TACTILE KEYBOARD SWITCH ASSEMBLY WITH METALLIC OR ElASTOMERIC TYPE CONDUCTIVE CONTACTS ON DIAPHRAGM SUPPORT

Inventors: Gideon A. DuRocher; Daniel J. DuRocher, both of Mt. Clemens, Mich.


Filed: Oct. 31, 1973

U.S. Cl. 200/5 A; 200/159 B; 200/264
Int. Cl. H01h 13/70; H01h 1/02
Field of Search 200/1 R 5 R 5 A 83 N 200/86 R 86 A 159 R 159 B 262 264 267

References Cited
UNITED STATES PATENTS
2,040,919 5/1936 Caldwell 200/159 B
2,697,766 12/1954 Goldmuntz 200/83 N
3,643,041 2/1972 Jackson 200/5 A
3,668,337 6/1972 Sinclair 200/5 A
3,707,609 12/1972 Dapot et al. 200/5 R
3,742,157 6/1973 Leposavic 200/5 A
3,758,733 9/1973 DuRocher et al. 100/159 R X

ABSTRACT
A tactile switch plate for a keyboard comprises a non-conductive member sandwiched between a pair of conductors, the member having a planar body portion provided with a plurality of outwardly deformed carrier portions corresponding in number and spacing to the number and spacing of the keys of the keyboard. Each of the carrier portions is resiliently flexible for movement toward the plane of the body and each carrier portion carries a preferably elastomeric switching member that is adapted to bridge the conductors and establish an electrical circuit between the conductors. The plate and switching members preferably are produced by a molding process and the elastomeric switching members are cured by heat generated by an electrical current.

20 Claims, 10 Drawing Figures
TACTILE KEYBOARD SWITCH ASSEMBLY WITH METALLIC OR ELASTOMERIC TYPE CONDUCTIVE CONTACTS ON DIAPHRAGM SUPPORT

The invention disclosed herein relates to an electrical switch plate construction for use in connection with keyboards for calculators and the like having a plurality of keys movable between inactive and operating positions so as to make and break an electrical circuit. Keyboards of the type with which the invention is concerned are in wide usage in electrical and electronic calculators, computers, machine control consoles, and the like.

Keyboards of the kind to which the invention relates conventionally employ a plurality of depressible keys any one of which may be actuated so as to establish a circuit between a source of electrical energy and electrical apparatus that is responsive to the establishing of the circuit. In those instances in which the keys are manually manipulatable, it is desirable that the operator be able to sense the movement of each key to its operative position. The previously known keyboard constructions have relied largely upon the operator's sense of touch, hearing, or both, as a means of informing the operator of the actuation of the associated switch. One of the objections associated with previously proposed tactile sensing means is that the movable part of a switch may have some chattering-type movement which can result in unreliable electrical signals being generated.

A disadvantage of those switching devices which rely upon an audible signal to indicate energization of the electrical circuit is that the use of a number of such keyboards at one time in a confined space can generate an excessive and distracting amount of noise.

Known keyboard devices have other disadvantages. For example, some of the keyboards are so constructed that reliable operation of a switch depends upon the application of a force that is substantially along the longitudinal axis of a key. It is not always possible to assure the application of such a force, however, particularly when the keyboard is manually operated. Occasionally, therefore, an operator will depress a key in such a manner that the force is applied obliquely to the line of movement of the key with the result that a circuit is not completed. In addition, most of the known keyboards incorporate a large number of components for each switching mechanism as a consequence of which the cost of such switching mechanisms and the keyboard in which they are incorporated is excessive.

An object of this invention is to provide a switching construction for keyboards of the kind referred to and wherein the operation of the switching mechanism provides a positive, tactile sensation that may be virtually noiseless.

Another object of the invention is to provide a switching mechanism of the character described and which is operable under various conditions of force application.

A further object of the invention is to provide such a switching mechanism wherein there is a significant reduction in the number of parts heretofore required.

Another object of the invention is to provide a switching mechanism for a multiple key keyboard and wherein the operating characteristics of all keys are uniform.

A further object of the invention is to provide an improved method for establishing an electrically conductive path through a non-conductive member.

Other objects and advantages of the invention will be pointed out specifically or will become apparent from the following description when it is considered in conjunction with the accompanying drawings, in which:

FIG. 1 is an isometric view of a calculator having a keyboard of the kind with which the invention is adapted for use;

FIG. 2 is an exploded view of the parts of a switching mechanism constructed according to the invention;

FIG. 3 is an enlarged, transverse sectional view taken on the line 3—3 of FIG. 1;

FIG. 4 is a greatly enlarged view taken on the line 4—4 of FIG. 2;

FIG. 5 is a greatly enlarged view taken on the line 5—5 of FIG. 2;

FIG. 6 is a force versus travel graph of a typical switching operation.

FIG. 7 is a fragmentary, enlarged sectional view of a modification;

FIG. 8 is a fragmentary, enlarged sectional view of a typical mold in which a switchplate according to the invention may be formed;

FIG. 9 is a fragmentary, sectional view of a switchplate produced in the mold of FIG. 8; and

FIG. 10 is a fragmentary, sectional view of apparatus for curing switching members carried by the switchplate.

Tactile switching apparatus constructed in accordance with the invention is adapted for use in conjunction with a device such as an electrically operated calculator 1 having a base 2 that is fitted to a cover 3 having a depending skirt 4 embracing the base. The cover 3 has therein a plurality of spaced apart openings 5 in columns and rows and in each of which is accommodated a reciprocable key 6. Each key has flanges 7 engageable with the lower surface of the cover 3 so as to prevent withdrawal of the key from the cover. The cover also has a window opening 8 covered by a transparent pane 9 through which indicia (not shown) may be seen. The calculator 1 may have sufficient space between the cover and the base to accommodate logic circuit components and batteries (not shown) as usual. The construction of the calculator 1 as thus far described is conventional.

A switching assembly constructed in accordance with the invention is designed generally by the reference character 10 and comprises a pair of electrically conductive members 11 and 12 between which is sandwiched a switch plate 13. The conductive member 11 comprises a relatively rigid printed circuit board 14 of non-conductive material on the upper surface of which are a plurality of electrically conductive circuit elements 15 and a plurality of terminals 16. The conductive elements 15 may be coupled through the board 14 to conductive leads (not shown) on the lower surface of the board as is conventional and which, in turn, are coupled to the logic devices (not shown) for operating the indicia viewable through the window 9. The terminals 16 are adapted to be coupled to a source of energy such as one or more batteries (not shown).

The conductor 12 comprises a substrate or sheet 17 of flexible, non-conductive polyester or other suitable material on one side of which is a plurality of parallel strips 18 of electrically conductive material. The strips
are of such length as to span the length of each column of keys 6 and the number and spacing of the strips 18 correspond to the number and transverse spacing of the keys 6.

The switch plate 13 comprises a flat, plate-like body 19 formed of polycarbonate, polypropylene or other suitable thermoplastic, non-conductive material and is of such thickness as to be stiffer than the substrate 17. The body, however, does have some inherent resilience. The body 19 is a one-piece molded member and is substantially planar except for a plurality of spaced apart carriers or dimples 20 which are deformed outwardly from the plane of the body. Each carrier, however, is completely surrounded by a flat portion of the body. The number and spacing of the carriers correspond to the number and spacing of the keys 6.

Each carrier 20 is coniform and has a web 21 terminating adjacent the apex in an annular enlargement 22 which surrounds an opening 23. The web preferably is continuous, but may be spider-like if desired. Fitted into each opening 23 is a switching pad or member 24 which protrudes beyond both ends of the opening 23 so as to be exposed on both sides of the carrier. The switching member is composed of a non-conductive elastomer, such as silicone rubber, throughout which is dispersed a quantity of discrete, electrically conductive particles. The silicone rubber may be produced, for example, from a mixture of 4404 silicone resin (General Electric Company, Schenectady, New York) and "Varox" catalyst (R.T. Vanderbilt Chemical Co., New York City), but other resins and catalysts also may be used.

Each switching member 24 may be either normally conductive or normally non-conductive, depending upon the size and quantity of particles contained therein and depending upon whether such switching member is molded under a compressive force or under atmospheric pressure. In any case, compression of a switching member 24 will cause a sufficient number of particles to move into engagement with one another as to establish an electrically conductive train of particles through the switching member.

At one end of the body 19 is a plurality of openings 25 each of which is filled with an elastomeric pad or member 26 corresponding in all respects to the switching members 24.

The particles contained in the members 24 and 26 preferably comprise spheres of a base metal, such as copper, coated with a noble metal, such as silver, which has a low resistance and an electrically conductive oxide. The conductivity of the particles thus will correspond to the conductivity of the coating or, stated differently, the electrical resistance of the members 24 and 26 will correspond to the resistance of the coating on such particles.

The size of the particles is so selected as to be capable of accommodating a predetermined current, such as that normally encountered in the electrical circuitry of the apparatus. Preferably, the size of the particles is between 3 and 8 mils in diameter, although other size particles may be utilized if desired.

To condition for operation the apparatus thus far described, printed circuit board 14 to which is coupled the logic circuitry is secured to the base member 2 with the circuit elements 15 and the terminals 16 uppermost. The terminals 16 are connected through the board 14 to a D.C. battery carried in the calculator or to a wire assembly which may be connected to a source of A.D. energy. The switch plate 13 then is placed atop the board 14 with the carriers 20 uppermost and with the pads 26 so arranged that they overlie and engage the terminals 16. The plate 13 is secured to the base by screws (not shown) or the like so that the members 26 are maintained under compression sufficient to render them conductive. The carriers 20 will overlie the circuit elements 15 and the switching members 24 will overlie, but be spaced from, predetermined portions of such circuit elements 15.

The flexible printed circuit 12 then is placed atop the plate 13 in such manner that the conductive strips 18 overlie and confront he switching members 24 and the conductive pads 26. The cover 3 then is fixed over the base 2 and is screwed or otherwise fixed to the base. As is illustrated in FIG. 3, the inner surface of the skirt 4 has a shoulder 27 which overlies the printed circuit 12 so as to cause the marginal edges of the latter to be clamped forcibly against the plate 13, thereby constantly maintaining the pads 26 and the confronting ends of the conductive strips 18 under compressive force.

When the parts are assembled in the manner disclosed, each key 6 will overlie a carrier 20 and will bear directly against the upper, non-conductive surface of the printed circuit member 12. The conical configuration of each carrier 20 will maintain its associated key 6 in its projected position in which the flange 7 engages the lower surface of the cover 3, as is shown in FIG. 3. Each key may be depressed, however, as is permitted by the flexibility of the web 21 of the associated carrier 20, whereupon the associated switching member 24 may be moved into engagement with the associated circuit element 15 so as to establish an electrical path from the battery, the associated conductive strip 18, and the circuit element 15 to effect operation of the appropriate electrical component of the logic circuit.

The presence of the conductive particles in the elastomeric switching members 24 causes the surface thereof to be slightly abrasive or gritty. As a consequence, compression of the members 24 between the members 15 and 18 causes scrubbing of such members, thereby avoiding the likelihood of non-conductivity due to oxidation of the members 15 and 18.

As has been stated hereinbefore, the thickness of the material constituting the body 19 is such that the latter is relatively stiff. As a consequence, it resists deformation. Although the web 21 of each carrier 20 is formed of the same material as the body 19, the web preferably has a thickness less than that of the body so as to be resiliently flexible as compared to the body itself. Thus, upon the application by a key 6 of a downward force F on a switching member 24, the switching member will move or travel toward the plane of the body 19. As the switching member 24 moves toward the plane of the body, the radius of the web 21 must shorten and, as a consequence, the web 21 must buckle or distort. The construction of each carrier 20 is such that, as the lower surface of its switching member 24 approaches the level of its associated circuit element 15, the web 21 is distorted so as to assume an undulating configuration, as indicated in dotted lines in FIG. 4. Such distortion occurs very rapidly and produces a tactile sensation which the operator may sense through his finger. Since the web 21 is composed of a plastic material, rather than metal, the noise associated with such distor-
Following the distortion of the web 21, the force required to move the switching member 24 into engagement with the associated circuit element 15 is much less than that required to effect distortion of the web. Therefore, the switching member may be moved into engagement with the circuit element quite easily, thereby minimizing the likelihood of chattering movement of the switching member.

The force required to move a switching member into engagement with its associated circuit element 15 is stored in the distorted, resilient web 21. Consequently, when the force F is removed, the resiliency of the web 21 enables its automatic return to its original position. Return of the web to its original position breaks the circuit between the conductive elements 15 and 18 and restores the depressed key to its projected position.

FIG. 6 illustrates in graphic form the foregoing force/travel characteristics of a typical carrier 20 when the associated switching member 24 moves through one cycle of operation. In the graph segment a indicates that a force of about 0.66 pound must be applied to the carrier 20 via a key 6 to initiate distortion of the web 21 and, when the web commences its distortion, the switching member 24 will have moved toward the plane of the body 19 a distance of about 0.006 inch, as is indicated by the point b. As the web 21 distorts, the force required to exert on the switching member to effect its engagement with the associated switch element 15 is reduced to about 0.16 pound, as is indicated by the segment c, and the additional movement of the switching member toward the circuit element 15 amounts to about 0.001 inch, as is indicated by the point d. Thereafter, the operator may exert whatever force he desires (within reasonable limits) to maintain the switching member 24 in conductive engagement with the circuit element 15. It will be understood that the movement of switching member 24 into engagement with the circuit element 15 will be effected by a smooth application of a downward force on a key 6. However, the graph illustrates the variations in force accompanying distortion of the web 21 which produces the desired tactile sensation.

When the operator removes his finger from the depressed key, the resilient web 21 immediately commences its recovery to its initial conical configuration due to the energy stored in the distorted web, thereby resulting in a lessening of the force to which the web 21 is subjected, as is indicated by the segment e. At the point at which the distorted web commences its restorative action, the web is subjected to an increasing force, as is indicated by the segment g, until such time as the web is fully restored, as indicated by the point h, whereupon the force to which the web is subjected diminishes rapidly as indicated by the segment i.

An important advantage of the invention is that, for any given switch plate 13, each carrier requires the application of the identical force to effect its switching function. As a consequence, the operating characteristics of each key of the entire keyboard will be the same. Such uniformity of key-to-key operation minimizes errors in the operation of the calculator or the like.

Among the advantages of the invention are the ease and simplicity by means of which the operating characteristics of a given switch plate 13 may be varied. Since each body 19 is a one-piece, molded member, the mold for a particular body may be so constructed as to produce webs of any desired thickness. The thickness of a web 21 determines, to a large extent, the force which must be applied thereto to effect its distortion and, in general, the thicker the web the greater must be the applied force. In addition, the thickness of a web, together with the material from which it is made, has a direct relationship upon the tactile sensation and the noise of operation. That is, the thicker the web, the greater the tactile sensation and the greater the noise.

As a consequence, the tactile sensation and the noise of operation of a switch constructed in accordance with the invention may be varied within wide limits.

A switching assembly constructed according to the invention effectively overcomes the aforementioned problem associated with the application of an oblique force on an operating key. If the applied force has a component sufficient to depress the key, the key will effect deformation of the associated carrier 20 inasmuch as the transmission of force from the key to the carrier occurs at substantially a point contact due to the conical configuration of the carrier.

Although it is preferred that the members 24 and 26 be elastomeric, they could be formed of other materials. For example, FIG. 7 discloses a switch plate 19a identical in all respects to the switch plate body 19 except that the switching member 24a is a conductive, metallic rivet. A similar rivet could be fitted into each of the openings 25.

The body 19 of a switch plate 13 according to the invention preferably is molded in a mold 30 which, as is illustrated in FIG. 8, has a base 31 on the upper surface of which is a plurality of upstanding conical projections 32 corresponding to the configuration of the carriers 20 except that at the apex of each projection 32 is a cylindrical pin 33. Adapted to mate with the mold base 31 is a cover 34 which has in its lower surface a plurality of recesses 35 corresponding in number and spacing to the projections 32. At the base of each recess is a socket 36 that is adapted to receive the pin 33 of the associated projection 32. The base also carries adjacent one end thereof a plurality of upstanding pins 33a and the cover has a corresponding number of sockets 36a.

At the marginal edges of the mold halves 31 and 34 are ribs 37 which space the confronting surfaces of the mold members so as to define therebetween a cavity 38 which corresponds to the shape and thickness of the body 19 that is to be molded. Suitable openings (not shown) are provided in communication with the cavity 38 for the admission of a liquid thermoplastic material so as to enable the body 19 shown in FIG. 9 to be molded.

The molded body 19 produced by the mold 30 has the webs 21, the enlargements 22, and the openings 23 and 25, but none of the openings at this time contains a switching member. If the metal switching member 24a is to be utilized, the molded body 19 is presented to a riveting machine of conventional construction wherein a rivet 24a is fitted into each opening 23 and 25.

In practicing the preferred method, use is made of a fixture 39 having a base 40 and a cover 41. The base 40 of the fixture has a plurality of openings 42 therein corresponding to the number and spacing of carriers 20 and in each opening 42 is secured an electrically non-conductive post 43 having an upper surface 44 that
corresponds to the contour of the lower surface of the carrier 20. Each post 43 supports an electrode 45 having a concave upper surface 46 in register with the opening 23 of the carrier 20. The fixture cover 41 has a number of openings 47 corresponding to the number of openings 42 and in each of which is secured a non-conductive post 48 having a lower surface 49 which corresponds to the contour of the upper surface of the carrier 20. Each post 48 carries an electrode 50 having a concave lower surface 51 which registers with the opening 23.

The fixture base 40 has openings 52 corresponding to the number and spacing of the conductive members 26 and the cover 41 has similar openings 53. In each of the openings 52 is a non-conductive post 54 and a similar post 55 is fitted into each of the openings 53. Each post 54 has an electrode 56 having a concave upper surface 57 and each post 55 has a similar electrode 58 having a concave lower surface 59.

Following the molding of a body 19 the latter is placed atop the fixture base 40 so that the carriers 20 overlie the posts 43 with the openings 23 and 25 in register with the electrodes 45 and 56, respectively. A putty-like module composed of an uncured mixture of silicone resin, catalyst, and electrically conductive particles is then introduced into each of the openings 23 and 25 and in such quantity that the module occupies not only the corresponding openings, but also engages the concave surfaces 46 and 57 of the respective electrodes 45 and 56 and projects above the upper surface of the body 19. Thereafter, the upper fixture half 41 may be lowered so as to overlie the body 19 with the concave surfaces of the electrodes 50 and 58 engaging the upper surfaces of the uncured modules. The halves 40 and 41 of the fixture 39 are then clamped against the body 19 so that the modules are subjected to sufficient compression to cause the particles in the modules to establish an electrically conductive path through each module.

In the preferred method, the modules are cured to form the switching members 24 and 26 by the heat of an electric current that is passed in series through each module. This procedure may be effected by connecting one end of a source of direct current electrical energy E through a switch 60 to each of the electrodes 45, 50, 56, and 58 in a series circuit so that, upon closing of the switch 60, current will pass through each of the electrodes in turn.

The current selected for the curing of the modules will depend upon a number of factors, such as the curing time and temperature of a specific resin and catalyst, the number and size of modules to be cured, and the size and conductivity of the conductive particles contained in the modules. Modules containing between about 80–93 percent (by weight) of 3–8 mil diameter silver coated copper particles and having a diameter of about 0.125 inch and a thickness of about 0.06 inch successfully have been cured by passing therethrough a direct current of between 25–28 amperes for about 12 seconds. Following curing of the modules to form the switching members 24 and 26, the fixture 39 may be opened and the completed switch plate 13 removed.

It is not essential that the modules constituting the switching members 24 and 26 be cured by the passage of current therethrough. It is possible to effect curing of the modules by heating the entire fixture to the curing temperature of the resin and catalyst and maintaining the temperature for the prescribed curing time. The electrical current curing process, however, is considerably faster and requires the use of considerably less heat energy.

In many instances the curing temperature of elastomeric modules is higher than the liquefication temperature of the material from which the body 19 is composed. Inasmuch as the body 19 is clamped within a fixture having confronting surfaces corresponding to the surfaces of the body, however, any liquefaction of the body 19 is not a consequence inasmuch as the liquified material will solidify once the application of heat terminates. Liquefaction of the material of the body 19 adjacent the openings 23 and 25 may be advantageous in the establishment of a strong, adhesive bond between the switching members and the material of the body.

Although the methods herein described are directed primarily to the production of a tactile switching member, it should be understood that such methods are applicable to the provision of an electrically conductive path through an non-conductive member.

The disclosed apparatus and methods are representative of presently preferred forms thereof, but are intended to be illustrative rather than definitive of the invention. The invention is defined in the claims.

We claim:
1. A switch plate adapted for use in an electrical switch for making and breaking an electrical circuit between a pair of conductors, said switch plate comprising a body having a substantially planar portion surrounding a carrier portion extending outwardly of and to one side of the plane of said body portion; and a switching member carried by said carrier portion and normally occupying a position spaced from said plane, said carrier portion being formed of a stiff material that is sufficiently resilient to enable said switching member to be moved from its normal position toward said plane, the distance between said plane and said switching member when the latter is in its normal position being such that said carrier portion buckles as said switching member approaches said plane and produces a tactile sensation, and the resilience of the material of said carrier portion constantly tending to restore said switching member to its normal position.
2. A construction according to claim 1 wherein said switching member extends through said carrier portion and is exposed on opposite sides of the latter.
3. A construction according to claim 2 wherein said carrier portion is conform in configuration.
4. A construction according to claim 3 wherein said switching member is located at the apex of said carrier portion.
5. A construction according to claim 1 wherein said switching member normally is conductive.
6. A construction according to claim 1 wherein said switching member normally is non-conductive and is rendered conductive in response to the application thereof of compressive force.
7. A construction according to claim 1 wherein said switching member comprises a pad of resilient, non-conductive material throughout which is dispersed a plurality of discrete, electrically conductive particles.
8. A construction according to claim 1 wherein said switching member comprises an electrically conductive metallic member.
9. In a key operated device having spaced apart electrical conductors and a plurality of movable, spaced
apart operating keys, the combination of a tactile switch plate underlying said keys and comprising a non-conductive, substantially planar body having a plurality of spaced apart carrier portions extending outwardly of and to one side of the plane of said body, the number and spacing of said carrier portions corresponding to the number and spacing of said keys, and a switching member carried by each of said carrier portions adapted to bridge selected ones of said conductors and normally occupying a position spaced from said plane, each of said carrier portions being formed of a still material that is sufficiently resilient to enable the associated switching member to be moved from its normal position toward said plane and into bridging engagement with the selected conductors in response to corresponding movement of the associated key, the distance between said plane and each of said switching members when the latter is in its normal position being such that the associated carrier portion buckles as the switching member approaches said plane and produces a tactile sensation.

10. The construction according to claim 9 wherein the resilience of the material of each of said carrier portions constantly tends to return the latter to its normal position following movement thereof toward the plane of said body.

11. The construction according to claim 9 wherein each of said switching members extends through its associated carrier portion and is exposed on opposite sides of the latter.

12. The construction according to claim 9 wherein each of said carrier portions is conform in configuration.

13. The construction according to claim 12 wherein each of said switching members is located at the apex of its associated carrier portion.

14. The construction according to claim 9 wherein each of said switching members normally is conductive.

15. The construction according to claim 9 wherein each of said switching members normally is non-conductive and is rendered conductive in response to the application thereto by its associated key of compressive force.

16. The construction according to claim 9 wherein each of said switching members comprises a pad of resilient, non-conductive material throughout which is dispersed a plurality of discrete, electrically conductive particles.

17. A construction according to claim 9 wherein each of said switching members comprises an electrically conductive metallic member.

18. The construction according to claim 9 wherein said body is interposed between said conductors.

19. The construction according to claim 18 wherein at least one of said conductors occupies a position between said keys and said body.

20. The construction according to claim 19 wherein said one of said conductors comprises a flexible printed circuit.