A touch sensitive electronic switch which has no moving parts and is actuated by the skin resistance of an operator causing a lowering of D.C. resistance across the face of the switch is disclosed. The electronic switch, in the preferred embodiment shown, includes three electrodes spaced and arranged with respect to each other upon an insulator. The second electrode is laterally spaced and insulated from the first electrode and arranged around and about the first electrode with the level of the top surface of the second electrode rising above the level of the top surface of the first electrode. The third electrode is laterally spaced and insulated from one electrode and vertically spaced from the other electrode to provide a conductive electrical shielding electrode between the first and second electrodes. The first and second electrodes are exposed to the finger of an operator upon the top surface of the insulator in a manner that the operator's finger bridging between the first and second electrodes allows a direct current path to be set up laterally between the first electrode and the second electrode to thereby provide an activation of the switch through a lowering of the D.C. resistance across the face of the switch. When the operator's finger is removed, the shielding effect of the third electrode prevents any leakage currents from flowing between the first electrode and the second electrode and establishing such a direct current path.

4 Claims, 5 Drawing Figures
TOUCH SENSITIVE ELECTRONIC SWITCH

CROSS REFERENCES

This invention is an improvement upon the subject matter disclosed and claimed in an application for patent filed in the name of Willis A. Larson on July 9, 1971, Ser. No. 161,948, which is a continuation of application Ser. No. 865,760, filed Oct. 13, 1969 (hereinafter referred to as the "original application"). The present application is further an improvement upon the subject matter disclosed and a companion application to the applications for patent filed on Nov. 16, 1971 by Willis A. Larson and Raymond M. Warner, Jr., Ser. No. 199,227, entitled "Composite D.C. Amplifier For Use With A Touch Sensitive Electronic Switch;" Willis A. Larson, Ser. No. 199,226, entitled "Touch Sensitive Electronic Switch;" Willis A. Larson and Arthur Kimmell, Ser. No. 199,384, entitled "Touch Sensitive Electronic Switch;" and Willis A. Larson, Ser. No. 199,195, entitled "Touch Sensitive Electronic Switch" (hereinafter referred to as the "companion applications").

BACKGROUND

This invention relates generally to electronic switching and more specifically to a touch sensitive electronic switch which has no moving parts and is actuated by the skin resistance of an operator lowering the D.C. resistance across the face of the switch.

In the above referenced to original and companion applications, the problem of avoiding current leakage between the operative electrodes of a touch sensitive electronic switch were discussed and solutions provided. The present invention offers another solution which eliminates the problem of undesired activation due to current leakage between the operative electrodes of the electronic switch.

SUMMARY

In summary, a preferred embodiment of the present invention eliminates the problem of undesired activation due to current leakage between the operative electrodes of the electronic switch by providing, in the preferred embodiment, a first electrode immovably arranged upon an insulator and a second electrode also immovably arranged upon an insulator. The second electrode is further arranged around and about and laterally spaced and insulated from the first electrode. A third electrode is also immovably arranged upon the insulator in a spaced and insulated relationship with both the first and second electrodes and laterally spaced from the first electrode and vertically spaced from the second electrode. The first and second electrodes are exposed to the finger of an operator upon the top surface of the insulating media in a manner that the operator's finger bridging between the second electrode and the first electrode allows a direct current path to be established laterally between the second and the first electrodes to thereby provide an actuation of the switch through a lowering of the D.C. resistance across the face of the switch. When the operator's finger is removed, the shielding effect of the interposed third electrode prevents any leakage currents from flowing between the second electrode and the first electrode and establishing such a direct current path.

It is thus a broad object of the present invention to provide a novel touch sensitive electronic switch.

It is a further object of the present invention to provide such a switch having extremely low leakage currents between electrodes to thus maintain the integrity of the switch in the OFF condition.

It is a further object of the present invention to provide such a switch where an electrode acts as a shield to prevent a flow of leakage current between other electrodes.

It is a further object of the present invention to provide such a switch which may be more easily fabricated than switches known heretofore.

These and further objects and advantages of the present invention, including those set out in the original and companion applications, will become clearer in the light of the following detailed description of an illustrative embodiment of this invention described in connection with the drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a top view of a preferred embodiment of a touch sensitive electronic switch according to the present invention.

FIG. 2 shows a cross-sectional view of a touch sensitive electronic switch according to section line 2—2 in FIG. 1.

FIGS. 3 and 4 show simplified top views of various components of the touch sensitive electronic switch according to the present invention which are useful in explaining its fabrication.

FIG. 5 shows a schematic representation of electronic circuitry for use with the touch sensitive electronic switch of the present invention.

Where used in the various Figures of the drawing, the same numerals designate the same or similar parts. Furthermore, when the terms "right," "left," "front," "back," "vertical," "horizontal," "right edge," "left edge," "right side," "left side," "top," "bottom," and similar terms are used herein, it should be understood that these terms have reference only to the structure as shown in the drawings as they would appear to person viewing the drawings, and are utilized only to facilitate describing the present invention.

DESCRIPTION

In FIGS. 1 and 2, a touch sensitive electronic switch, generally designated 30, is shown. Switch 30 includes a square of insulating media or insulating material 38 which can be conventional printed-circuit board material. Insulator 38 includes a flat or planar top surface or face 39 and a bottom surface or face 40.

Insulator 38 supports supply conductor or electrode 42 including a digitated array of nine fingers commonly designated 44 which extend across the top face or switch face 39 of insulator 38 from top to bottom as viewed in FIG. 1. A conductive trace 48 positioned at the top edge of switch face 39 perpendicularly to the supply fingers 44 interconnects the supply fingers to form supply electrode 42.

Insulator 38 also supports an input conductor or electrode 50 which includes a digitated array of eight fingers, commonly referred to as 52, which extends across the switch face 39 from bottom to top as viewed in FIG. 1. Input fingers 52 are arranged between supply
fingers 44 and in particular are arranged with one input finger positioned between each two supply fingers. A conductive trace 56 arranged on the bottom edge of switch face 39, as viewed in FIG. 1, perpendicularly to the input fingers 52 interconnects the input fingers to form input electrode 50.

Thus, supply electrode 42 and input electrode 50 take the form of an array of interlaced or interdigitated components including fingers extending from an edge of switch face 39 towards one another.

Insulator 38 also supports a reference, common, or ground conductor or electrode 58. Ground 58 also includes a digitated array of nine fingers arranged vertically below and in the same configuration as supply fingers 44. A conductive trace 60 forms a rightward extension of the right-most finger 59 of ground electrode, as shown in FIGS. 1 and 2, to thus extend to the right-most edge of switch face 39. Ground electrode 58 is insulated from supply electrode 42 by an insulator layer 61, such as mylar, which insulator 61 is formed in the pattern of supply electrode 42 and ground electrode 58, as will be explained further hereinafter.

In fabricating the preferred embodiment of electronic switch 30, top surface 39 of insulator 58 is first entirely clad with a conductor, such as one ounce nickel, in a fashion conventional for the fabrication of standard printed-circuit boards. In fact, a multitude of switches such as switch 30 shown in the figures may be fabricated simultaneously and later separated. In this manner, not only can multiple and thus rapid fabrication be had, but conventional registration techniques such as pins projecting from a jig can control the registration of the various layers as will be explained hereinafter.

Assuming multiple fabrication and a projecting pin registration system, a conventional photographic resist material is applied over the entire surface of the conductor applied to top surface 39 of insulator 58; the photographic resist material is photographically exposed in the pattern of input electrode 50 and ground electrode 58; and insulator 38 is removed from the photographic jig, and the conductive coating is conventionally etched to form the pattern of input electrode 50 and ground electrode 58. FIG. 3 shows switch 30 of the present invention at this stage of fabrication with the number of fingers shown reduced for simplicity.

The next fabrication step uses a sheet of insulation material, such as mylar, completely coated on one side with a conductive material such as one ounce nickel in a manner to bond the nickel to the mylar. A sheet of adhesive is placed over the partially completed switch 30 of the present invention such as is shown in FIG. 3, and the mylar and nickel combination sheet is placed over the adhesive with the nickel side vertically upward. The mylar and nickel combined sheet is then firmly bonded to the partially completed switch 30. Then, a photographic resist material is applied to the exposed nickel surface, and the array of switches 30 of the present invention is returned to the photographic jig and realigned upon the conventional projecting pins. This allows the substantially exact registration of the supply electrodes 42 over ground electrode 58 as will now be explained.

Next, the exposed nickel surface is photographically exposed in the pattern of supply electrode 42, which is identical to the pattern of ground electrode 58 with the exception of the elimination of conductive trace 60. The supply electrode 42 is then conventionally etched from the exposed nickel material upon mylar sheet 61 to form supply electrode 42, such as is shown in FIG. 4.

Next, with the supply electrode 42 forming the resist, portions of mylar sheet 61 not protected by supply electrode 42 are dissolved by a solvent to leave the mylar insulator 61 between supply electrode 42 and ground electrode 58.

Thus, digitated pattern of ground electrode 58, portions of mylar sheet 61, and supply electrode 42 may be fabricated in a vertical arrangement of substantially identical registration with mylar sheet 61 insulating supply electrode 42 from ground electrode 58.

The overall arrangement of the three electrodes 42, 50, and 58 of the electronic switch 30 of the present invention may now be explained. As is shown in the Figures, input electrode 50 is laterally immovably arranged with insulator 38, with a top surface of input electrode 50 exposed to the finger of an operator upon the top surface of insulator 38. Supply electrode 42 is also laterally immovably arranged with the insulator 38 and with input electrode 50, and is arranged laterally around and about, spaced, and insulated from input electrode 50 in a manner to expose the top surface of supply electrode 42 to the finger of the operator upon the top surface of its surrounding insulating material.

The level of the top surface of supply electrode 42 is further arranged above the level of the top surface of input electrode 50 in a manner that the finger of the operator touches supply electrode 42 before contact is made between the finger and input electrode 50 to thereby allow good contact of the operator’s finger with supply electrode 42 before contact is made with input electrode 50 and thereby allow the harmless grounding of the switch shall be excited by an alternating voltage injected from an external source into an operator’s body as also explained in the original and companion applications. This arrangement of electrodes also allows a direct current path to be set up laterally between the input electrode 50 and the supply electrode 42 as soon as the finger of the operator touches the input electrode 50.

Ground electrode 58 is also laterally immovably arranged with its surrounding insulating media and with the input and supply electrodes 42 and 50. Ground electrode 58 is further arranged electrically between the input and supply electrodes 50 and 42 and is insulated from both electrodes as a conductive electrical shield electrode allowing leakage current which could otherwise flow between the input electrode 50 and the supply electrode 42 to be conducted to a reference point through the ground electrode 58 to thus aid in preventing the flow of leakage current between input electrode 50 and supply electrode 42 which would otherwise tend to set up a non-actuated direct current path from the input electrode to the supply electrode. Thus, a non-actuated direct current path between the electrodes is one such as may be caused by leakage current in the switch and not by a touching of the switch face by the operator’s finger or other external cause.

Wrap-around connections between conductive traces 60, 48, and 56 on the top side 39 of insulator 38 to other conductors on the bottom side 40 of insulator 38 may also be fabricated as described in application.
Ser. No. 199,195, or plated through holes, or other connection may be fabricated to allow electrical connection between conductive traces 60, 56, and 48 on the top face 39 of insulator 38 and conductors on bottom face 40 of insulator 38. It is to be noted that the height, spacing and other requirements of face configurations according to the original and companion applications can thus be adhered to by the switch 30 of the present invention. Further, using switch 30 as described herein, the problems described in application Ser. No. 199,195 in allowing an operator's finger to contact supply and input electrodes 42 and 50 and ground electrode 58 may be completely eliminated since ground electrode 58 is beneath one of the electrodes 42 and 50 rather than laterally beside the electrodes 42 and 50.

Further, because of the positioning of ground electrode 58, the critical nature of the lateral spacing between electrodes 42 and 50 can be reduced and they may be more easily fabricated.

Now that the arrangement and fabrication of switch 30 of the present invention has been explained, it will be clear to those skilled in the art that it may be connected with electronic circuitry such as that shown in the original and companion applications, or other circuitry. For clarity, the manner of connection to the circuitry shown in the companion applications is set out below in the description of FIG. 5.

In FIG. 5, switch face 39 is shown in schematic form with supply electrode 42, input electrode 50, and ground electrode 58 also schematically represented.

Input electrode 50 is connected by a lead 71 to input 72 of a composite amplifier, generally designated 74, including outputs 76 and 78. Output 76 is connected to a first terminal 80 of a D.C. voltage source or supply through resistor 82 representing an electrical load. Supply terminal 80 is also connected to a supply electrode 42 through a lead 84. Output 78 is connected to a second supply terminal 86 of the D.C. voltage supply through a connection 88. Terminal 86 is further connected to ground electrode 58 by a connection 90. The D.C. voltage source, not specifically shown, includes the first and second terminals 80 and 86, and provides direct current to amplifier 74.

As shown in FIG. 5, terminal 86 is a common, ground, or reference terminal, and terminal 80 is of a positive D.C. voltage differing from the voltage at 86.

Input 72 to composite amplifier 74 is connected to input 92 of a first amplifier 94 through a buffer amplifier 96. First amplifier 94 further includes two outputs in the form of junction points 98 and 100. A current limiting resistor 102 is connected between junction point 98 and supply terminal 80, and a leakage prevention resistor 104 is connected between junction point 100 and supply terminal 86. Junction point 100 is further connected to an input junction point 106 of a second amplifier 108 through a lead 110. Second amplifier 108 includes an output junction point 112 connected to an input junction point 114 of a third amplifier 116 by a lead 118 and to supply terminal 86 by another leakage prevention resistor 119. Second amplifier 108 further includes output junction point 120 connected to supply terminal 80 by a current limiting and parasitic oscillation reducing resistor 122. Third amplifier 116 includes an output junction point 124 connected to output 76 of amplifier 74 and an output junction point 126 connected to output 78 of amplifier 74.

Buffer amplifier 96 includes a base current limiting resistor 128 connected between input 72 and the base of an NPN transistor 130. Transistor 130 has its emitter connected to supply terminal 86 and its collector connected to input junction point 92 of first amplifier 94.

First amplifier 94 includes PNP transistor 132 having its base connected to junction point 92, its emitter connected to junction point 98, and its collector connected to junction point 100.

Second amplifier 108 includes two amplifying stages in the form of NPN transistors 134 and 136 connected in a Darlington type arrangement. First Darlington transistor 134 has a base connected to junction point 106, a collector connected to supply terminal 80 through another current limiting and oscillation reducing resistor 138. The emitter of transistor 134 provides an output current to the base of the second Darlington transistor 136 through junction point 140. Second Darlington transistor 136 has its emitter connected to junction point 112, and its collector connected to junction point 120.

A leakage prevention resistor 142 is connected between junction point 140 and supply terminal 86.

Third amplifier 116 includes NPN transistor 144 with its base connected to junction point 114, its collector connected to junction point 124, and its emitter connected to junction point 126.

OPERATION

Generally, in operating the touch sensitive electronic switch 30 shown in the Figures, the finger of an operator is placed upon the switch face 39, for example as shown by the finger portion 144 shown in FIG. 2. The electrical skin resistance of the operator causes a direct current path to be set up between input electrode 50 and supply electrode 42 to thus cause a small current to flow between these electrodes. The current flowing is generally in the nanoampere range (30–300 nanoamperes) with normal skin resistances and supply voltages of approximately 5 volts. This D.C. input current is amplified by the various stages of composite amplifier 74 shown in FIG. 5 to a point where output transistor 144 saturates and approximates an electronic switch in the closed ON condition to the electrical load 82 also connected across supply terminals 80 and 86. When the operator's finger 144 is removed from switch 30, the characteristics of the switch prevent input current from reaching input 72 of composite amplifier 74 and rapidly render the amplifying stages to and including output transistor 144 nonconducting. Thus, with the operator's finger removed from switch 30, composite amplifier 74 appears as an electrical switch in an open of OFF condition to load 82, and no current is allowed to flow in the electrical load.

In particular, grounding electrode 58 is connected to a reference point within direct current amplifier 74. That is, ground electrode 58 is connected to the lowest potential point in the electronic circuit to which the input electrode 50 and supply electrode 42 are connected. By its interposition between the input electrode 50 and the supply electrode 42, leakage current attempting to flow between the input electrode 50 and the supply electrode 42 first encounters the conductive
electrical shielding effect of ground electrode 58 and is conducted to such reference or ground. Thus, the electrical shielding of ground electrode 58 prevents a flow of leakage current between the input electrode without actuation of the switch by the finger of an operator, which is an undesired actuation of the electronic switch 30.

It is not necessary, however, that electrode 58 be connected to the ground point in the D. C. amplifier. Electrode 58 may be connected to any potential supply of a voltage below that of the supply voltage to the amplifier and yet provide some shielding. It is apparent, however, that the maximum shielding is provided when electrode 58 is in fact connected to the reference, ground, or common point of the D. C. amplifier to which switch 30 is connected.

It is to be noted that actuation of the switch 30 of the present invention is made without moving parts, aside from movement of the operator's finger. That is, each of the supply electrode 42 and input electrode 50 is laterally immovably attached to insulator 38. Laterally immovably attached for the purposes of this invention is defined as where the input and supply electrodes are fixed with respect to each other in a manner to prevent the input electrode from coming into direct electrical contact with the supply electrode. Either electrode may be made vertically movable, as by using a soft or spongy material or springs to give the effect or feeling of vertical movement to an operator's finger. Other means for effecting this illusion of vertical movement upon actuation will be envisioned by those skilled in the art.

Thus, since the invention disclosed herein may be embodied in other specific forms without departing from the spirit of general characteristics thereof, some of which forms have been indicated, the embodiment described herein is to be considered in all respects illustrative and not restrictive. The scope of the invention is indicated by the appended claims, rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.

What is claimed is:

1. Electronic switch apparatus operable by the lateral bridging of the switch electrodes by the skin resistance of an operator, comprising in combination: insulating media having a top surface; first electrode means laterally immovably arranged with the insulating media with the top surface of the first electrode exposed to the finger of an operator upon the top surface of the insulating media; second electrode means laterally immovably arranged with the insulating media and the first electrode laterally around and about, spaced, and insulated from the first electrode with the top surface of the second electrode exposed to the finger of an operator upon the top surface of the insulating media laterally from the first electrode and with the top surface of the second electrode arranged above the level of the top surface of the first electrode in a manner that the finger of an operator touches the second electrode before contact is made between the finger and the first electrode to thereby allow good contact of the operator's finger with the second electrode before contact is made with the first electrode and thereby allow the harmless discharge of voltage in an operator's body and allow a direct current path to be set up laterally between the first electrode and the second electrode as soon as the finger of the operator touches the first electrode; third electrode means laterally immovably arranged with the insulating media, with the first electrode, and with the second electrode, electrically between the first and second electrodes, spaced vertically and insulated from one of the first and second electrodes and laterally spaced and insulated from the other of the first and second electrodes as a conductive electrical shielding electrode allowing leakage current flowing between the first electrode and the second electrode to be conducted to a reference point to aid in preventing a flow of leakage current between the first electrode and second electrode tending to set up a non-actuated direct current path from the first electrode to the second electrode: first means for providing an electrical connection to the first electrode; second means for providing an electrical connection to the second electrode; and third means for providing an electrical connection to the third electrode.

2. The electronic switch apparatus of claim 1, wherein the first connection means comprises means for providing an electrical connection between the first electrode and the input of a D. C. amplifier.

3. The electronic switch apparatus of claim 2, wherein the third connection means comprises means for providing an electrical connection between the third electrode and a reference point within the D. C. amplifier.

4. The electronic switch apparatus of claim 3, wherein the second connection means comprises means for providing an electrical connection between the second electrode and a means for supplying D. C. voltage to the D. C. amplifier.
THE UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,728,501 Dated April 17, 1973

Willis A. Larson
Stephen R. Tell

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the ABSTRACT, line 17, cancel "fist" and substitute therefor --first--.
Column 1, line 28, cancel "referenced" and substitute therefor --referred--.
Column 6, line 44, "approximate" should read --approximates--;
Column 6, line 45, after "the closed" cancel "of" and substitute --or--;
Column 6, line 46, delete "also"; cancel "across supply" and substitute --between--; cancel "86." and substitute --76.--;
Column 6, line 54, after "open", cancel "of" and substitute --or--;
Column 6, line 59, after "electronic circuit" insert --74--.
Claim 1, column 8, line 8, "electride" should read --electrode--;
Column 8, insert the following claim:

--5. The electronic switch apparatus of claim 1, wherein the third electrode is arranged immediately below the second electrode.--.

Signed and sealed this 8th day of January 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR. RENE D. TEGTMEYER
Attesting Officer Acting Commissioner of Patents
THE UNITED STATES PATENT OFFICE

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