standpoints of effective increases in speed and effective reduction of size requirements.

In accordance with another specific embodiment of the invention the over-all arrangement is generally similar to that above described except for the fact that the common central spring carries at its free end a cylindrical member with a plurality of diode elements positioned around the peripheral surface thereof; a corresponding number of circularly arranged outer springs, when pulled together

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by normal operation of the relay, make contact engagement with the respective diode elements.

A feature of the present invention is asymmetric relay contacts so poled as to obtain various desired circuit relationships through a single energization of the relay.

A further feature of the invention, as exemplified in one of the specific illustrative embodiments thereof, is means for so supporting a plurality of diode contact members in relation to a corresponding number of contact springs that full and complete engagement results between all respective opposed members when the relay is operated, even though slight positional irregularities may exist in the structure.

A still further feature of the invention is a single diode contact positioned on the common center spring of the switch and effective as an asymmetric element only with regard to current flow between the common center spring and the opposed outer springs.

A full understanding of the arrangements contemplated by the present invention as well as an appreciation of the various advantageous features thereof may be gained from consideration of the following detailed description in connection with the accompanying drawing in which:

FIG. 1 is a side elevation, in partial section, of one specific illustrative embodiment of the invention;

FIG. 2 is an enlarged end view taken on line 2—2 of FIG. 1 showing particularly the arrangement of the contact members on the reed springs;

FIG. 3 is a schematic showing of the current paths resulting from one particular arrangement of the asymmetric contacts, the switch being energized to engage the contacts;

FIG. 4 is a schematic showing of the current paths resulting from another arrangement of the contacts whereby the action of a polarized relay is attained;

FIG. 5 is a schematic showing of an embodiment of the invention wherein a single diode contact is positioned on the common center spring;

FIG. 6 is a side elevation, in partial section, of another specific illustrative embodiment of the invention wherein a plurality of diode contacts are positioned on a cylindrical member carried by the center spring; and

FIG. 7 is an enlarged end view taken on line 7—7 of FIG. 6 showing particularly the arrangement of the contacts on the cylindrical member and on the reed springs.

Referring now to the drawing and first to FIGS. 1 and 2, there is shown a glass sealed reed switch which is generally similar in certain respects to that disclosed in United States Patent 2,289,830, issued July 14, 1942, to W. B. Ellwood. The reed switch comprises three reed spring members 11, 12 and 13 of magnetically soft material sealed within tubular glass vessel 14. The two opposed outer reed springs 11 and 12 extend from one end of the vessel 14 while the common central spring 13 extends from the opposite end of the vessel with its free or contact end positioned between the free ends of the respective outer springs. Energizing winding 17 surrounds vessel 14 and is provided with suitable terminals (not shown) for connection in the external circuit. (It will be understood, also, that each reed spring is provided with suitable terminals for connections to the external circuits.) Normally, that is in the absence of controlling flux, the opposed free ends of reed springs 11 and 12 are held in separated position and out of contact with spring 13 by the inherent spring bias of the reeds. When winding 17 is energized the resulting flux acts to pull reed springs 11 and 12 toward each other whereby to engage the respective opposed contact surfaces of common center reed spring 13. The outer reed springs 11 and 12 are provided with respective contact points 21 and 22 of suitable material, for example, palladium or gold. Center spring 13 is provided with two diode con-

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tacts, diode 23 being positioned on the upper face of the reed spring and diode 24 being positioned on the lower face thereof. These diodes are preferably of the semiconductor junction type and, as shown more clearly in the enlarged view of FIG. 2, each comprises in the specific illustrative embodiment a section of p-type silicon and a section of n-type silicon in junction.

It is well known in the art that rectifying contacts can be made between two semiconductors, such as silicon of opposite conductivity types, the direction of "easy flow" being that for which the p-type is positive and the n-type negative. (See "Editorial Note Regarding Semiconductors," Bell System Technical Journal, vol XXVIII, No. 3, July 1949, page 335. Such rectifiers are discussed further in the articles "On the Theory of the A-C Impedance of a Contact Rectifier" and "The Theory of p-n Junctions in Semiconductors and p-n Junction Transistors" in the above volume, pages 428 and 435, respectively.)

Diode contact 23 is provided on its upper surface with metallic electrode 27 and, similarly, diode contact 24 is provided on its lower surface with metallic electrode 28. These electrodes may be of any suitable material, for example, gold or palladium.

As pointed out above, when coil 17 is energized in the normal way, the resulting flux draws the outer reed springs 11 and 12 together to engage common reed spring 13 whereupon springs 11 and 13 are electrically connected through contact point 21, electrode 27 and diode 23, and springs 12 and 13 are electrically connected through contact point 22, electrode 28 and diode 24. By relative positioning of the respective p-type and n-type sections each diode may be polarized or biased as desired whereby to obtain particular combinations or segregations of current paths through the switch.

One contemplated arrangement of the diode contacts whereby to attain a particular arrangement of current flow paths, is shown schematically in FIG. 3. In considering the arrangement illustrated in FIG. 3 it will be assumed for purposes of description that the normal direction of current flow is from ground to battery. As schematically indicated, diodes 23 and 24 have been so "directed" or polarized that the direction of "easy flow" is from the respective outer reed spring to the common center spring. That is, the diode elements are polarized symmetrically with regard to the center spring and in respectively opposite directions. Accordingly, when the switch is operated and the contacts engaged, two independent current flow paths are set up, one path from ground, reed spring 11, contact point 21, electrode 27, diode 23, reed spring 13, and through the load resistor 41 to battery, and the other path from ground, reed spring 12, contact point 22, electrode 28, diode 24, reed spring 13, and through load resistor 41 to battery. The particular polarization of the diodes illustrated provides segregation of the respective current paths in reed springs 11 and 12 which is here assumed to be desirable since the path through spring 12 is associated by way of lead 42 with certain other circuits (not shown) with which the path through spring 11 is not concerned.

Referring now to FIG. 4 there is schematically shown a different arrangement of the respective diodes whereby the action of a polarized relay is attained. Here again a normal direction of current flow from ground to battery is assumed, and for purposes of description an energizing coil 43 has been shown schematically together with energizing paths therefor. It will be assumed that, as indicated schematically, both diodes are directed or polarized in a downward direction with respect to the reed springs. It will be assumed, further, that respective pairs of contacts A1 and A2 and B1 and B2 are coupled mechanically. Assuming, first, that contacts A1 and A2 are closed, the switch is operated by flux resulting from energization of coil 43, and a first path is completed from ground, make contact A2, load resistor 44, reed spring 11, con-

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tact point 21, electrode 27, diodes 23 and 24, electrode 28, contact point 22, reed spring 12, load resistor 47 to battery. In this instance there is no current flow in reed spring 13 since contact B2 is open.

Assuming now that contacts B1 and B2 are closed instead of contacts A1 and A2 as just described, a second path is now completed from ground, make contact B2, reed spring 13, diode 24, electrode 28, contact point 22, reed spring 12, load resistor 47 to battery. Flow of current from reed spring 13 to reed spring 11 is blocked by diode 23 because of its particular "direction" or polarization, so that interference with any other circuits connected by way of lead 51 is prevented.

Referring now to FIG. 5, there is shown schematically an arrangement in accordance with which a single diode contact 52 is provided on common center spring 53. Outer springs 54 and 57 are provided with contact points 58 and 71, respectively, which may be, for example, gold or palladium. Diode contact 52, as in the instances described above, comprises sections of semiconductor material of respectively opposite conductivity types, that is, n-type and p-type, but it will be observed that the arrangement is such that the path between outer reed springs 54 and 57 is completed through one section only. (In the specific illustrative embodiment, the path is completed through the n-type section.) Accordingly, the path between the two outer springs is nonasymmetric. However, with regard to the respective paths between outer reed spring 54 and center reed spring 53, and outer reed spring 57 and center reed spring 53, here the complete diode 52, n-type plus p-type, is involved so that the paths are asymmetric, the direction of "easy flow" being determined by the relative positioning of the two sections. For example, the polarization of the diode 52 may be so established that when the switch is closed a first directional path will be closed from outer reed spring 54, contact point 58, electrode 61, diode 52, to center reed spring 53, and a second directional path will be closed from outer reed spring 57, contact point 71, electrode 62, diode 52 to center reed spring 53. At the same time a nondirectional path will be maintained between outer springs 54 and 57, but there will be no transmission from the common spring 53 to either outer springs 54 or 57.

Referring now to FIGS. 6 and 7, the device there illustrated is of generally similar form to that of FIG. 1. However, in the device of FIGS. 6 and 7, provision is made for a larger number of outer reed springs, four reed springs 72, 73, 74 and 77 being shown in the specific illustrative embodiment. These reed springs are provided with respective contact points 78, 81, 82 and 83 of suitable material, for example gold or palladium. The four outer reed springs extend in evenly spaced circular relationship from the left-hand end of enclosing tube or vessel 84, and it is obvious that a different number of springs than the four illustrated may be provided as occasion arises.

Common center reed spring 87, which projects from the right-hand end of the vessel 84, is preferably round in cross-section whereby to promote flexibility in all directions perpendicular to its longer axis for a purpose discussed subsequently. A cylindrical element 88 of suitable conductive material is mounted on the free end of reed 87 and supports a plurality of diode contacts equal in number to, and respectively associated with, the outer reed springs. Each diode contact, as above described, comprises two sections of semiconductor material of respectively opposite conductivity types, n-type and p-type, and each diode contact assembly is provided with a suitable metallic electrode, for example of gold or palladium. Thus diode 101, which is opposed to contact point 78, is provided with electrode 102; diode 103, which is opposed to contact point 83, is provided with electrode 104; diode 106, which is opposed to contact point 81, is provided with electrode 107; and diode

111, which is opposed to contact point 82, is provided with electrode 112.

Normally, that is, in the absence of controlling flux, the outer springs are held out of contact with cylindrical element 88 by their inherent spring bias. When coil 113 is energized, however, the resulting flux acts to pull the free ends of all the reed springs into engagement. With the provision of a relatively large number of reed springs it is recognized that instances of imperfect matching of opposed contacts may occasionally result due to off-center mountings or other manufacturing imperfections. However, by virtue of the novel arrangement contemplated, a perfect engagement of all the opposed contacts is assured. As mentioned above, common center spring 87 is designed to provide flexibility in all directions perpendicular to its longer axis. Accordingly, as coil 113 is energized and the resulting flux acts to bring the free ends of the reed springs into contact, cylinder 88 will be free to "wobble" slightly under the influence of the flux whereby to attain firm and even contact between all diode electrodes and opposed contact points even though the resulting combination may necessarily be slightly off-center for attainment of such result. This is a particularly valuable feature, permitting as it does successful application of a multiple contact arrangement of the nature disclosed without the necessity of unduly stringent manufacturing requirements with regard to spring spacing and mounting.

It will be understood that various polarizations of the diode contacts provided in the embodiment just described may be utilized to obtain desired current paths. Also, it will be understood that diode contacts may be provided on some, or all, of the outer reed springs as desired. Also, if desirable, other types of asymmetric conductors may be utilized in the various embodiments of our invention in place of the semiconductor diode elements disclosed.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A switching device comprising a pair of spring contact members mounted in parallel relationship with their opposed contact portions normally held in separated position by inherent spring bias, a third spring contact member mounted with its free end positioned between the respective contact portions of said pair of spring contact members, a diode element positioned on both major surfaces of said free end of said third spring contact member, and means for drawing together said opposed contact portions of said pair of spring members whereby

to attain engagement of said diode elements and said opposed contact portions.

2. In a switching device the combination defined by claim 1 further characterized in that said diode elements are polarized symmetrically with regard to said third spring contact member and in respectively opposite directions.

3. In a switching device the combination defined by claim 1 further characterized in that said diode elements are polarized in the same direction and unsymmetrically with regard to said third spring contact member.

4. A switching device comprising a tubular enclosing vessel, a plurality of spring reed contact members sealed in one end of said vessel and extending therefrom in evenly spaced circular relationship into said vessel with their respective free ends held in separated position by inherent spring bias, an additional spring reed member sealed in the other end of said vessel and extending therefrom into said vessel with its free end positioned substantially in the center of the area encompassed by the free ends of said plurality of spring reed contact members, a plurality of asymmetric conductors equal in number to the number of said first-mentioned spring reed contact members, means for so supporting said asymmetric conductors on said additional spring reed member that each asymmetric conductor is in an opposed position to a respective free end of said plurality of spring reed contact members, and flux producing means for drawing together the free ends of said plurality of spring reed contact members whereby to obtain engagement between the respective free ends of said plurality of spring reed contact members and the respective asymmetric conductors.

5. In a switching device the combination defined by claim 4 further characterized in that said asymmetric conductors comprise semiconductor diodes.

6. In a switching device the combination defined in claim 4 further characterized in that said supporting means comprises a cylindrical element of conductive material with said asymmetric conductors spaced around the peripheral surface thereof.

7. In a switching device the combination defined in claim 6 further characterized in that the arrangement of said additional spring reed member is such as to promote flexibility thereof in all directions perpendicular to its longer axis.

References Cited by the Examiner

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ARTHUR GAUSS, *Primary Examiner.*