Oct. 8, 1968 E. GIKOW 3,405,289

SWITCH

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FIG. 1

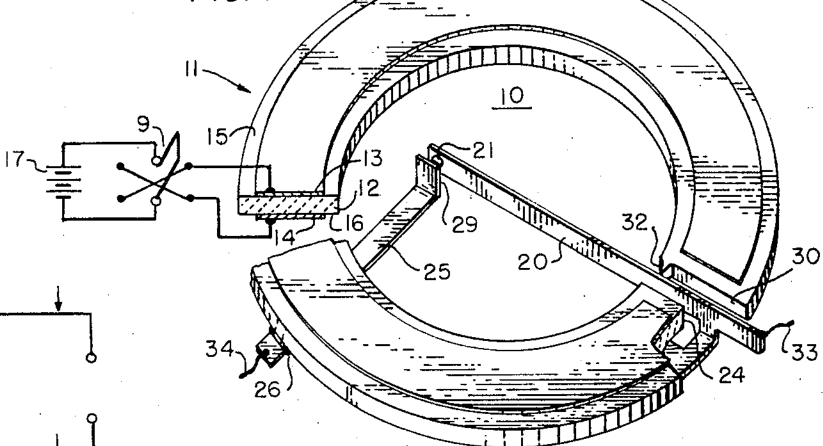

FIG. 2

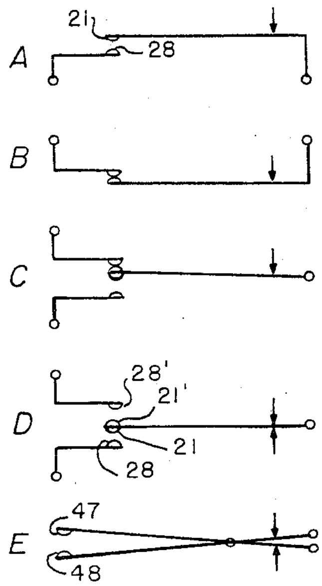

FIG. 3

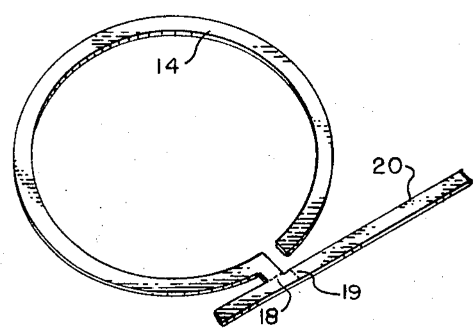

FIG. 4

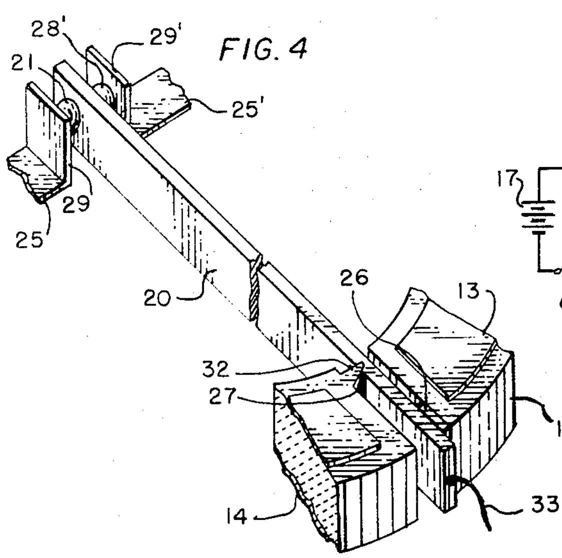

FIG. 5

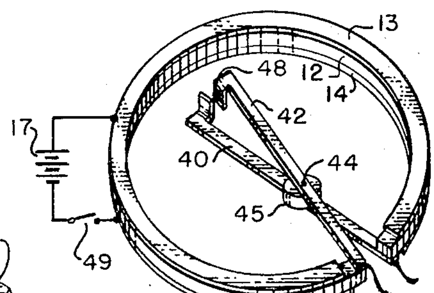

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FIG. 6

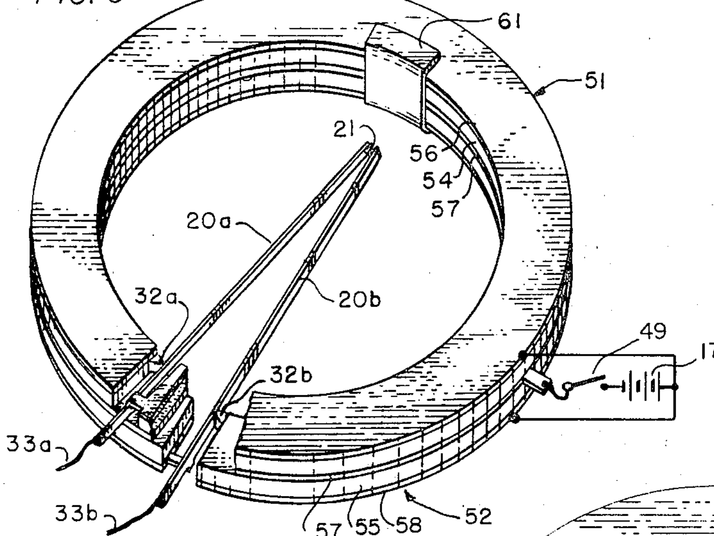

FIG. 7

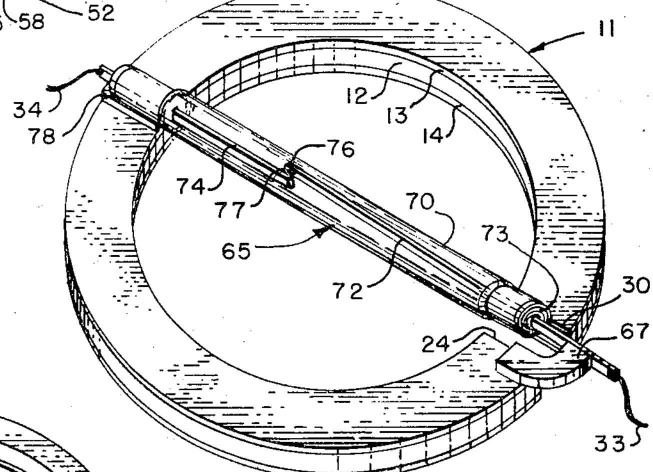

FIG. 9

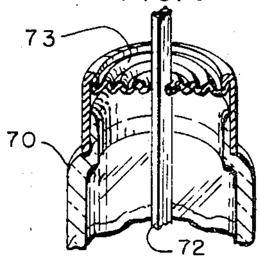

FIG. 8

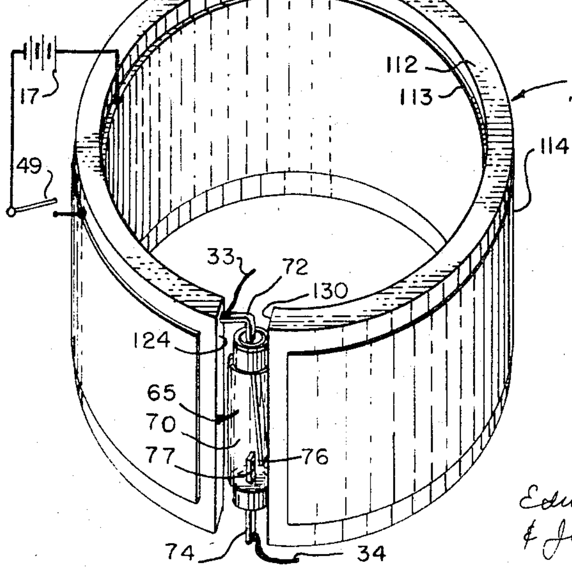

FIG. 10

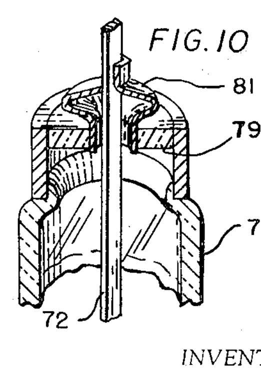

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FIG. 11

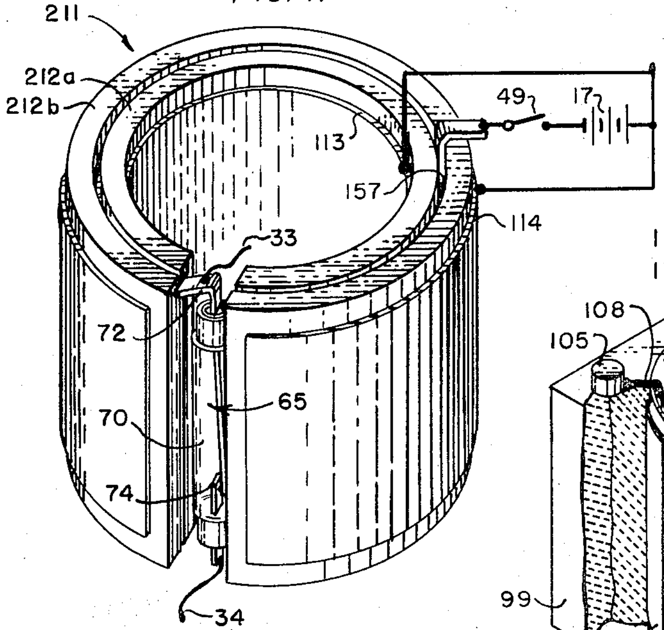


FIG. 12

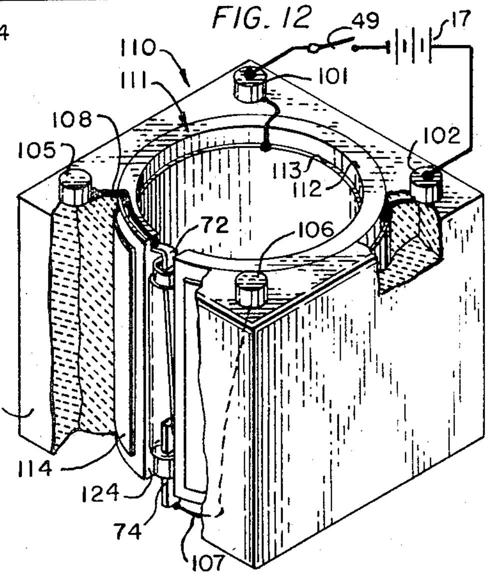


FIG. 14

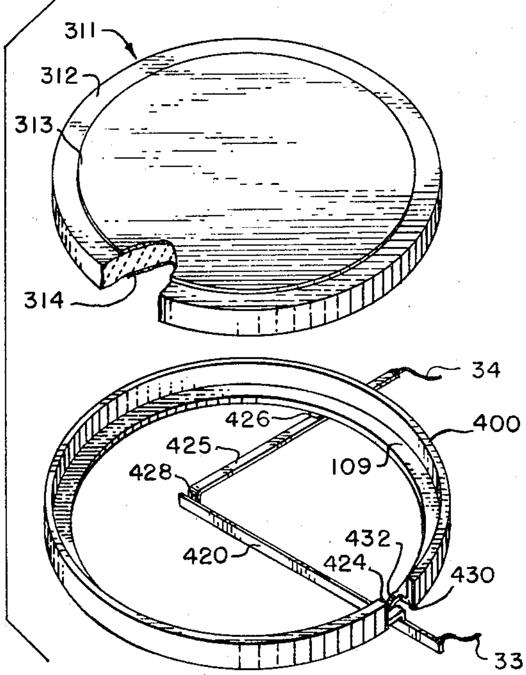
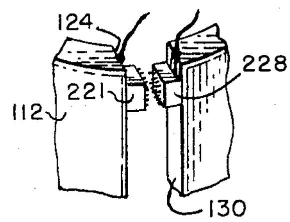


FIG. 13



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United States Patent Office

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SWITCH

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15 Claims. (Cl. 310—8.5)

ABSTRACT OF THE DISCLOSURE

A switch having at least one switch contact arm movable in response to either flexural deformation of an arcuate piezoelectric or electrostrictive transducer member or radial deformation of a discoidal piezoelectric or electrostrictive transducer member occasioned by exposure of said member to an electric field.

The transducer member can be in the form of a split ring provided with electrodes to which a unidirectional control voltage may be applied. Flexural movement of the split ring causes the ends of the ring to move relative to one another and a switch arm carried at one end face of the ring moves with said one end face. This movement can be accentuated by having a projection on the opposite end face of the split ring exert pressure on the moveable arm at a region intermediate the ends of the moveable arm, but remote from the free end of said arm, thereby obtaining a lever action. This projection may be bonded to the moveable switch arm to permit actuation of the moveable arm in either direction. Both switch arms may be moveable and may intersect at a pivot.

The transducer member can be in the form of a split hollow cylinder electroded on inner and outer surfaces with a sealed switch body disposed lengthwise along the gap formed between the two end faces of the split member and bonded to one end face. The switch body encloses portions of moveable and stationary switch arms with the outer arm of the fixed arm engaging one end face of the cylindrical member and a moveable arm being pivotally mounted at one end of the switch body. Relative movement of the two ends of the cylinder causes the moveable arm to pivot until contact is made with the fixed arm inside the switch body. This switch body also may be used in connection with the split ring transducer member already described.

The transducer member can be a discoidal member electroded on opposite faces and capable of distorting radially. The disc is received in a split retaining ring having juxtaposed end faces forming a gap. The moveable switch arm is carried on one end of the retaining ring and a projecting tab is on the other end of said ring and disposed radially inwardly from the region of support of the moveable switch arm.

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

This invention relates to a switch and, more particularly, to a switch having a switch contact arm movable in response to deformation of an arcuate transducer member of the piezoelectric or electrostrictive type occasioned by exposure of said member to an electrical field.

In one embodiment of the invention the transducer member comprises a ring of piezoelectric or electrostrictive material cut through at one point to form a slit; opposite surfaces of the ring are provided with electrodes to which a unidirectional control voltage may be applied. During application of the aforesaid voltage, the split ring is subjected to flexural movement, causing the ends of the ring to move more or less toward one another or away from one another, depending upon the polarization of the ring material and the polarity of the applied voltage. A

switch arm carrying at one end at least one switch contact is mounted to move with one of the end faces of the split ring. This movement can be accentuated by having a projection on the opposite end face of the split ring exert pressure upon the movable arm at a region intermediate the ends of the arm, but remote from the free end of said arm during application of the unidirectional control potential. A lever action thus is attained and the mechanical advantage made use of to multiply the relatively small displacement of the element and consequently, to achieve a greater throw of the movable switch arm. A stationary switch arm may be mounted to a portion of the split ring and electrically insulated therefrom. The movable arm contact either makes contact with or breaks contact with the stationary arm contact, depending upon the aforesaid polarization and the polarity of applied control voltage. A single pole double throw switch can be obtained in this manner simply by incorporating a second stationary contact arm with associated contact and by reversing the polarity of the applied voltage when contact with a different one of the stationary contact arms is desired. The projection on the one end face, in some cases, may be bonded to the movable switch arm to permit actuation of the movable arm in either direction.

The arcuate element may be composed of a single layer of piezoelectric or electrostrictive material electroded on the upper and lower surfaces, or it may be made of multiple layers of piezoelectric or electrostrictive material, said layers being alternately polarized and the control potential connected to the electrodes to permit uniform motion of all layers.

The movable switch arm may be integral with one of the electrodes and bent near one end more or less perpendicular to the plane of said electrode; in an alternative arrangement, the movable switch arm is attached to a portion of one end face near the outer periphery of the ring, said end face having a portion shimmed to permit freedom of motion of the switch arm.

In another embodiment of the invention, a split hollow cylindrical transducer member of piezoelectric or electrostrictive material is electroded on inner and outer surfaces; application of a unidirectional control potential to these electrodes will subject the member to flexural motion, causing relative movement of the two end faces of the cylinder. A sealed switch body is disposed substantially lengthwise along the gap formed between the two end faces of the split cylindrical member and is bonded to one end face thereof. The switch body encloses portions of a movable and a stationary switch arm having contacts mounted at or near the inner ends thereof. The outer ends of the respective switch arms protrude through opposite ends of the switch body. A portion of the movable switch arm extending from one end of the body portion is bent over to engage the other end face of the cylindrical member. The movable switch arm is pivotally mounted at said one end of the switch body, as by means of a bellows arrangement. When a control potential is applied to the element, the two ends of the cylinder move relatively and the force applied to the bent movable arm will cause it to pivot at the end of the switch body until the contact at the end of the movable switch arm within the switch body makes contact with the contact at the end of the stationary arm inside the switch body. The switch may, in some cases, be encased in a solid container, with connection to the switch arms being made by flexible leads.

In some cases, the switch contacts may be attached directly to the opposite end faces of the split cylindrical member, thereby eliminating the need for a sealed switch assembly.

This sealed switch assembly above described may be used in the case of the split ring embodiment of switch, in which case, the switch body extends more or less diametrically across the ring with the protruding end of the fixed switch arm being insulatedly mounted directly to a portion of the annular transducer member opposite the slit and the protruding end of the pivotally mounted movable switch arm being bent, as before, to engage one of the end faces of the split ring member.

In another embodiment of the invention, a polarized piezoelectric or electrostrictive discoidal member is electroded on the opposite faces and, in response to a direct current control voltage applied to those electrodes, is caused to expand or contract radially within a split metallic retaining ring which fits snugly around the periphery of the disc. The ends of the retaining ring move in response to application of a potential to the electrodes and a movable switch arm carried on or adjacent to one of the ends of the split retaining ring can be made to move either into or out of engagement with an associated stationary contact arm.

The sealed switch assembly may be used with this embodiment of switch; the sealed switch body then would extend more or less diametrically across the retaining ring, with the body fixed to one end of the retaining ring end with the other end of the retaining ring having an extension which is affixed to a portion of the movable switch arm disposed external of the switch body.

Switches of the electromagnetic type have been used for many years. Such devices normally have a relatively large mass and occupy considerable space, owing, in part, to the need for a magnetic field producing means. The size of the switch according to the invention is considerably smaller than that of a electromagnetic switch of the same rating. By virtue of the small mass, as well as the structural simplicity, the switch of the subject invention is quite rugged and may be made still more rugged by placing it within a plastic or ceramic container. Unlike electromagnetic switches, the velocity of the moving arm of the switch of the invention reaches zero at the point of maximum deflection and contact bounce is minimized.

The switches of the invention, unlike switches of the electromagnetic type, do not draw current and no power is required to keep the switch closed or open, as the case may be.

Since there is no coil wire to corrode, the switch of the invention is more resistant to humid or corrosive atmosphere than electromagnetic switches.

Switches embodying bimorph or bender transducers have been made wherein one contact is at the end of a cantilever type linear element. The obvious disadvantage of this type of switch is that, in order to obtain sufficient sensitivity, stiffness of the element must be sacrificed. This is because the sensitivity of the bender element is inversely proportional to the thickness (the distance between electrodes) of the bender element, whereas the stiffness of said element is directly proportional to the thickness. The movement of such an element is in the thickness direction and, because the stiffness of such element is limited, there is a tendency for such elements to sag under their own weight. Although the rigidity of such bender elements can be improved by increasing the thickness of the element, this would decrease the sensitivity and require unduly high voltages for operation. The only alternative is to sandwich several thin layers; such multiple-layering is expensive and the bending problem becomes comparatively difficult. In contrast, motion of the switch of the invention is in a plane perpendicular to the thickness direction, thus permitting greater stiffness than is possible with the linear bender type switch.

Since the deflection of such bender element is proportional to length, such elements tend to become fragile for a reasonable amount of deflection. Furthermore, since these elements are usually made of ceramic, the stress in shear may be sufficient to cause breakage. The switch according to the invention, having arcuate transducer members which are nearly reentrant, can achieve greater

displacement per volume of space occupied than prior bender elements. Furthermore, the arcuate transducer members of the switches of the invention move in either the flexural or radial mode and are characterized by motion in a direction substantially perpendicular to the thickness dimension of the element. Consequently, with the switches of the invention, one need not sacrifice sensitivity for the sake of stiffness or strength, as would be the case with switches using linear bender elements. The arcuate members used for switches of the invention are further characterized in that the forces resulting from flexural or radial motion are exerted in compression; this is advantageous when such ceramics as barium titanate are used in the switches, since ceramics are relatively strong in compression, but relatively weak in tension and shear.

The switch of the invention, being a low-loss, non-magnetic device, does not generate a magnetic field and can be used in applications in electromagnetic environments susceptible to magnetic fields or lossy dielectrics.

Another advantage of the switch of the invention is high switching speed, which is of the order of microseconds, as contrasted, for example, to switching speeds in electromagnetic switches of the order of milliseconds.

Other advantages of the switch of the invention are high efficiency, owing to low power requirements, and high sensitivity, owing to low current requirements.

The switches of the subject invention are of relatively low cost, since fabrication of the ceramic requires no precision tolerance and since the material of the switches is relatively inexpensive.

The operating life of the switch according to the invention is very long since the movements are so small contrasted with the elastic limit of the materials involved; the switch life is limited essentially only by the life of the contacts.

Other objects of the invention will become more apparent upon examination of the drawings wherein:

FIG. 1 is a pictorial view showing a switch according to the invention wherein the transducer is in the form of a split ring;

FIG. 2 comprises a series of schematic representations of possible types of switch action which can be accomplished by the switches of the invention;

FIG. 3 is a detail view showing a switch arm integral with an electrode of a split ring transducer of the type shown in FIGURES 1 and 6;

FIG. 4 is a view showing an alternate means to that shown in FIGURE 3 for mounting the movable switch arm to the split ring transducer, as well as bonding of the tab to the switch arm, and also showing double throw switching possibilities;

FIG. 5 is a view of a switch using a split ring type transducer but with scissors type mounting of the switch arms (represented schematically in FIGURE 2E);

FIG. 6 is a view, partly broken away, of a switch using a transducer with multiple layers and with both switch arms movable and integral with the electrodes of the transducer;

FIG. 7 is a pictorial view of a switch using a split ring type transducer, together with a sealed reed type switch assembly;

FIG. 8 is a pictorial view of a switch using a split cylindrical type of transducer, with a sealed reed type switch assembly;

FIG. 9 is a detail view showing a portion of one type of means for permitting pivotal mounting of the moving switch arm of a reed type switch assembly such as shown in FIGURES 7, 8, 11 and 12;

FIG. 10 is a detail view showing a portion of a second type of means for permitting pivotal mounting of the movable switch arm of a reed type switch assembly such as used in the switches of FIGURES 7, 8, 11 and 12;

FIG. 11 is a view showing a switch similar to that of FIGURE 8 except that the transducer is made up of multiple layers;

FIG. 12 is a view showing a switch similar to that of FIGURE 1, with the transducer of certain leads and terminals encased;

FIG. 13 is a detail view of a means for mounting switch contacts directly to the face of the split cylindrical type transducer member, and further showing multi-pronged contacts particularly suitable for such an arrangement; and

FIG. 14 is an exploded view showing a switch in which an electroded discoidal transducer member capable of radial distortion is carried within a split retaining ring having one of the switch arms integral therewith.

Referring to drawing, FIGURE 1 illustrates a switch assembly **10**, including a transducer **11** in the form of a split ring. Transducer **11** includes an arcuate member **12** provided with electrodes **13** and **14** disposed on opposite surfaces **15** and **16** thereof. The electrodes may be disposed on the surface of the transducer member **12** by any well known coating technique or the electrodes may be thin arcuate metal strips bonded to the respective surfaces of member **12**. The transducer member **12** can be made of any material, such as barium titanate ceramic, having either piezoelectric or electrostrictive properties whereby the member deforms in flexure when subjected to unidirectional electrical potential. The split annular transducer member **12** terminates in juxtaposed end faces **24** and **30** which, normally, that is, in the absence of a unidirectional control potential across electrodes **13** and **14**, are spaced apart a small predetermined amount. The unidirectional control voltage from a direct current source, such as battery **17**, is applied by way of double pole, double throw switch **9** to electrodes **13** and **14**. The transducer member **12** initially is polarized in one of two possible directions before insertion into the switch **10** of FIGURE 1. This is true, moreover, of all the transducer members shown in the drawing. The initial polarization will determine, for any given polarity of direct current control potential to electrodes **13** and **14**, whether the juxtapositioned end faces **24** and **30** of the annular transducer member **12** will separate or approach one another. As shown in FIGURES 1 and 3, one of the electrodes, namely electrode **14**, is in the form of a thin annular strip having integral therewith an elongated finger portion **20** near one end of the ring. This electrode, with its integral portion **20**, may be stamped from one piece of metal stock. A portion **20** may be bent along dotted lines **18** and **19** as shown in FIGURE 3, to a position such as indicated in FIGURE 1, thereby forming the movable switch arm **20** of switch **10**. Because of the temperature coefficient of expansion of the transducer **11**, in some applications where large changes in temperature are encountered, the movable switch arm **20** can be a bimetallic member so designed that its flexure owing to temperature change will compensate for flexure of the transducer **11** resulting from said temperature change. This temperature compensation technique, of course, can be used in all the devices hereinafter described. The movable switch arm **20**, which carries a switch contact **21** at one end thereof, is bent so that it is spaced slightly from end face **24** of the split annular member **12**. Switch **10** further includes a fixed switch arm **25** which can be supported from the transducer member **12**, as by bonding, to an insulating strip **26**; strip **26**, in turn, is bonded to the electroded surface **16** of the transducer **11**. The fixed switch arm **25**, like movable switch arm **20**, is provided with a contact; this contact **28** is not visible in FIGURE 1, but is attached to upturned portion **29** of the fixed switch arm **25**. As shown in FIGURE 1, the fixed end of movable switch arm **20** is mounted near the outer rim of the split transducer member **12**. A projection or tab **32** is provided at a region along the end face **30** of member **12** disposed radially inwardly from the fixed end of the switch arm **20**. This tab **32** may be integral with transducer member **12**, or, as shown in FIGURE 1, may be a more or less triangular tab bonded to the end face **30** of transducer member **12** near the inner periphery. Leads **33** and **34** connected in the respective switch arms

20 and **25** provide means for connection to a circuit in which switching is to be accomplished.

Depending upon the position of reversing switch **9**, a direct current control voltage of a given polarity can be applied to the electrodes **13** and **14** of the transducer **11**. The transducer, therefore, operates in flexure, that is, it is distorted from its condition during absence of an applied direct current control potential, whereupon end faces **24** and **30** of transducer member **12** move relative to one another. As previously mentioned, whether or not the end faces **24** or **30** approach or move away from one another will depend upon the polarity of the applied direct current potential from source **17** and upon the initial polarization of the transducer member **12**. For a given initial polarization, reversing the applied direct current control voltage will reverse the relative movement of the end faces of the transducer member. Similarly, for a given polarity of an applied control voltage, reversing the initial polarization will result in opposite relative motion of the end faces **24** and **30** of transducer member **12**. These relationships between polarity of control voltage and polarization of the transducer and the relative motion of the ends of the transducer obtain for all of the switches shown in the drawing, as well as for that shown in FIGURE 1. The switch arms **20** and **25** are shown in FIGURE 1 as they would be with the transducer in the condition of no control excitation. The position of the movable switch arm **20**, when no direct current control potential is applied to electrodes **13** and **14**, will be referred to as the null position. With no direct current control potential, the switch contacts **21** and **28** at the free ends of the respective switch arms **20** and **25** are spaced apart and the switch **10** is open. When the direct current control potential from source **17** is applied to electrodes **13** and **14**, however, the transducer undergoes flexure and, if the polarity and polarization are correct, the end faces **24** and **30** of the transducer will approach one another. The projecting tab **32** on the end face **30** will exert a force on the movable switch arm **20** causing the latter to be deflected toward end face **24** until contact **21** at the free end of movable switch arm **20** comes into contact with the contact **28** at the free end of fixed switch arm **25**, thereby closing switch **10**. The action is that of a cantilever or of a lever wherein a force is applied to a point intermediate the fixed and free ends of movable switch arm **20**. Since the force exerted on the switch arm **20** at the region of tab **32** is much closer to the support point for the switch arm than to the free end of the switch arm (where the switch contact is mounted), a mechanical amplification of the relative small motion of the end faces of the transducer member **12** is achieved. Because of this amplification of motion, the portion of the movable switch arm **20** which carries switch contact **21** will move through a greater distance than the portion of that arm **20** which is disposed in the gap between end faces **24** and **30** of transducer member **12**. It is necessary that the switch arm **20** be spaced from end face **24** only enough to permit free motion of the switch arm **20** within the gap between end faces. When the movable switch contact **21** closes against fixed switch contact **28**, the switch arm **20** should still be free from end face **24** of the transducer member **12**.

Since the projecting tab **32** is not bonded to movable switch arm **20** in the device shown in FIGURE 1, the switch will be normally open until closed by application of a direct current control potential and will operate only in the manner indicated schematically in FIGURE 2A. If the polarization and direct current control potential are so arranged that the end faces **24** and **30** move apart while energized, then the already open contacts **21** and **28** remain spaced apart, only more so than previously. It is possible, of course, to position the stationary switch arm **25** on the opposite side of switch arm **20** from that in FIGURE 1 and to have the movable contact **21** positioned on the opposite side of switch arm **20**, in the manner of contact 21′ of FIGURE 4 and switch arm 25′ of FIGURE 4, to be described later. If the two contacts in FIGURE 1 were together in the null position, the application of a direct current control potential in the proper polarity would cause the movable switch arm 20 to be moved away from the stationary switch arm and the switch would be open. This is the type of operation represented schematically in FIGURE 2B.

If, as is shown in FIGURE 4, the projecting tab 32 is attached, as by an epoxy cement 27, to the movable switch arm 20, the latter will move always along with the tab 32, regardless of whether the end faces 24 and 30 of the transducer member are approaching or receding. In FIGURE 4, therefore, an extra contact 21′ (not visible in FIGURE 1) is provided at the free end of movable switch arm 20 and a second stationary switch arm 25′ with associated switch contact 28′ is provided. In this manner, two separate circuits may be switched alternately, depending upon the polarity of direct current control potential applied to electrodes 13 and 14. From a null position in which the movable switch arm 20 is midway between contacts 28 (visible in FIGURE 2D) and 28′ of respective stationary switch arms 25 and 25′, the movable switch arm 20 will move, for one polarity of control potential, so that contact 21 is against contact 28, thereby closing a circuit connected to leads 33 and 34. The movable switch arm 20 will move, for the opposite polarity of direct current control potential, toward stationary switch arm 25′ until contact 21′ engages contact 28′, thereby closing a circuit connected to leads 33 and 34′. This is the type of operation represented schematically in FIGURE 2D.

It is possible, of course, to have the null position such that the movable switch arm is biased over to one side or the other, for example, so that contact 21 energizes contact 28′ of stationary switch arm 25′. From this position, movable switch arm 20 could be moved, in response to application of a direct current control potential, so that contacts 21′ and 28′ open and contacts 21 and 28 close. This is the type of operation represented in FIGURE 2C.

During the description of the switch 10 of FIGURE 1, the movable switch arm 20 was described as being integral with either one of the electrodes of the transducer member 12. Alternately, the moving switch arm 20 may be mounted directly to the end face 24 opposite the projecting tab 22, as indicated in FIGURE 4. In this arrangement, movable switch arm 20 is spaced from the end face 24 by means of a shim 26 bonded to the end face 24. The movable switch arm 20 is mounted near the outer periphery of the transducer 11. The shim 26 permits freedom of movement of the portion of arm 20 adjacent the projecting tab 32 of end face 30. This type of mounting of switch arm 20 to end face 24 may be used in conjunction with a tab 30 bonded to switch arm 20 or in conjunction with tab 30 separate from the switch arm 20 (see FIGURE 1). Since the tab 30 projects a considerable distance from the flat face 30, and since arm 20 is bent relative to tab 32 at the inner edge of the split ring during movement apart of the end faces 24 and 30, normally there would be no need for a shim attached to the surface 30 when the switch is used in the manner shown in FIGURE 4.

FIG. 5 illustrates a modification of the split ring type switch in which a portion of the electrodes 13 and 14 are cut back at opposite ends to permit bonding of switch arms 40 and 42 to the electrical insulating transducer member without contacting the respective electrical conductive electrodes 13 and 14. The switch arms 40 and 42 are pivotally mounted together, in the manner of scissor blades, by a pin 44 passing through an insulator 45 between the two switch arms. The free ends of the switch arms 40 and 42 carry respective contacts 47 and 48—only one of which is visible in FIGURE 5. When the direct current control potential from source 17 is applied by way of switch 49 to electrodes 13 and 14, the flexural distortion of transducer 11 causes the ends of the transducer to move relative to one another and, therefore, the movable arms 40 and 42 move along with the switch contacts at the free ends thereof. If the polarization and polarity are such that the end faces of the transducer member 12 moves together upon application of the control potential, then the switch contacts can be made to move from a normally open into a closed position. This manner of operation is represented schematically in FIGURE 2E.

In FIGURE 6 a pair of split ring transducers 51 and 52 are shown which have respective members 54 and 55 made of a material which is either piezo-electric or electrostrictive, like the member 12 of FIGURE 1. Member 54 has disposed thereon electrodes 56 and 57, the latter electrode being common to both transducers. Similarly, member 55 has disposed thereon electrode 58 and the aforesaid common electrode 57. Members 54 and 55 are oppositely polarized and are energized by application of a direct current control voltage from battery 17 through switch 49. Transducers 51 and 52 are fixedly mounted near opposite ends thereof by a clamp 61 which may be at the nodal point of the transducers. The electrodes 56 and 58 are provided with integral switch arm extensions 20*a* and 20*b*, similar to extension 20 shown in FIGURE 1. The tabs 32*a* and 32*b* function similarly to the single tab 32 in the switch of FIGURE 1. The switch arms 20*a* and 20*b* extend inwardly and have respective contacts 21 and 28, only one of which is visible in FIGURE 6. In response to a control potential from source 17 contacts 21 and 28 can be made to close from the normally open position or open from a normally closed position, depending upon the polarization of members 54 and 55, as well as upon the polarity of the direct current potential from the control source 17. Leads 33*a* and 33*b* attached to switch arms 20*a* and 20*b* are connected to a circuit which is to be switched. In switches of the type shown in FIGURE 6 where the two transducers move relative to one another, temperature compensation can be realized by polarization of transducers 51 and 52 in the same direction. This compensation comes about because one of the transducers will contract when subjected to a control potential while the other transducer simultaneously will expand upon application of said control potential. In contrast, where both transducers are oppositely polarized, both transducers will either contract or expand simultaneously upon application of a control potential. In such an arrangement, exposure to extreme temperature changes may cause accidental operation of the switch.

As in the case of the switch of FIGURE 5, the switch of FIGURE 6 includes two movable arms. Several transducer members may be used in the switch of FIGURE 6, and indeed in the switches of all the figures of the drawing, if greater sensitivity is desired; in such case, adjacent members are oppositely polarized.

FIGURE 7 discloses a switch assembly 10 using a split ring transducer 11 with a sealed reed type switch 65 extended more or less diametrically across the transducer. The transducer 11 includes the usual member 12 and electrodes 13 and 14 and differs from that shown in FIGURE 1 only in that the electrode 13 of FIGURE 7 has an integral tab 67 extending away from the end face 30 adjacent the outer rim of the transducer, rather than adjacent the inner rim, as in FIGURE 1. The reed switch 65 includes an elongated tube 70 of electrically insulating material, such as glass, having a movable reed or switch arm 72 and a stationary switch arm 74 partly enclosed therein. The inner ends of the switch arms 72 and 74 are juxtaposed near the free ends and carry respective switch contacts 76 and 77. The other ends of the switch arms 72 and 74 extend from opposite ends of the switch tube 70. The fixed switch arm 74 may be sealed by a conventional glass to metal sealing technique in one end of tube 70. The movable switch arm of said tube is mounted pivotally at the other end of tube 70. Details of two alternative means of pivotally mounting movable switch arm

72 are shown in FIGURES 9 and 10. The movable switch arm **72** may be attached to a flexible diaphragm **73** sealed at the end of the tube **70**, as indicated in FIGURE 9. Another approach is shown in FIGURE 10 wherein the movable switch arm **72** is mounted to a flexible bellows-like member **81**, which, in turn, is attached to an insulating disc **79** at the end of the tube. The end of tube **70** through which the movable arm **72** extends is bonded, as by an epoxy cement, to one end face of the split ring, for example, end face **24** of FIGURE 7. The end of tube **70** through which fixed switch arm **74** extends is insulatedly mounted from the member **12** by an insulating element **78** bonded, in turn, to electrode **14**. Leads **33** and **34** are attached to the ends of the switch arms, as shown in FIGURE 7, for connection to an external circuit in which switching is to be accomplished. When a direct current voltage of the correct polarity is applied between electrodes **13** and **14**, the split ring transducer **11** flexes and the end faces **24** and **30** move toward one another. In so doing, the tab **67** mounted on electrode **13** exerts a force adjacent the outer end of the movable switch arm **72**; this arm pivots about the flexible diaphragm (see either FIGURE 9 or FIGURE 10) and causes movement of the arm towards the fixed switch arm **74** until the two contacts **76** and **77** engage. The sealed switch of FIGURE 7 is not exposed to contamination or oxidation, and consequently, provides longer operation in some cases than the switch illustrates in FIGURES 1, 4, 5 and 6.

In FIGURE 8 the switch assembly **110** includes the enclosed reed type of switch, illustrated in FIGURE 7, mounted along the length of a gap in a split cylindrical transducer **111**. Transducer **111** includes a tubular member **112** carrying electrodes **113** and **114** on the inner and outer peripheries. The tubular body **70** of reed switch **65** is bonded at one end to end face **130** of transducer member **112** near one end of the gap. The fixed switch arm **74** extends through the tube **70** and has a lead **34** attached thereto for connection to an external circuit. The movable switch arm **72**, extending through a flexible member **77**, is bent over to engage the end face **124** of tubular member **112**. A lead **33** is affixed to the external portion of movable switch arm **72** for connection to the aforesaid external circuit. As shown in FIGURE 8, the outer end of switch arm **72** merely rests against end face **124**; however, if desired, the switch arm can be permanently attached to said end face. A source **17** of direct current potential is connected to the inner and outer electrodes **113** and **114** through a control switch **49**. Upon application of the control potential to electrodes **111** and **114**, the cylindrical transducer **111** undergoes flexural movement and end faces **124** and **130** may be made to move toward one another, assuming the proper polarization and polarity of direct current control voltage. This causes a force to be exerted upon the outer end of switch arm **72** and causes motion of the enclosed end of arm **72** about the flexible pivot such that the inner end of said arm and its contact **76** is moved into engagement with contact **77** on the inner end of fixed switch arm **74**.

As shown in FIGURE 11, the transducer assembly can be made up of several individual members arranged back to back with adjacent elements being of opposite polarity. The transducer assembly **211** of FIGURE 11, for example, includes a pair of transducer members **212*a*** and **212*b***. Member **212*a*** has an electrode **113** and a common electrode **157**, while member **212*b*** carries electrode **114** and the aforesaid electrode **157**. A source **17** of direct control potential is applied to both transducer members **212*a*** and **212*b*** through control switch **49**. The reed switch assembly **65** is similar to that of FIGURE 10, with the longitudinal axis of the tubular body **70** being more or less parallel to the length of the gap between the composite end faces. The outer end of the movable switch arm can be made to rest against the end faces of either or both members **212*a*** or **212*b*** of the components transducer **211**.

FIGURE 12 illustrates a switch assembly in the cylindrical transducer **111** disposed within a more or less cubical block **99** of electrically insulating material, such as plastic, and having an annular recess for receiving transducer **111**. Leads and terminal posts are provided which may be potted within the block **99**. The source **17** of direct current control potential is connected through control switch **49** to terminal posts **101** and **102**. Leads **103** and **104** from this terminal post are connected to the inner and outer electrodes **113** and **114** respectively. The ends of the switch arms **72** and **74** external to the tab **70** can be connected as shown in FIGURE 12 to the corresponding terminal posts **105** and **106**. A circuit to be switched is connected to terminal posts **105** and **106**. The lead **107** for connecting the end of the fixed switch arm **74** to terminal post **105** is shown in the dotted line as being encapsulated within block **99**, while the lead **108** for connecting the end of movable switch arm **72** to terminal post **106** is shown in a printed circuit deposited along the end face **124**, the top of cylindrical element **112** and the top of block **99**. The alternative methods of circuit connections are shown to illustrate possible methods of connection; for example, both leads **107** and **108** can be printed on the external portions of the transducer and the block, or both leads can be wires embedded in the block.

FIGURE 13 illustrates a switch similar to that shown in FIGURES 8, 11 and 12 wherein the contacts **221** and **228** are mounted directly to the end faces **124** and **130**, respectively, of the cylindrical transducer member **112**, rather than being enclosed within a tube **70** of a reed assembly **65** disposed in the gap of the split cylindrical member **112**. These contacts each may be provided with several individual wires, in the manner of a wire brush, so that positive contact between the two exposed contacts is assured. This type of switch can be immersed in oil. Although shown as part of a cylindrical switch assembly, it is possible to use this type of direct contact member in the split ring switches of FIGURES 1, 3 and 5.

FIGURE 14 discloses a switch assembly **310** using a discoidal transducer **311** which includes a transducer member **312** in the form of a disc and having opposite electrodes **313** and **314** which would be attached to opposite terminals of a direct current control potential source, as in previous embodiments. The disc **312**, when energized by the direct current control potential, will expand or contract radially. As shown in FIGURE 14, the device is adapted to expand when energized. The disc **312** is received in a split retaining ring **400** having a ledge **109** against which the disc **312** is seated. The end faces **424** and **430** at the ends of the split ring **400** form therebetween a gap. A fixed switch arm **425** carrying a contact **428**, visible in FIGURE 14, at the free end is electrically insulatedly mounted to the ring **400** by means of an insulating shim **426** bonded to ledge **109**. A movable switch arm **420** is bonded to the end face **424** of split retaining ring **400** adjacent the outer edge of the ledge **109**.

A projecting tab **432** which may be integral with the ledge **109** of retaining ring **400**, is bonded to movable switch arm **420** adjacent to the region of attachment of said switch arm to retaining ring **400**, but disposed radially inwardly from this region of support of switch arm **420**. The switch arm **420** carries a movable switch contact **421** (not visible in FIGURE 14) at the free end thereof. As the transducer is energized, the radial expansion of disc **312** allows the movable switch arm **420** to pivot about tab **432**. This produces the lever action previously described in connection with the device of FIGURE 4 and the movable switch arm **420** moves toward stationary switch arm **425** until contact **421** on the free end of arm **420** engages the contact **428** on stationary switch arm **425**. Leads **33** and **34**, attached to the ends of the respective switch arms **420** and **425**, provide means for connection to the external circuit to be switched.

The sealed switch sub-assembly **65** shown in FIG. 7 may be used in lieu of the exposed switch arms **420** and **425** in the device of FIGURE 414. In this case, the tubular body **70** of the reed switch sub-assembly **65** would be attached adjacent one end to one end face of the split retaining ring **400**, for example, end face **424** and an outwardly directed extension of ledge **109** of retaining ring **400** would be adapted to exert a force on the portion of the movable switch arm **72** outside the switch tube **70**. Radial deformation of the disc **311** would then result in relative motion of the end faces of the retaining ring **400** and causes movement of the movable and stationary switch arms.

While there has been described what is at present considered to be the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is therefore aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed:

1. A switch comprising a transducer member of a material which deforms when subjected to an applied electrical potential, said member being in the form of a split ring having opposed major faces and having juxtaposed end faces at the ends thereof forming therebetween a gap, a cylindrical assembly having a body portion enclosing two switch contacts mounted on respective switch contact arms, a first of said arms extending through one end of said body and insulatedly mounted to a portion of said ring diametrically opposite said gap, said first arm further being fixedly mounted to said one end of said body, a second of said arms extending through the other end of said body through a flexible diaphragm and pivotally mounted at the other end of said body for movement relative to the first of said arms, said switch body being affixed to one of the end faces of said member, said member element having electrodes attached to said opposed major surfaces, one of said electrodes having a projecting tab adjacent said other end face, the second of said arms being attached to said projecting tab, and means for applying a unidirectional potential to said electrodes to effect a change in said gap and a consequent motion of said movable switch contact arm relative to said fixed contact arm.

2. A switch comprising a transducer member of a material which deforms when subjected to an applied electrical potential, said member being in the form of a split cylinder having inner and outer opposed major faces and having juxtaposed end faces at the ends thereof constituting therebetween a gap, a cylindrical assembly having a body portion enclosing two switch contacts mounted on respective switch contact arms, a first of said arms extending through one end of said body and being fixedly mounted at said one end to said body, the second of said arms extending through the other end of said body through a flexible diaphragm and pivotally mounted at the other end of said body for movement relative to the first of said arms, said body being affixed to one of the end faces of said member, the second of said arms being in contact with the other of said end faces of said member, said member having electrodes attached to said opposed major faces, and means for applying a unidirectional potential to said electrodes to effect a change in said gap and a consequent motion of said movable switch contact arm relative to said fixed contact arm.

3. A switch as set forth in claim **2** wherein said assembly is mounted entirely within said gap with the longitudinal axis of said assembly substantially parallel with said end faces.

4. A switch comprising a transducer member of a material which deforms when subjected to an applied electrical potential, said member being in the form of a split ring having opposed major faces and having juxtaposed end faces at the ends thereof forming therebetween a gap, a cylindrical assembly having a body portion enclosing two switch contacts mounted on respective switch contact arms, a first of said arms extending through one end of said body and being fixedly mounted to said one end of said body, the second of said arms extending through the other end of said body through a flexible diaphragm and pivotally mounted at the other end of said body for movement relative to the first of said arms, said switch body being affixed to one of the end faces of said member, the second of said arms being movable with the other of said end faces of said member, said member having electrodes attached to said opposed major faces, and means for applying a unidirectional potential to said electrodes to effect a change in said gap and a consequent motion of said movable switch contact arm relative to said fixed switch contact arm.

5. A switch comprising a transducer member made of a material which deforms when subjected to an applied electrical potential, said member being in the form of a split ring having opposed major faces and having juxtaposed end faces at the ends thereof forming therebetween a gap, said member having electrodes attached to said opposed major faces, one of said electrodes terminating at one end thereof in an elongated flexural finger, said flexural finger forming a movable switch arm and being adjacent a first of said end faces but spaced therefrom to allow freedom of movement of said finger, the second of said end faces having an element projecting therefrom, said element being engageable with the flexural finger at a region intermediate the ends of said finger, means for applying a unidirectional potential to said electrodes to effect a change in said gap and consequent change in position of said finger.

6. A switch comprising a transducer member made of a material which deforms when subjected to an applied electrical potential, said member being in the form of a split ring having opposed major faces and having juxtaposed end faces at the ends thereof forming therebetween a gap, said member having electrodes attached to said opposed major faces, one of said electrodes terminating at one end thereof in an elongated flexural finger, said flexural finger forming a movable switch arm and being adjacent a first of said end faces but spaced therefrom to allow freedom of movement of said finger, the second of said end faces having an element projecting therefrom, said element being affixed to the flexural finger at a region intermediate the ends of said finger and means for applying a unidirectional potential to said electrodes to effect a change in said gap and consequent change in position of said finger.

7. A switch comprising a transducer member made of a material which deforms when subjected to an applied electrical potential, said means being in the form of a split ring having opposed major faces and having juxtaposed end faces at the ends thereof forming therebetween a gap, a switch arm attached at an end thereof directly to a first portion of one of said end faces, said one end face further including a tapered portion spaced from said switch arm, the other of said end faces having an element projecting therefrom, said element being engageable with the switch arm at a region spaced from the attached end of the switch arm, said member having electrodes attached to said opposed major faces, and means for applying a unidirectional potential to said electrodes to effect a change in said gap and consequent change in position of said switch arm.

8. A switch comprising a transducer member made of a material which deforms when subjected to an applied electrical potential, said member being in the form of a split ring having opposed major faces and having juxtaposed end faces at the ends thereof forming therebetween a gap, a switch arm mounted at an end thereof to one end of said end faces, the other of said end faces having an element projecting therefrom, said element being affixed to the switch arm at a region spaced from the attached end of the switch arm, said member having electrodes attached to said opposed major faces, and means for applying a unidirectional potential to said electrodes to effect a change in said gap and consequent change in position of said switch arm.

9. A switch comprising a transducer assembly including a pair of arcuate members made of a material which deforms when subjected to an applied electrical potential, said members being in the form of split rings, said split rings being back-to-back and having opposed major faces, said split rings further having juxtaposed end faces at the ends thereof forming therebetween a gap, a pair of switch arms, one of said switch arms being movable with one of the end faces of a first ring, the other of said switch arms being movable with one end face of the second ring, said rings being clamped, said members having electrodes attached to opposed major faces, and means for applying a unidirectional potential to adjacent electrodes to effect a change in said gap and consequent change in position of said switch arm.

10. A switch as set forth in claim 9 wherein said split rings are oppositely polarized.

11. A switch as set forth in claim 9 wherein said split rings are polarized in the same direction.

12. A switch comprising a transducer member made of a material which deforms when subjected to an applied electrical potential, said member being in the form of a split ring having opposed major faces and having juxtaposed end faces at the end thereof forming therebetween a gap, said member having electrodes attached to said opposed major faces, one of said electrodes having at each end thereof an extension forming an elongated switch arm, said switch arms intersecting one another and being pivotally mounted at the point of intersection, and means for applying a unidirectional potential to said electrodes to effect a change in said gap and consequent change in position of said pivotally mounted switch arms.

13. A switch comprising at least one discoidal transducer member of a material which deforms when subjected to an applied electrical potential, said member having electrodes attached to opposite surfaces thereof, a split retaining ring for receiving said discoidal member, one end of said ring having a movable switch arm supported from one region thereof, the other end of said ring carrying a projecting element engageable with the switch arm at a point spaced from the aforesaid region, means for applying the unidirectional potential to said electrodes to effect a radial deformation of said discoidal member, said retaining ring moving in response to said radial deformation to produce movement of said switch arm.

14. A switch comprising at least one discoidal transducer member of a material which deforms when subjected to an applied electrical potential, said member having electrodes attached to opposite surfaces thereof, a split retaining ring for receiving said discoidal member, one end of said ring having a movable switch arm supported from one region thereof, the other end of said ring carrying a projecting member engageable with the switch arm at a point spaced from the aforesaid region, a stationary switch arm insulatedly mounted to said retaining ring, and means for applying the unidirectional potential to said electrodes to effect a radial deformation of said discoidal member, said retaining ring moving in response to said radial deformation to produce movement of said movable switch arm relative to said first stationary arm.

15. A switch comprising a transducer member of a material which deforms when subjected to an applied electrical potential, said member being in the form of a disc, a split retaining ring for receiving said disc, said retaining ring having juxtaposed end faces at the ends thereof constituting therebetween a gap, a cylindrical assembly having a body portion enclosing two switch contacts mounted on respective switch contact arms, a first of said arms extending through one end of said body and being fixedly mounted at said one end of said body, the second of said arms extending through the other end of said body through a flexible diaphragm and pivotally mounted at the other end of said body for movement relative to the first of said arms, said body being affixed to one of the end faces of said retaining ring, the second of said arms being in contact with the other of said end faces of said retaining ring, said member having electrodes attached to said opposed major faces, and means for applying a unidirectional potential to said electrodes to effect a change in the gap in said retaining ring and a consequent motion of said movable switch contact arm relative to said affixed contact arm.

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