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Larson

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[54] TOUCH SENSITIVE ELECTRONIC SWITCH

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[52] **U.S. Cl.** .....**200/159 R,** 200/DIG. 2

[51] **Int. Cl.** **H01h 35/00**

[58] **Field of Search** .....200/159 R, 159 B, DIG. 1, DIG. 2; 317/DIG. 2, DIG. 1; 307/116

[56] **References Cited**

UNITED STATES PATENTS

2,186,825	1/1940	Dome	250/20
2,576,929	12/1951	Ercolino	200/159 A X
2,659,533	11/1953	Quinby et al.	200/DIG. 1
3,320,438	5/1967	Myers	200/DIG. 1

OTHER PUBLICATIONS

Johnson, IBM Technical Disclosure Bulletin, April, 1971, Vol. 13, No. 11, p. 3551 (Pushbutton switch with no moving parts)

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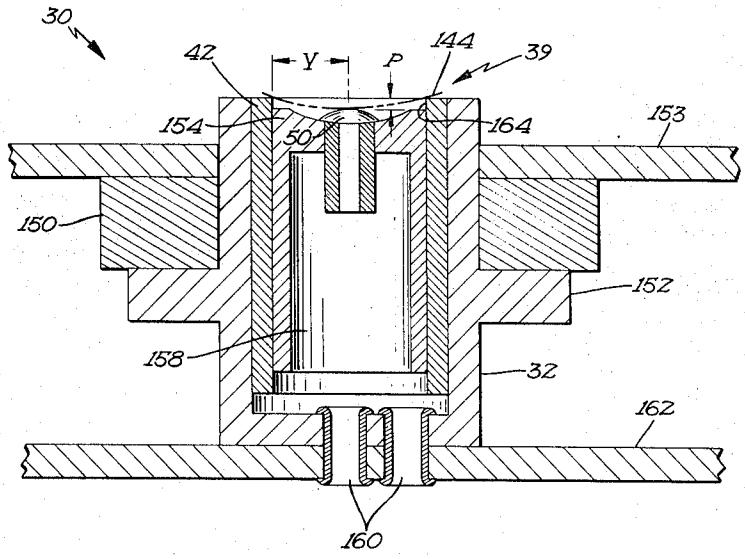
Assistant Examiner—William J. Smith
Attorney—Jack W. Wicks et al.

[57] **ABSTRACT**

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 switch is disclosed. The electronic switch shown includes two electrodes laterally spaced and insulated from each other. The top surfaces of the electrodes are exposed to the finger of the operator upon the top surface of an insulator mounting the electrodes in a manner that the operator's finger first touches an outer electrode and then an inner electrode to allow a direct current path to be set up laterally between the outer electrode and the inner electrode to thereby provide a lowering of the D.C. resistance across the switch. The relationship of the top surface of the outer electrode and the top surface of the inner electrode insures that the finger of the operator first touches the outer electrode before contact is made between the finger and the inner electrode to thereby allow the harmless grounding of the usual voltage in the operator's body.

2 Claims, 2 Drawing Figures



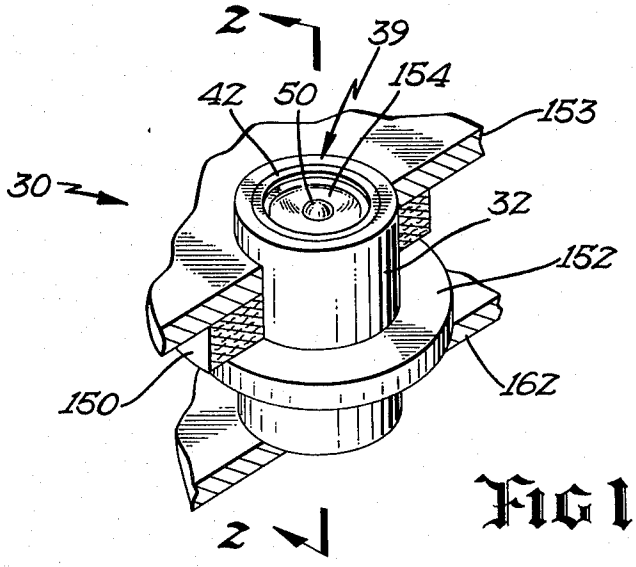


Fig 1

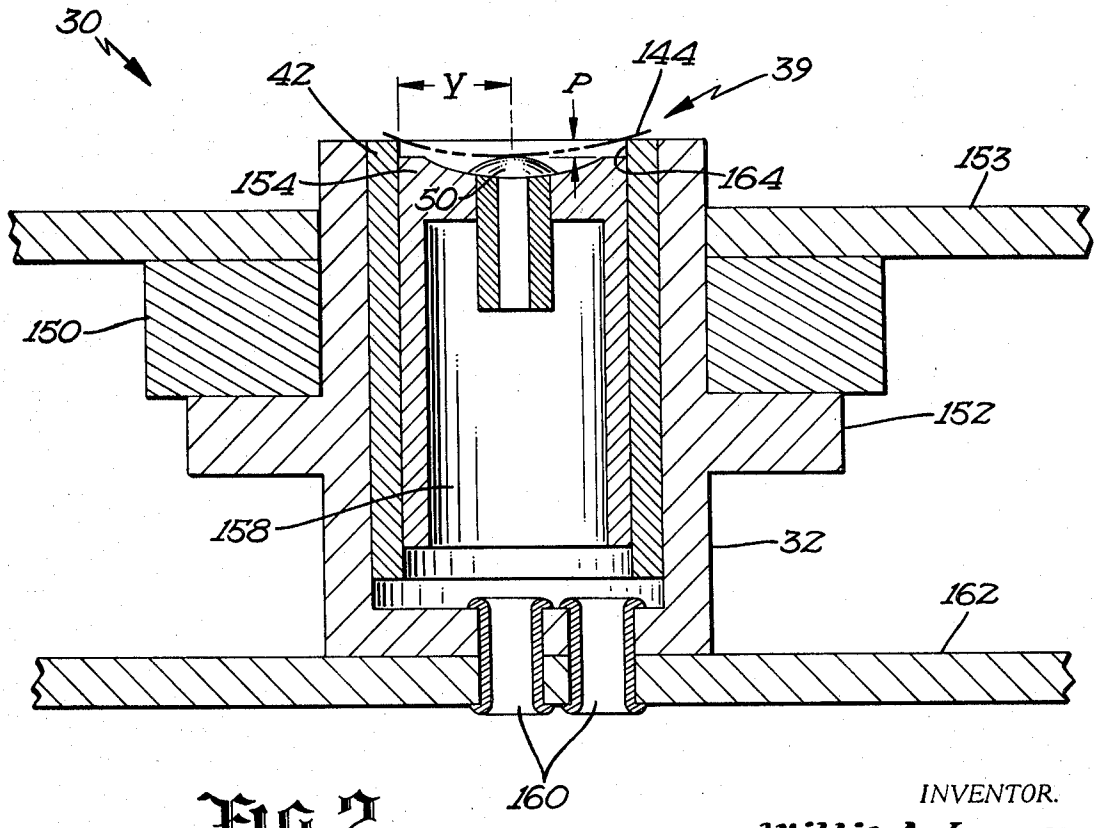


Fig 2

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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. 161948, 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 a companion application to the applications for patent filed of even date herewith by: Willis A. Larson and Raymond M. Warner, Jr., Ser. No. 199227, entitled "Composite D.C. Amplifier For Use With A Touch Sensitive Electronic Switch"; Willis A. Larson, Ser. No. 199195, entitled "Touch Sensitive Electronic Switch"; and Willis A. Larson and Arthur Kimmell, Ser. No. 199384, entitled "Touch Sensitive Electronic Switch."

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 switch to provide a D.C. input signal to a D.C. amplifier.

In the above referred to original application by Willis A. Larson, the advantage in a touch sensitive electronic switch of the operator's finger first making contact with an electrode arranged to be connected to the voltage supply terminal of a D.C. amplifier before contact is made with an electrode arranged to be connected to the input of a D.C. amplifier was disclosed. As was stated, this arrangement allows good contact of the operator's finger with the supply connected electrode before contact is made with the input connected electrode and thereby allows the harmless grounding of the usual alternating voltage induced from an external source into the operator's body.

Variance of the touch threshold of such a switch was further disclosed by varying the depth of the input connected electrode with respect to the supply connected electrode. It was indicated that the deeper the input connected electrode was placed with respect to the supply connected electrode, the heavier the touch required to force the fingertip into contact with both electrodes.

Thus, a design choice was necessary to provide a switch which would allow harmless grounding of the voltage in an operators body and yet not require a high degree of contact force before actuation of the switch is achieved. The present invention discloses a relationship which may be used to determined the minimum depth required to provide for reliable grounding of the voltage within an operators body and yet minimize the touch threshold required to reliably actuate the switch.

Also, because of the relationship of the present invention, a touch sensitive electronic switch may now be designed with more specificity than heretobefore possible. Once the minimum depth to provide reliable grounding of the voltage within an operator's body is known, the actual depth for which the switch is designed may be varied from the minimum depth to thus vary the touch threshold of the switch.

SUMMARY

In summary, a preferred embodiment of the present invention includes a first electrode immovably arranged within a housing and a second electrode also immovably arranged within the housing. The second electrode is further arranged around and about and laterally spaced and insulated from the first electrode. The first and second electrodes are exposed to the finger of an operator upon the top surface of the insulating media of the housing in a manner that an operator's finger touches the second electrode and then the first electrode to allow a direct current path to be set up laterally between the second and first electrode. The direct current path provides a lowering of the D.C. resistance across the electronic switch to provide an input signal to a D.C. amplifier which can be used with the electronic switch. The vertical distance between the top surface of the second electrode and the top surface of the first electrode, which is also termed the height differential between the electrodes, and the lateral distance or spacing between the electrodes, and the dimensions of an operator's finger have been found to be interrelated in a fashion which allows a switch design minimizing the touch sensitivity or threshold of the switch and yet insuring a height differential between the electrodes which will allow grounding of the voltage in an operator's body by the second electrode before a direct current path is set up between the second electrode and the first electrode.

It is thus an object of the present invention to provide a touch sensitive electronic switch which may be designed with more specificity than heretofore possible.

It is a further object of the present invention to provide such an electronic switch wherein the spacing and height differential between electrodes can be more precisely specified to insure a grounding of voltage in an operator's body and yet provide a minimum or near minimum touch sensitivity, if desired.

It is a further object of the present invention to provide such an electronic switch wherein the height differential between electrodes may be varied to thereby vary the touch threshold or touch sensitivity, if desired.

These and further objects and advantages of the present invention will become clearer in 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 prospective view of the electronic switch of the present invention showing the disposition of the electrodes and housing especially adapted for printed circuit board use; and

FIG. 2 is an enlarged cross section taken along the lines 2—2 of the housing illustrated in FIG. 1.

DESCRIPTION

As disclosed in the above referred to original application by Willis A. Larson, in the figures, a switch **30** is shown as including a housing **32**, which may be made of any suitable durable insulating material, and a switch face **39**. Switch **30** is shown as it would be utilized in a printed wiring board. A dust seal **150** of foam rubber or

the like is placed between a flange **152** of housing **32** and a panel **153** through which the housing extends for manual access.

As best shown in FIG. **1**, the electronic switch electrodes comprise an input, first, or center electrode **50**, and a supply, second or annular electrode **42** concentrically disposed to center electrode **50**, but extending longitudinally upward beyond the uppermost limit of the center electrode **50**. The center electrode **50** and the annular electrode **42** are separated and held in their respective positions by an insulator ring **154**.

It will be observed in FIG. **2** that the insulator ring **154** takes the form of a hollow cylinder to provide a chamber **158** into which the electronic components of a high gain D.C. amplifier may be placed, as is discussed in the original application. A pair of hollow conductors **160** are embedded in the bottom portion of housing **32** to provide communication with the chamber **158**. These hollow conductors permit a pair of leads to be brought from chamber **158** to the lower surface of a printed wiring board **162** where they may be soldered into place in the usual manner. The solder will also adhere to the hollow conductors **160** to provide a certain degree of mechanical strength in attaching the switching system to the printed wiring board **162**.

The particular arrangement of the electrodes **42** and **50** of the electronic switch **30** of the present invention may now be explained. As is shown in the figures, center electrode **50** is immovably arranged with insulating ring **154**, with a top surface of the electrode **50** exposed to the finger of an operator, a portion **144** of which is shown in FIG. **2**, upon the top surface of the insulating ring **154**. Annular electrode **42** is also immovably arranged with the insulating material of housing **32** and the insulating ring **154**, and with electrode **50**, and is arranged laterally around and about, spaced, and insulated from electrode **50** in a manner to expose the top surface of the annular electrode **42** to the finger of an operator upon the top surface of the surrounding insulating material. THe level of the top surface of annular electrode **42** is further arranged above the level of the top surface of center electrode **50** in a manner that the finger of the operator touches annular electrode **42** before contact is made between the finger and center electrode **50** to thereby allow good contact of the operator's finger with annular electrode **42** before contact is made with center electrode **50** and thereby allow the harmless grounding of the usual voltage induced from external sources into the operator's body. This arrangement of electrodes also allows a direct current path to be set up laterally between center electrode **50** and annular electrode **42** as soon as the finger of the operator touches center electrode **50**.

The specific arrangement and relationship of the present invention between the heretofore set out parts of electronic switch **30** may now be explained. It has been found that the relationship between the level of the top surface of center electrode **50** and the level of the top surface of annular electrode **42** and the lateral spacing between center electrode **50** and annular electrode **42** is such that P is at least equal to R minus the square root of the quantity $(R^2 - Y^2)$, where P represents the height differential between the level of the top surface of center electrode **50** and the level of the top surface of annular electrode **42**, Y represents the lateral spacing between center electrode **50** and annular electrode **42**, and R represents the curvature of the smallest finger expected to operate the electronic switch of the present invention.

That is, the mathematical expression may be set out as follows:

$$P = R - (R^2 - Y^2)^{1/2}$$

The height differential is directly related to the touch threshold or touch sensitivity of the electronic switch **30** of the present invention. That is, with a height differential in excess of P as established by the above expression, the bottom of the finger must be further extended from the point at which the inside edge **164** of electrode **42** is first touched by the finger to the point at which the bottom-most portion of the finger first touches the center electrode **50**, the position of finger portion **144** shown in FIG. **2**.

Further, as shown, Y is the lateral spacing between the electrodes as taken between the center line of the center electrode **50** and the inside edge **164** of the annular electrode **42**. It has been found, however, that if the width of the center electrode **50** is below a value approximately 10,000ths of an inch, Y may be taken as the spacing between the center electrode **50** and the annular electrode **42**, that is between the outer edge of the center electrode **50** and the inner edge of the annular electrode **42**. Configurations of switch **30** where the center electrode may be less than ten thousandths of an inch are set out in the above referred-to application for patent filed of even date herewith by Willis A. Larson, entitled "Touch Sensitive Electronic Switch."

The curvature of a finger can be most simply expressed as an approximate radius. That is, most fingers range from between ⅛ of an inch radius to 4/8ths of an inch radius. However, if it is desired to obtain a more exact relationship, the curvature of the finger may be expressed as a mathematical expression of this expression substituted for R. In general, it has been found sufficient to determine the approximate radius of the smallest finger expected to operate the electronic switch **30** of the present invention and use that particular number for R in the expression, as a worst case condition.

OPERATION

Generally, in operating the touch 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 the center electrode **50** and the annular electrode **42** to thus cause a small current to flow between these electrodes. The current flowing is generally in the nanoamperes range (30–300 nanoamperes) with normal skin resistances and a supply voltage of approximately 5 volts. This current may then be amplified by a D.C. amplifier to a point where an output current is provided, thus approximating an electronic switch in the closed or ON condition to an electrical load. When the operator's finger **144** is removed from switch **30**, the characteristics of the switch prevent any current flow across the switch thus providing no input current which can be amplified, thus approximating an electronic switch in an open or OFF condition to an electrical load.

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 housing 32. 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.

The relationship of the present invention allows a switch design minimizing the touch sensitivity or threshold of the switch and yet insuring a height differential between the electrodes which will allow grounding of the alternating voltage in an operator's body by the annular electrode 42 before a direct current path is set up between the annular electrode 42 and the center electrode 50. As explained in the original application, if it were possible to touch the center electrode 50 without first touching the annular electrode 42, the usual alternating voltage induced into the operator's body from external sources would cause the switching system to turn ON and OFF at the alternating frequency, typically 60Hz. That is, in the normal case where center electrode 50 is arranged to be connected to the input of a D.C. amplifier, the alternating voltage existing in the operator's body can alternately turn the D.C. amplifier ON and OFF and thus cause an alternating switch output, i.e. where the output turns ON and OFF at the alternating frequency. Where a D.C. switch output is desired upon contact of the operator's finger with switch face 39, this is a detrimental result. Since annular electrode 42 is arranged to be connected to a voltage supply terminal of the D.C. amplifier, insuring that the operator's finger first contacts annular electrode 42 insures that the alternating voltage within the operator's body will be conducted to A.C. ground or to circuit ground to give reference to the switch through the supply terminal. Also, static electricity within an operator's body can exist within a range of 1,000 to 10,000 volts, and any rapid discharge of this static electricity through input electrode 50 and to the input to a D.C. amplifier can damage the input stage. It is thus also best for the purposes of discharging the static electricity that the finger of an operator first discharge the static electricity through the annular supply electrode 42. It is further desirable if the annular supply electrode 42 has sharp corners to thus provide the best discharge path. Thus, when the operator's finger makes contact with the center electrode 50, the voltage has been eliminated and what remains is a D.C. bridging of electrodes 42 and 50 to provide a lowering of D.C. resistance across switch face 39 thus providing an actuation of the switch and its associated D.C. amplifier. The elimination of the voltage within the operator's body is particularly important since the current input to the D.C. amplifier can be as low as 30 nanoamperes, which can be easily overshadowed by the current caused by the alternating voltage within an operator's body or the amperage range current which can be caused by a rapid discharge of the static electricity within an operator's body.

By use of the relationship of the present invention between P, Y, and R, the minimum offset between the center electrode 50 and the annular electrode 42 may be determined. That is, the minimum spacing can be determined at which a finger of a given radius can contact an electrode 50 which is set below the level of an electrode 42 arranged around and about electrode 50.

It has further been found that in order to reliably insure that the finger of an operator will in fact contact the supply electrode before contact is made with the input electrode to allow the harmless grounding or referencing of voltage in the operator's body, the height differential for which the switch 30 of the present invention should be designed exceeds the minimum. That is, the practical measure of P should exceed the quantity R minus the square root of the quantity $(R^2 - Y^2)$ to allow for manufacturing tolerances, differing finger characteristics as far as the ability of the skin to compress, various finger placements upon switch 30, and to allow for a variance of the touch threshold. That is, once the relationship of parameters of the present invention is known, the height differential between the electrodes may be set beyond the minimum necessary to insure grounding or referencing of the voltage within an operator's body and to such an increased level as desired to establish a particular touch threshold for the switch. Applications may be desired where the touch threshold is extremely light for all ranges of fingers, such as a general purpose application. Other applications may be desired where the touch threshold is exceedingly heavy, such as in a switch which may be used on an armament where an undesired actuation would cause an extremely dangerous condition. Further applications may be desired with intermediate touch thresholds.

Thus, since the invention disclosed herein may be embodied in other specific forms without departing from the spirit or 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 extending from and 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 extending from and exposed to the finger of an operator upon the top surface of the insulating media laterally from the first electrode and with the relationship between the level of a top surface of the first electrode and the level of the top surface of the second electrode and the lateral spacing between the first electrode and the second electrode such that P is at least equal to R minus the square root of the quantity $(R^2 - Y^2)$ where P

represents the height differential between the level of the top surface of the first electrode and the level of the top surface of the second electrode, Y represents the lateral spacing between the first electrode and the second electrode, and R represents the curvature of the smallest finger expected to operate the electrical switch, the relationship insuring 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 grounding of the 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.

2. The electronic switch apparatus of claim 1, wherein P is greater than the quantity R minus the square root of the quantity $(R^2 - Y^2)$ to allow for variance of the touch threshold of the switch.

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