`183 Patent Claim Language	`183 Patent Support
	circuitry shown in FIG. 6 is very stable over the temperature range of -40° C. to 105° C. The output of the touch switch circuitry drops at a rate of approximately 40 mV/°C when temperature falls below 0° C. If application requires operation at low temperatures (-40° C.) the following three methods may be used to increase the output of the switch:increase the oscillator's regulated supply voltage, increase the resistance of resistor 416, and use a 40 higher gain transistor 410. All of these methods would increase sensitivity at high temperatures." Col. 16:33-41.
<u>a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;</u>	See Figures 4, 11; and Claims 8, 12, 16, 27. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50kHz and preferably at or above 800 kHz to minimize the effects of surface contamination for materials such a skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small size touch terminals in a physical close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads." Col. 6:1-3. The `183 Patent discloses "Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Us of frequencies as low as 50 kHz may also be possible depending

`183 Patent Claim Language	`183 Patent Support
	upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27. The `183 Patent discloses "Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6. Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5 volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8. Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 12:6-33. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the

`183 Patent Claim Language	`183 Patent Support
	resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies." Col. 14:22-25. The `183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components similar to those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of the first embodiment in that it includes an array of touch circuits designated as 9001 through 900nm, which, as shown, include both the touch circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 9001 through 900nm by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.
<u>the</u> first and second touch terminals defining areas for an operator to provide an input by proximity and touch; and	See Claim 27.

`183 Patent Claim Language	`183 Patent Support
a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator <u>via said microcontroller</u> and [the] <u>a</u> presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by [an] <u>the</u> operator to provide a control output signal for actuation of the controlled device, said detector circuit being configured to generate said control output signal when [an] <u>the</u> operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.	See Figures 4, 11; and Claims 8, 12, 16, 27. The `183 Patent discloses "Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6. Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5 volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8. Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 12:6-33. The `183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components similar to

`183 Patent Claim Language	`183 Patent Support
	those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of the first embodiment in that it includes an array of touch circuits designated as 9001 through 900nm, which, as shown, include both the touch circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 9001 through 900nm by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.

J. New Claim 38

`183 Patent Claim Language	`183 Patent Support
38. The capacitive responsive electronic switching circuit as defined in claim 37, wherein feedback to the operator is provided by an indicator activated by the microcontroller after the operator touches the second touch terminal.	See Claims 27, 32. The `183 Patent discloses "The microprocessor also allows the use of visual indicators such as LEDs or annunciators such as a bell or tone generator to confirm the actuation of a given touch switch or switches. This is particularly useful in cases where a sequence of actuations is required before an action occurs. The feedback

`183 Patent Claim Language	`183 Patent Support
	to the operator provided by a visual or audio indicator activated by the microprocessor in response to intermediate touches in a required sequence can minimize time lost and/or frustration on the part of the operator due to failed actuations from partial touches or wrong actuations from touching the wrong pad in a given required sequence or combination of touches." Col. 6:31-42. The `183 Patent discloses "A further option is to provide one or more LEDs 2205 or audible annunciators for visual or audible feedback to the operator. Specifically, in FIG. 19 the LED 2205 will come on when button 2201 has been successfully activated to cue the operator that it is time to move to button 2202. Where required a second LED with a different color than the first (yellow for the first LED and red for the second) can be provided to provide visual confirmation that the second button 2202 has been activated or that the required combination of the two buttons has been activated. Two different audible tone or sound generators could also be used in lieu of the LEDs to provide feedback to the operator." Col. 23:1-12. The `183 Patent discloses "A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310." Col. 23:28-30.

K. New Claim 39

`183 Patent Claim Language	`183 Patent Support
39. The capacitive responsive electronic switching circuit as defined in claim 37,	Claim 27.
wherein said detector circuit compares a sensed body capacitance change caused by the body capacitance	See Figure 11; and Claims 1, 12, 16, 18, 27, 28. The `183 Patent discloses "Another method for

`183 Patent Claim Language	`183 Patent Support
decreasing a second touch terminal signal on the detector to ground when proximate to the second touch terminal to a threshold level to generate the control output signal, and	implementing capacitive touch switches relies on the change in capacitive coupling between a touch terminal and ground. Systems utilizing such a method are described in U.S. Pat. No. 4,758,735 and U.S. Pat. No. 5,087,825. With this methodology the detection circuit consists of an oscillator (or AC line voltage derivative) providing a signal to a touch terminal whose voltage is then monitored by a detector. The touch terminal is driven in electrical series with other components that function in part as a charge pump. The touch of an operator then provides a capacitive short to ground via the operator's own body capacitance that lowers the amplitude of oscillator voltage seen at the touch terminal." Col. 3:44-56. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50kHz and preferably at or above 800 kHz to minimize the effects of surface contamination for materials such a skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small size touch terminals in a physical close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Us of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent discloses "Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8." Col. 12:24-28. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies." Col. 14:22-25.
wherein feedback to the operator is provided by an indicator activated by the microcontroller after the operator touches the second touch terminal.	See Claims 27, 32. The `183 Patent discloses "The microprocessor also allows the use of visual indicators such as LEDs or annunciators such as a bell or tone generator to confirm the actuation of a given touch switch or switches. This is particularly useful in cases where a sequence of actuations is required before an action occurs. The feedback to the operator provided by a visual or audio indicator activated by the microprocessor in response to intermediate touches in a required sequence can minimize time lost and/or frustration on the part of the operator due to failed actuations from partial touches or wrong actuations from touching the wrong pad in a given required sequence or combination of touches." Col. 6:31-42. The `183 Patent discloses "A further option is to provide one or more LEDs 2205 or audible annunciators for visual or audible feedback to the operator. Specifically, in FIG. 19 the LED 2205 will come on when button 2201 has been successfully activated to cue the operator that it is time to move to button 2202. Where required a second LED with a different color than the first (yellow for the first LED and red for the second)

`183 Patent Claim Language	`183 Patent Support
	can be provided to provide visual confirmation that the second button 2202 has been activated or that the required combination of the two buttons has been activated. Two different audible tone or sound generators could also be used in lieu of the LEDs to provide feedback to the operator." Col. 23:1-12. The `183 Patent discloses "A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310." Col. 23:28-30.

V. Conclusion

In view of the above, Patent Owner submits that the claims are in condition for allowance. No new matter has been added by this submission. If Examiner should have any questions, please contact Patent Owner's Attorney, Brian A. Carlson, at 972-732-1001. The Commissioner is hereby authorized to charge any fees due in connection with this filing, or credit any overpayment, to Deposit Account No. 50-1065.

Respectfully submitted,

November 19, 2012
Date

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EXAMINER	
NGUYEN, LINH M	

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MAIL DATE	DELIVERY MODE
04/10/2013	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

PTOL-90A (Rev. 04/07)

Notice of Intent to Issue Ex Parte Reexamination Certificate	**Control No.** 90/012,439	**Patent Under Reexamination** 5796183
	Examiner LINH M. NGUYEN	**Art Unit** 3992

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☐ Prosecution on the merits is (or remains) closed in this *ex parte* reexamination proceeding. This proceeding is subject to reopening at the initiative of the Office or upon petition. *Cf.* 37 CFR 1.313(a). A Certificate will be issued in view of
   (a) ☒ Patent owner's communication(s) filed: *19 November 2012*.
   (b) ☐ Patent owner's failure to file an appropriate timely response to the Office action mailed: ______.
   (c) ☐ Patent owner's failure to timely file an Appeal Brief (37 CFR 41.31).
   (d) ☐ The decision on appeal by the ☐ Board of Patent Appeals and Interferences ☐ Court dated ______
   (e) ☐ Other: ______.
2. The Reexamination Certificate will indicate the following:
   (a) Change in the Specification: ☐ Yes ☒ No
   (b) Change in the Drawing(s): ☐ Yes ☒ No
   (c) Status of the Claim(s):
      (1) Patent claim(s) confirmed: ______.
      (2) Patent claim(s) amended (including dependent on amended claim(s)): *18,27,28 and 32*
      (3) Patent claim(s) canceled: ______.
      (4) Newly presented claim(s) patentable: 33-39.
      (5) Newly presented canceled claims: ______.
      (6) Patent claim(s) ☐ previously ☐ currently disclaimed: ______
      (7) Patent claim(s) not subject to reexamination: 1-17, 19-26 and 29-31.
3. ☒ Note the attached statement of reasons for patentability and/or confirmation. Any comments considered necessary by patent owner regarding reasons for patentability and/or confirmation must be submitted promptly to avoid processing delays. Such submission(s) should be labeled: "Comments On Statement of Reasons for Patentability and/or Confirmation."
4. ☐ Note attached NOTICE OF REFERENCES CITED (PTO-892).
5. ☐ Note attached LIST OF REFERENCES CITED (PTO/SB/08 or PTO/SB/08 substitute).
6. ☐ The drawing correction request filed on ______ is: ☐ approved ☐ disapproved.
7. ☐ Acknowledgment is made of the priority claim under 35 U.S.C. § 119(a)-(d) or (f).
   a)☐ All b)☐ Some* c)☐ None of the certified copies have
      ☐ been received.
      ☐ not been received.
      ☐ been filed in Application No. ______.
      ☐ been filed in reexamination Control No. ______.
      ☐ been received by the International Bureau in PCT Application No. ______.

   * Certified copies not received: ______.
8. ☐ Note attached Examiner's Amendment.
9. ☐ Note attached Interview Summary (PTO-474).
10. ☐ Other: ______.

All correspondence relating to this reexamination proceeding should be directed to the **Central Reexamination Unit** at the mail, FAX, or hand-carry addresses given at the end of this Office action.

cc: Requester (if third party requester)

U.S. Patent and Trademark Office
PTOL-469 (Rev. 07-10) **Notice of Intent to Issue Ex Parte Reexamination Certificate** Part of Paper No 20130327

Notice of Intent to Issue Reexamination Certificate

This is a reexamination of United States Patent Number 5,796,183 ("the 183' patent"). In the reexamination request filed 08/17/2012 ("Request"), by Patent Owner, a substantial new question (SNQ) of patentability was raised as to claims 18 and 27. Those claims are thus reexamined herein. Reexamination was not requested of claims 1-17, 19-26 and 28-32. Therefore, claims 1-17, 19-26, and 27-31 will not be reexamined. See MPEP 2243. However, claims 28 and 32 will be reexamined, as further explained below.

A Patent Owner Statement was filed 11/19/2012, in which claims 18 and 27 were amended, as well as claims 28 and 32 due to their dependencies from claim 27. Furthermore, new claims 33-39 were added.

Within the examiner's discretion, the newly added claims 33-39 and the non-requested amended claims 28 and 32 are now subject to reexamination.

References

Boie et al., U.S. Patent No. 5,463,388, filed on January 29, 1993 and issued on October 31, 1996 ("Boie '388").

Statement of Reasons for Patentability and/or Confirmation

Claims 18, 27, amended non-requested claims 28, 32 and newly added claims 33-39 are patentable.

The examiner has no opinion as to the claims that were not reexamined. The following is an examiner's statement of reasons for patentability of the claims found patentable in this reexamination proceeding:

There is not taught or disclosed in the prior art *a capacitive responsive electronic switching circuit having a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a plurality of small sized input touch terminals of a keypad*, as called for in independent claim 18; nor *a capacitive responsive electronic switching circuit having a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals*, as called for in independent claims 27 and 37. The examiner agrees with the discussion articulated by Patent Owner in the Statement that Boie does not teach or suggest these claim elements. Rather, Boie discloses that "RF oscillator 408 provides an RF signal, for example, 100 kilohertz, to circuits 401, synchronous detector and filter 404 via inverter 410, and guard plane 411." Boie, col. 3:67-col. 4:2. Boie further discloses that "[t]he effects of electrode-to-electrode capacitances, wiring capacitances and other extraneous capacitances arc minimized by driving all electrodes and guard plane 411 in unison with the same RF signal from RF oscillator 408." *Id.* at col. 4:58-60 (emphasis added); *see id.* at Fig. 4. Thus Boie discloses driving the electrodes of electrode array 100 and guard plane 411 with a single RF signal. Boie does not teach or suggest providing signal output frequencies to these components. Accordingly, claims 18, 27, amended non-requested claims 28, 32, and newly added claims 33-39 are patentable.

Any comments considered necessary by PATENT OWNER regarding the above statement must be submitted promptly to avoid processing delays. Such submission by the patent owner should be labeled: "Comments on Statement of Reasons for Patentability and/or Confirmation" and will be placed in the reexamination file.

Correspondence

All correspondence relating to this *inter partes* reexamination proceeding should be directed:

By Mail to: Mail Stop *Inter Partes* Reexam
Attn: Central Reexamination Unit
Commissioner for Patents
United States Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

By FAX to: (571) 273-9900
Central Reexamination Unit

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Registered users of EFS-Web may alternatively submit such correspondence via the electronic filing system EFS-Web, at https://efs.uspto.gov/efile/myportal/efs-registered EFS-Web offers the benefit of quick submission to the particular area of the Office that needs to act on the correspondence. Also, EFS-Web submissions are "soft scanned" (i.e., electronically uploaded) directly into the official file for the reexamination proceeding, which offers parties the opportunity to review the content of their submissions after the "soft scanning" process is complete.

Any inquiry concerning this communication or earlier communications from the examiner, or as to the status of this proceeding, should be directed to the Central Reexamination Unit at telephone number (571) 272-7705.

/Linh M. Nguyen/
Primary Examiner, Art Unit 3992

Conferees:
/James Menefee/
Primary Examiner, Art Unit 3992

/Daniel Ryman/
Supervisory Patent Examiner, Art Unit 3992

US005796183C1

(12) EX PARTE REEXAMINATION CERTIFICATE (9614th)

United States Patent

Hourmand et al.

(10) **Number: US 5,796,183 C1**

(45) **Certificate Issued: Apr. 29, 2013**

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(54) **CAPACITIVE RESPONSIVE ELECTRONIC SWITCHING CIRCUIT**

(75) Inventors: **Byron Hourmand**, Hersey, MI (US); **John M. Washeleski**, Cadillac, MI (US); **Stephen R. W. Cooper**, Fowlerville, MI (US)

(73) Assignee: **Nartron Corporation**, Reed City, MI (US)

Reexamination Request:
No. 90/012,439, Aug. 17, 2012

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Appl. No.:	**08/601,268**
Filed:	**Jan. 31, 1996**

Certificate of Correction issued May 11, 1999

Certificate of Correction issued Oct. 11, 2011

(51) **Int. Cl.**
H03K 17/96 (2006.01)
H03K 17/94 (2006.01)

(52) **U.S. Cl.**
USPC **307/116**; 307/125; 307/139; 361/181

(58) **Field of Classification Search**
None
See application file for complete search history.

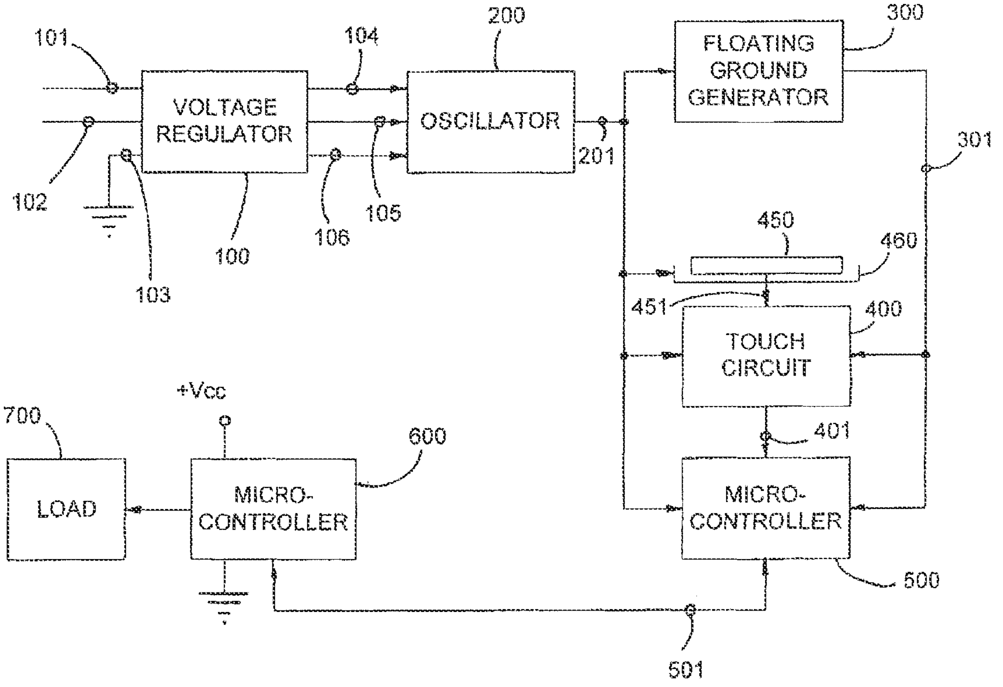
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/012,439, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner — Linh M. Nguyen

(57) **ABSTRACT**

A capacitive responsive electronic switching circuit comprises an oscillator providing a periodic output signal having a frequency of 50 kHz or greater, an input touch terminal defining an area for an operator provide an input by proximity and touch, and a detector circuit coupled to the oscillator for receiving the periodic output signal from the oscillator, and coupled to the input touch terminal. The detector circuit being responsive to signals from the oscillator and the presence of an operator's body capacitance to ground coupled to the touch terminal when in proximity or touched by an operator to provide a control output signal. Preferably, the oscillator provides a periodic output signal having a frequency of 800 kHz or greater. An array of touch terminals may be provided in close proximity due to the reduction in crosstalk that may result from contaminants by utilizing an oscillator outputting a signal having a frequency of 50 kHz or greater.



EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **18**, **27**, **28** and **32** are determined to be patentable as amended.

New claims **33-39** are added and determined to be patentable.

Claims **1-17**, **19-26** and **29-31** were not reexamined.

18. A capacitive responsive electronic switching circuit comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a plurality of small sized input touch terminals of a keypad;

[a] *the* plurality of *small sized* input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator *via said microcontroller* and [the] *a* presence of an operator's body capacitance to ground coupled *to* said touch terminals when proximal or touched by [an] *the* operator to provide a control output signal,

wherein said predefined frequency of said oscillator [is] *and said signal output frequencies are* selected to decrease [the] *a first* impedance of said dielectric substrate relative to [the] *a second* impedance of any contaminate that may create an electrical path on said dielectric substrate between said adjacent areas *defined by the plurality of small sized input touch terminals*, and wherein said detector circuit compares [the] *a* sensed body capacitance *change* to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.

27. A capacitive responsive electronic switching circuit for a controlled *keypad* device comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;

the first and second *input* touch terminals defining areas for an operator to provide an input by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator *via said microcontroller* and [the] *a* presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by [an] *the* operator to provide a control output signal for actuation of the controlled *keypad* device, said detector circuit being configured to generate said control output signal when [an] *the* operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

28. The capacitive responsive electronic switching circuit as defined in claim **27**, wherein said detector circuit generates said control signal only when [an] *the* operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.

32. The capacitive responsive electronic switching circuit as defined in claim **27** and further including an indicator for indicating when said detector circuit determines that [an] *the* operator is proximal or touches said first touch terminal.

33. The capacitive responsive electronic switching circuit as defined in claim 18, further comprising wherein said detector circuit compares the sensed body capacitance change caused by the body capacitance decreasing an input touch terminal signal on the detector to ground when proximate to the input touch terminal to a second threshold level to generate the control output signal.

34. The capacitive responsive electronic switching circuit as defined in claim 18, further comprising wherein said detector circuit compares the sensed body capacitance change caused by the body capacitance decreasing an input touch terminal signal amplitude on the detector to ground when proximate to the input touch terminal to a second threshold level to generate the control output signal.

35. The capacitive responsive electronic switching circuit as defined in claim 27, wherein when the second touch terminal is not touched on its defining area by the operator to provide input, the control output signal is prevented.

36. The capacitive responsive electronic switching circuit as defined in claim 27 and further including an indicator for indicating when said detector circuit determines that the operator is proximal or touches said second touch terminal.

37. A capacitive responsive electronic switching circuit for a controlled device comprising:

an oscillator providing a periodic output signal having a predefined frequency, wherein an oscillator voltage is greater than a supply voltage;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;

the first and second touch terminals defining areas for an operator to provide an input by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

38. The capacitive responsive electronic switching circuit as defined in claim 37, wherein feedback to the operator is provided by an indicator activated by the microcontroller after the operator touches the second touch terminal.

39. The capacitive responsive electronic switching circuit as defined in claim 37,

wherein said detector circuit compares a sensed body capacitance change caused by the body capacitance decreasing a second touch terminal signal on the detector to ground when proximate to the second touch terminal to a threshold level to generate the control output signal, and

wherein feedback to the operator is provided by an indicator activated by the microcontroller after the operator touches the second touch terminal.

* * * * *

EXHIBIT C

US005463388A

United States Patent [19]

Boie et al.

[11] **Patent Number: 5,463,388**

[45] **Date of Patent: * Oct. 31, 1995**

[54] **COMPUTER MOUSE OR KEYBOARD INPUT DEVICE UTILIZING CAPACITIVE SENSORS**

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[73] Assignee: **AT&T IPM Corp.**, Coral Gables, Fla.

[*] Notice: The portion of the term of this patent subsequent to May 12, 2009, has been disclaimed.

[21] Appl. No.: **11,040**

[22] Filed: **Jan. 29, 1993**

[51] **Int. Cl.^{6}** **H03K 17/94**

[52] **U.S. Cl.** **341/33**; 345/174

[58] **Field of Search** 341/33; 178/18, 178/19; 345/174

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Assistant Examiner—Thomas J. Mullen, Jr.
Attorney, Agent, or Firm—Geoffrey D. Green

[57] **ABSTRACT**

A computer input device for use as a computer mouse or keyboard comprises a thin, insulating surface covering an array of electrodes. Such electrodes are arranged in a grid pattern and can be connected in columns and rows. Each column and row is connected to circuitry for measuring the capacitance seen by each column and row. The position of an object, such as a finger or handheld stylus, with respect to the array is determined from the centroid of such capacitance values, which is calculated in a microcontroller. For applications in which the input device is used as a mouse, the microcontroller forwards position change information to the computer. For applications in which the input device is used as a keyboard, the microcomputer identifies a key from the position of the touching object and forwards such key identity to the computer.

10 Claims, 6 Drawing Sheets

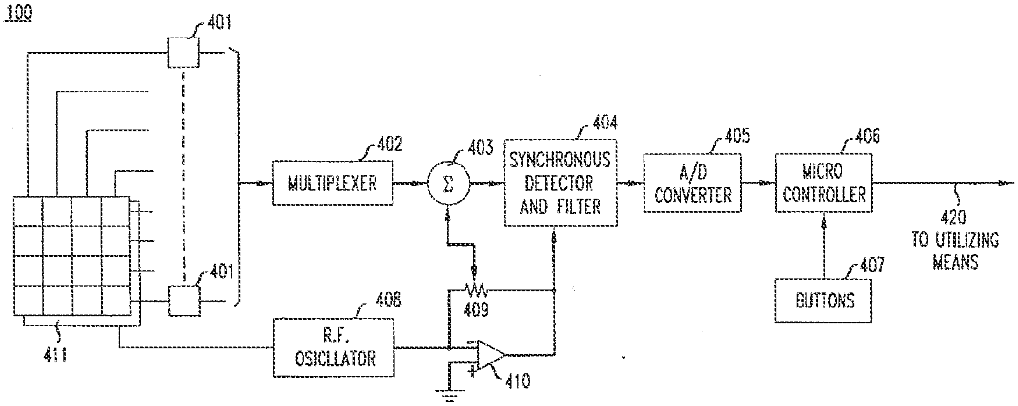


FIG. 1

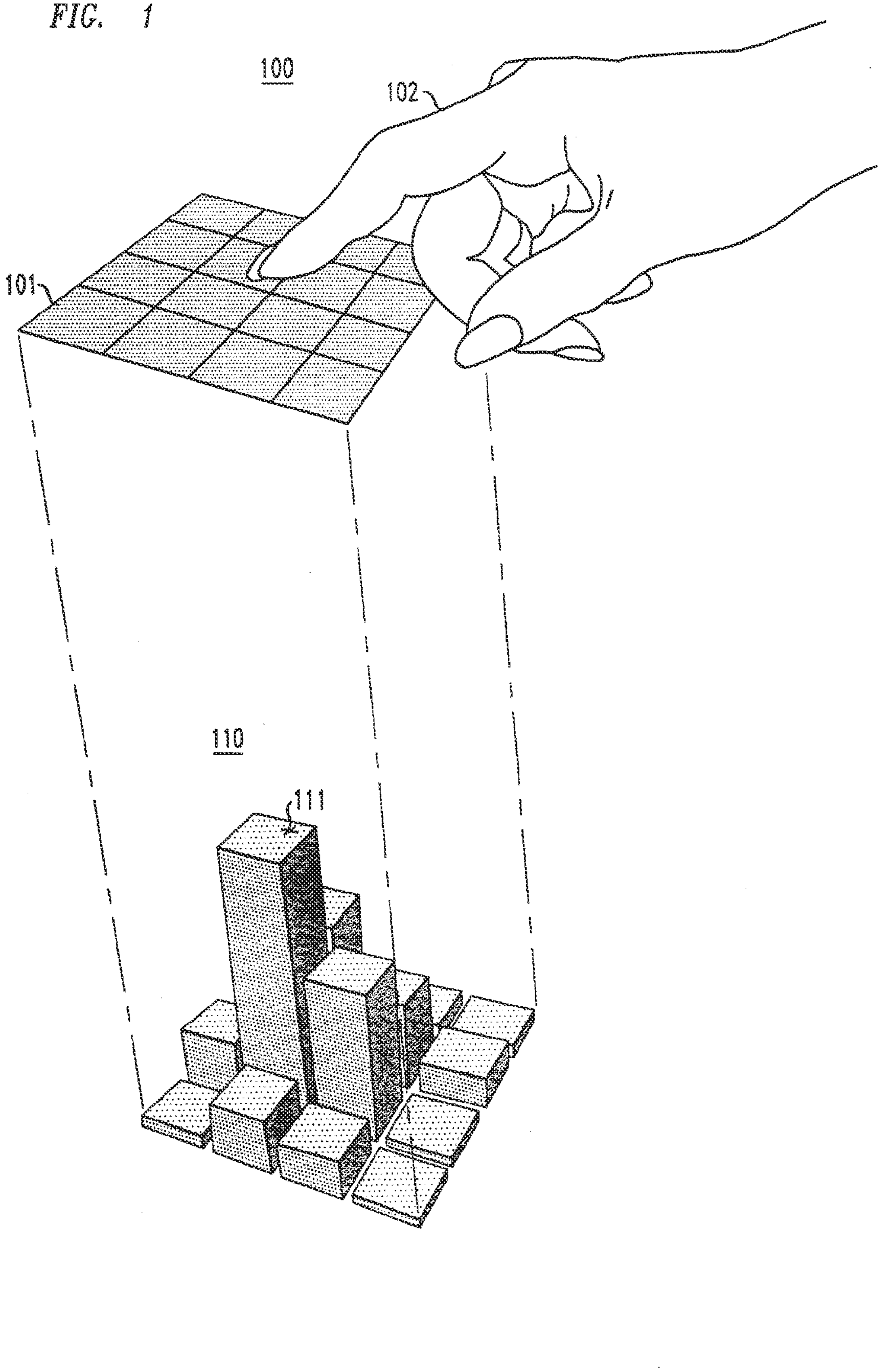


FIG. 2

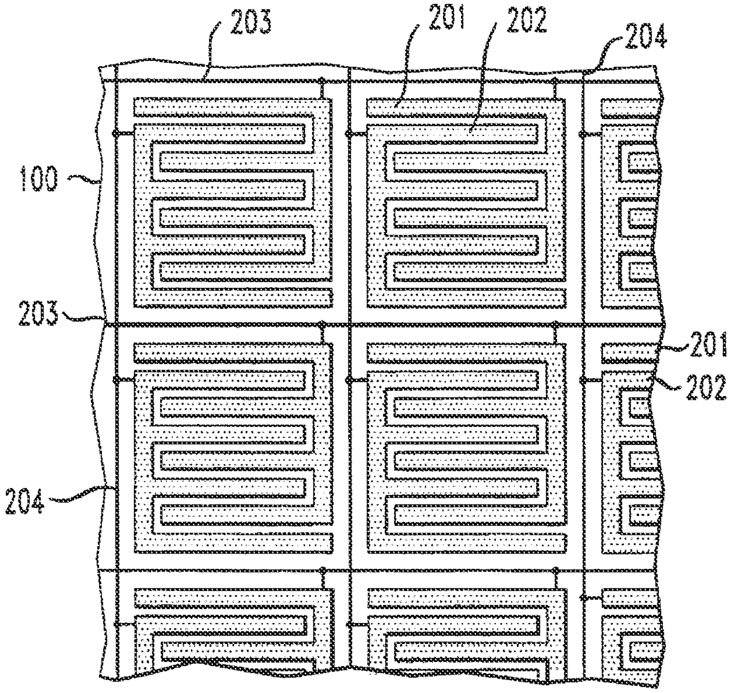


FIG. 3

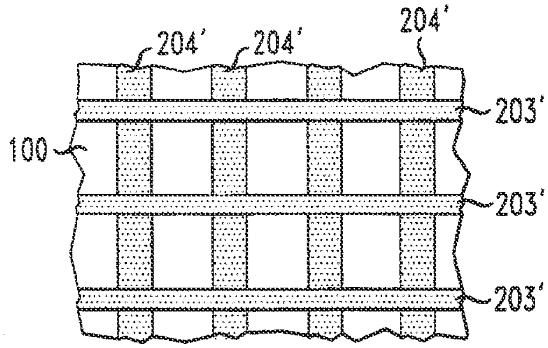


FIG. 4

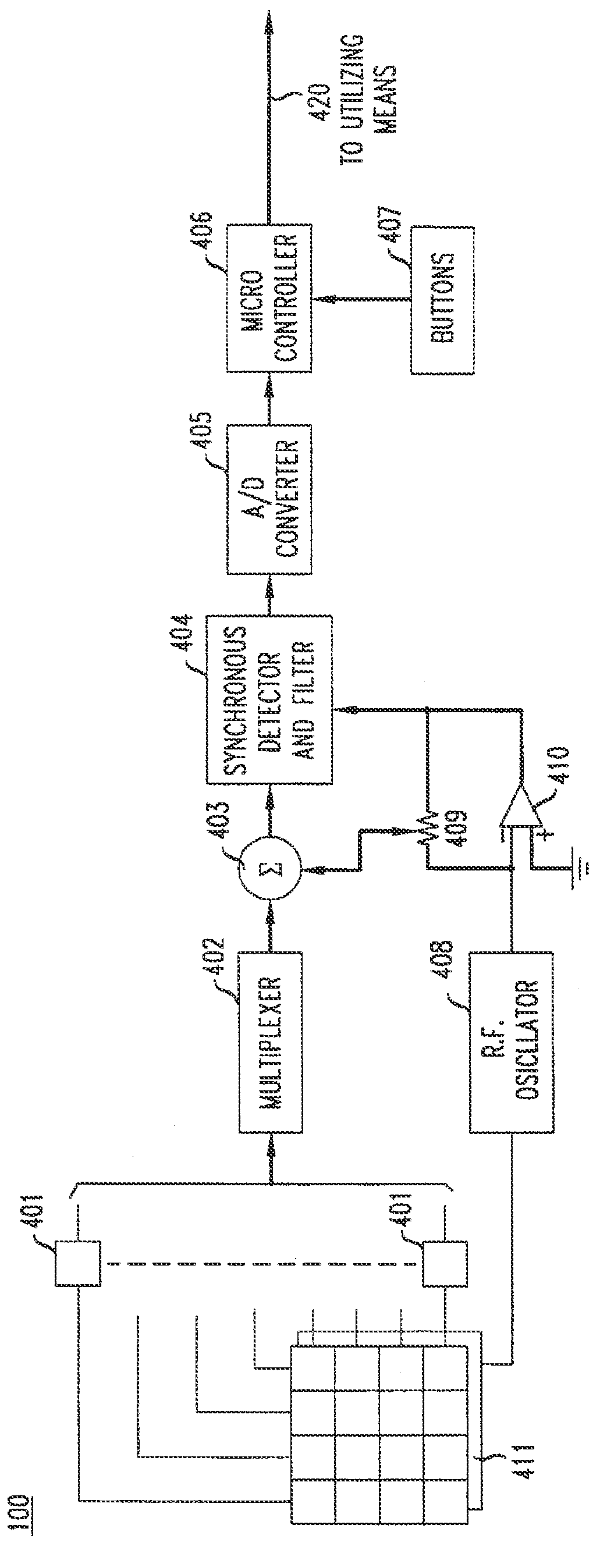

100
401
401
411
402
MULTIPLEXER
403
Σ
404
SYNCHRONOUS DETECTOR AND FILTER
405
A/D CONVERTER
406
MICRO CONTROLLER
407
BUTTONS
408
R.F. OSCILLATOR
409
410
-
+
420
TO UTILIZING MEANS

FIG. 5

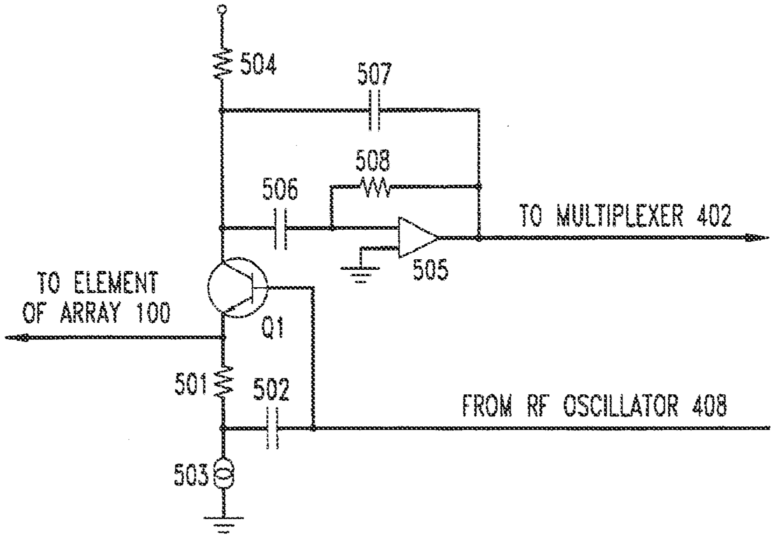

504
507
508
506
TO MULTIPLEXER 402
505
TO ELEMENT
OF ARRAY 100
Q1
501
502
FROM RF OSCILLATOR 408
503

FIG. 7

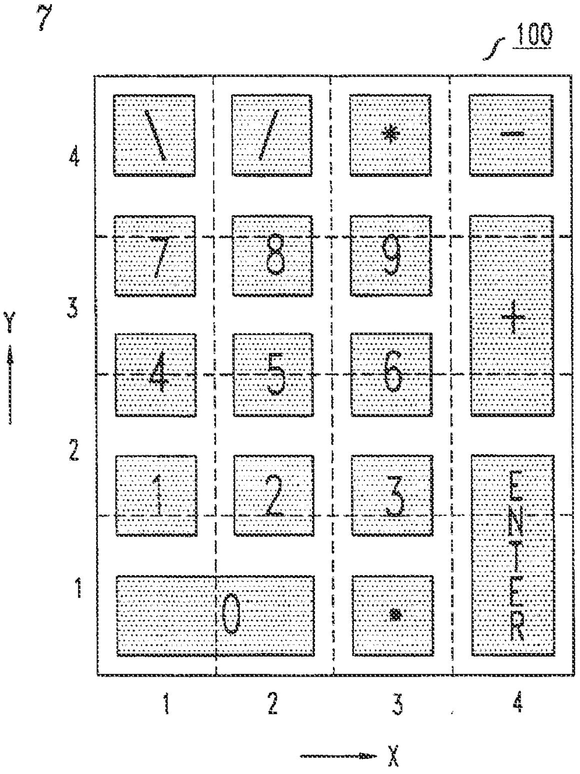

100
\
/
*
−
7
8
9
+
4
5
6
1
2
3
ENTER
0
.
4
3
2
1
Y
1
2
3
4
X

FIG. 6

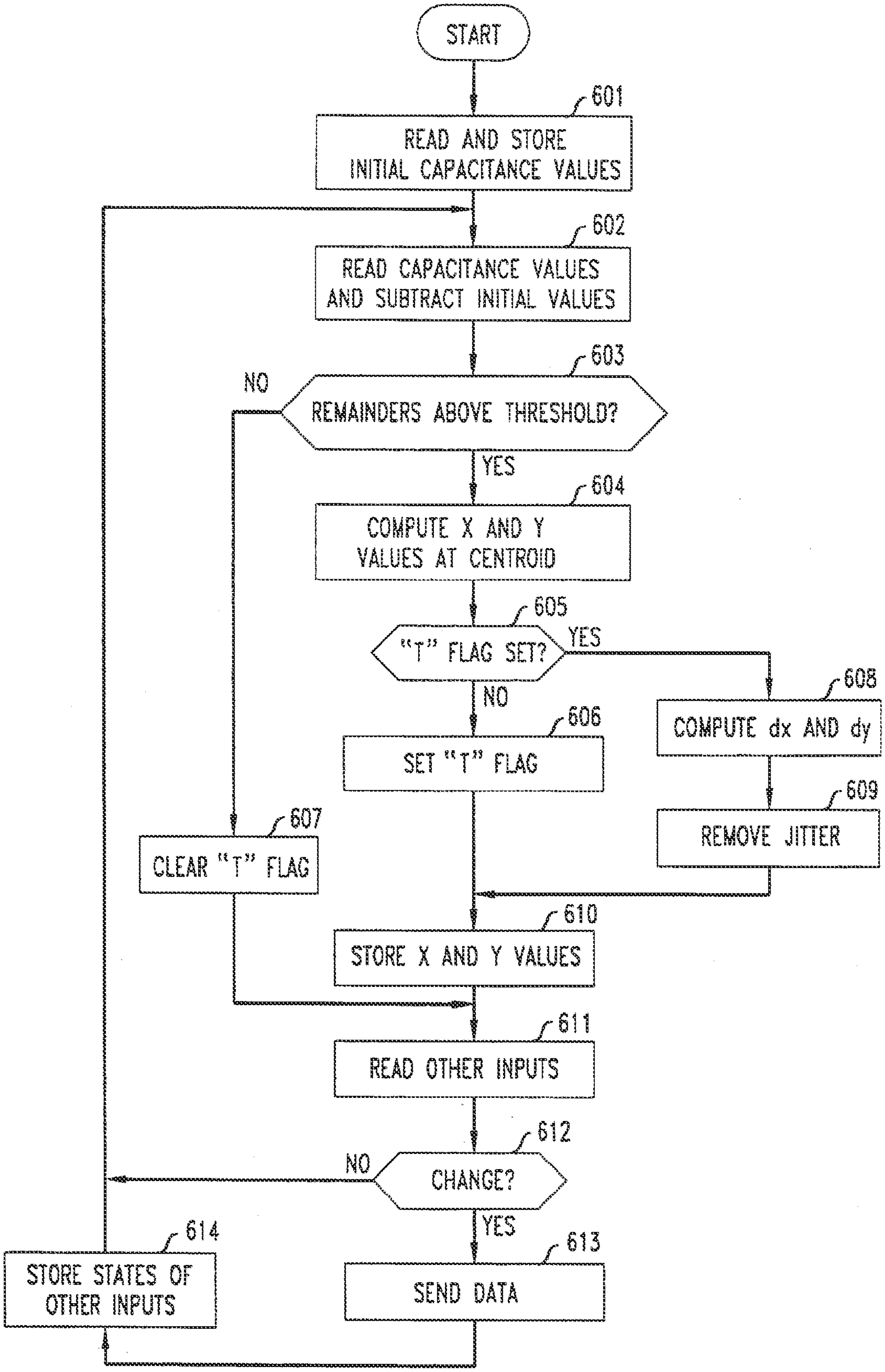
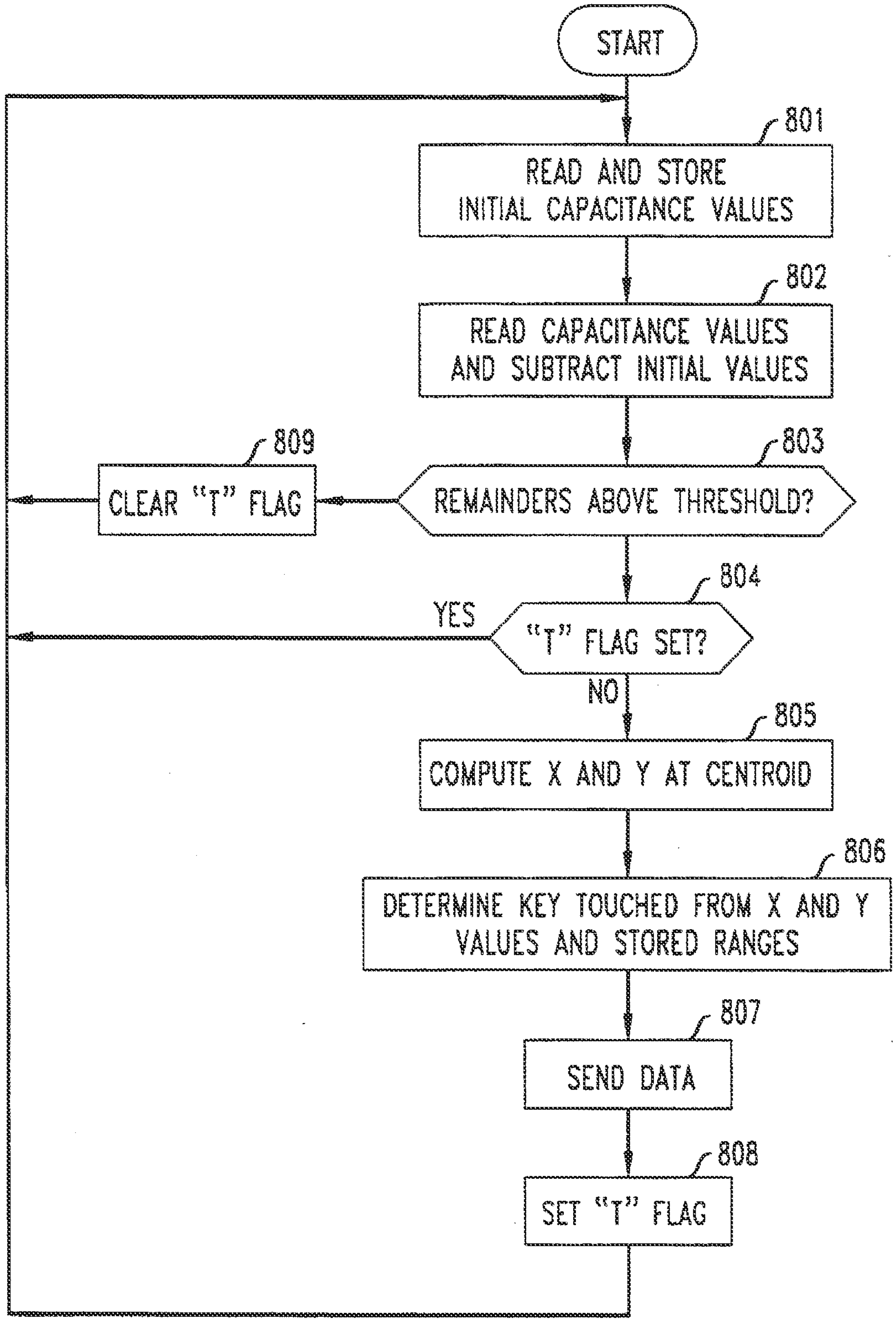

START
601
READ AND STORE INITIAL CAPACITANCE VALUES
602
READ CAPACITANCE VALUES AND SUBTRACT INITIAL VALUES
603
NO
REMAINDERS ABOVE THRESHOLD?
YES
604
COMPUTE X AND Y VALUES AT CENTROID
605
"T" FLAG SET?
YES
608
COMPUTE dx AND dy
NO
606
SET "T" FLAG
609
REMOVE JITTER
607
CLEAR "T" FLAG
610
STORE X AND Y VALUES
611
READ OTHER INPUTS
612
NO
CHANGE?
YES
614
STORE STATES OF OTHER INPUTS
613
SEND DATA

FIG. 8


START
801
READ AND STORE INITIAL CAPACITANCE VALUES
802
READ CAPACITANCE VALUES AND SUBTRACT INITIAL VALUES
809
CLEAR "T" FLAG
803
REMAINDERS ABOVE THRESHOLD?
804
YES
"T" FLAG SET?
NO
805
COMPUTE X AND Y AT CENTROID
806
DETERMINE KEY TOUCHED FROM X AND Y VALUES AND STORED RANGES
807
SEND DATA
808
SET "T" FLAG

COMPUTER MOUSE OR KEYBOARD INPUT DEVICE UTILIZING CAPACITIVE SENSORS

FIELD OF THE INVENTION

This invention relates to sensors for capacitively sensing the position or movement of an object, such as a finger, on a surface.

BACKGROUND OF THE INVENTION

Numerous devices are known for sensing the position of objects on surfaces, many of which relate to computer input tablets. For example, U.S. Pat. No. 5,113,041 to Greg E. Blonder et al. discloses a computer input tablet for use with a stylus in which the position of the stylus can be determined from signals transmitted to the stylus from a grid of signal lines embedded in the tablet, and U.S. Pat. No. 4,806,709 to Blair Evans discloses a touch-screen having a resistive layer with a number of point electrodes spaced thereon such that the position of a finger touching the screen can be determined from the relative values of the currents drawn from the point electrodes. The first such device requires means for the stylus itself to transmit information, such as a direct electrical connection. The second such device, and other kinds of tablets that sense the pressure of a finger or stylus, do not require such information-transmitting means.

Computer input tablets can be used for input of textual or graphical information. Various systems are known in the art which process handwritten text as if it were entered on a keyboard. Graphical information can also be captured by means of such tablets.

Other input devices such as computer "mice," joysticks and trackballs can be used with computers to control the position of a cursor on a display screen, such as a video terminal, for input of graphical information and for interactive programs such as computer games and programs using "windows" for display of information. Movement of a mouse in a particular direction on a surface causes a corresponding movement of the cursor or other object on the screen. Similarly, movement of a joystick or trackball in a particular direction causes such movement.

Input devices such as mice, joysticks and trackballs can be cumbersome because of their size and shape and, particularly with mice, the room needed for use. These drawbacks are more apparent with respect to portable computers, such as the so-called "notebook" computers. It is deskable, therefore, to furnish such control capabilities in an input device that can be incorporated in a small space, but without sacrificing ease of use. It is also desirable to be able to use such a device for multiple functions, for example, a particular area of a computer keyboard that can also be used as a mouse without losing its functionality as a keyboard. Further, it is desirable that such an input device be capable of operation by a finger or handheld stylus that does not require an electrical connection or other means for transmitting information.

SUMMARY OF THE INVENTION

The capacitive sensor of the invention comprises a thin, insulating surface covering a plurality of electrodes. The position of an object, such as a finger or hand-held stylus, with respect to the electrodes, is determined from the centroid of capacitance values measured at the electrodes. The electrodes can be arranged in one or two dimensions. In a two-dimensional array, the capacitance for each electrode can be measured separately or the electrodes can be divided into separate elements connected in columns and rows and the capacitances measured for each column and row. The x and y coordinates of the centroid are calculated in a microcontroller from the measured capacitances. For applications in which the sensor is used to emulate a mouse or trackball, the microcontroller forwards position change information to utilizing means. For applications in which the sensor is used to emulate a keyboard, the microcontroller identifies a key from the position of the touching object and forwards such key identification to utilizing means.

These and other aspects of the invention will become apparent from the attached drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a graphic diagram showing the relationship between the position of a user's finger and capacitances at electrodes in a two- dimensional sensor constructed in accordance with the invention.

FIG. **2** is a more detailed representation of interdigitated electrode components at the intersections of rows and columns in a two-dimensional sensor.

FIG. **3** is an alternate arrangement for electrodes in the array.

FIG. **4** is an overall block diagram of a two-dimensional capacitive position sensor in accordance with the invention.

FIG. **5** is a diagram of an integrating amplifier and bootstrap circuit associated with the electrodes.

FIG. **6** is a flow chart showing operation of the capacitive position sensor of the invention as a computer mouse or trackball.

FIG. **7** is a diagram showing use of the capacitive position sensor of the invention as a keyboard.

FIG. **8** is a flow chart showing operation of the capacitive position sensor of the invention as a keyboard.

DETAILED DESCRIPTION

The invention will be described in terms of a exemplary two-dimensional embodiment adapted to emulate a computer mouse or keyboard for use with a personal computer. However, it will be clear to those skilled in the art that the principles of the invention can be utilized in other applications in which it is convenient to sense position of an object capacitively in one or more dimensions.

The operational principle of the capacitive position sensor of the invention is shown in FIG. **1**. Electrode array **100** is a square or rectangular array of electrodes **101** arranged in a grid pattern of rows and columns, as in an array of tiles. A 4×4 array is shown, which we have found adequate for emulating a computer mouse by finger strokes on the array. However, the invention can be used with arrays of other sizes, if desired. The electrodes are covered with a thin layer of insulating material (not shown). Finger **102** is shown positioned with respect to array **100**. Electrode array **100** can be one- dimensional for applications in which position in only one dimension is to be sensed.

Histogram **110** shows the capacitances for electrodes **101** in array **100** with respect to finger **102**. Such capacitances are a two- dimensional sampling of the distribution of capacitance between array **100** and finger **102**. The centroid (center of gravity or first moment) **111** of such distribution will correspond to the position of finger **102**, or some other object touching array **100**, if suitable sampling criteria are met; that is, by choosing electrodes of sufficiently small size when compared to the extent of the distribution. Such criteria are discussed in the Blonder et al. patent referred to above.

The x and y coordinates of the centroid can be determined by directly measuring the capacitance at each electrode **101** and calculating such x and y coordinates from such measured capacitances. Thus, for the 4×4 array **100**, sixteen capacitance measurements would be needed. The number of measurements can be reduced, however, by taking advantage of the fact that the one-dimensional centroids of the projections of the distribution onto the x and y axes also correspond to the finger position. Such projections can be formed by subdividing each electrode **101** into two elements, as shown in FIG. **2**.

FIG. **2** shows four such subdivided electrodes in more detail at an intersection of two rows and two columns in array **100**. As can be seen from FIG. **2**, a horizontal element **201** and a vertical element **202** are situated at each intersection of a row and column. Horizontal elements **201** are interconnected by leads **203** and vertical elements **202** are interconnected by leads **204**. Elements **201** and **202** can be interdigitated as shown. It is advantageous for the conducting areas of elements **201** and **202** to cover the surface of array **100** as completely as possible. For finger strokes, we have used interdigitated elements **201** and **202** that are approximately 0.37" square. Smaller electrodes **101** or elements **201** and **202** be desirable for use with a hand-held stylus having a smaller cross-section than a finger.

As will be clear to those skilled in the art, elements **201** and **202** can be fabricated in one plane of a multi-layer printed circuit board together with one set of interconnections, for example, the horizontal row connections **203**. The vertical row connections **204** can then be fabricated in another plane of the circuit board with appropriate via connections between the planes.

Other electrode array configurations can be used, if desired. For example, FIG. **3** shows horizontal strip electrodes **203'** overlapping vertical strip electrodes **204'**. Electrodes **203'** and **204'** are separated by a thin insulating layer (not shown) and covered by another thin insulating layer (not shown). In such a configuration, areas of electrodes **204'** must be left unmasked by electrodes **203'** so that electrodes **204'** can still "see" the capacitance of an object touching the surface in which such electrodes are embedded. A similar configuration of electrodes is shown in the Blonder et al. patent. However, the structure of FIG. **2** is preferred because the interdigitated elements **201** and **202** do not overlap and the capacitance values measured can be higher for a given area of array **100**, thus providing greater noise immunity.

FIG. **4** is an overall block diagram of a capacitive sensor **400** in accordance with the invention. Electrode array **100** comprises rows and columns of electrodes, for example, rows and columns of connected horizontal and vertical elements as shown in FIG. **2**. Referring again to FIG. **4**, each row and column of electrodes from array **100** is connected to an integrating amplifier and bootstrap circuit **401**, which is shown in more detail in FIG. **5** and will be described below. Each of the outputs from circuits **401** can be selected by multiplexer **402** under control of microcontroller **406**. The selected output is then forwarded to summing circuit **403**, where such output is combined with a signal from trimmer resistor **409**. Synchronous detector and filter **404** convert the output from summing circuit **403** to a signal related to the capacitance of the row or column selected by multiplexer **402**. RF oscillator **408** provides an RF signal, for example, 100 kilohertz, to circuits **401**, synchronous detector and filter **404** via inverter **410**, and guard plane **411**. Guard plane **411** is a substantially continuous plane parallel to array **100** and associated connections, and serves to isolate array **100** from extraneous signals. The operation of synchronous detector and filter **404** is well known in the art, for example, see page 889 of "The Art of Electronics," Second Edition, by Horowitz and Hill, Cambridge University Press (1989). A capacitive proximity detector having a single electrode, a guard plane and similar circuitry is disclosed in co-pending Application No. 07/861,667 for R. A. Boie et al. filed Apr. 1, 1992, now U.S. Pat. No. 5,337,353.

Apparatus similar to that shown in FIG. **4** can also be used for applications in which it is desired to measure separate capacitance values for each electrode in array **100** instead of the collective capacitances of subdivided electrode elements connected in rows and columns. To measure such capacitances separately, a circuit **401** is provided for each electrode in array **100** and multiplexer **402** is enlarged to accommodate the outputs from all circuits **401**.

The output of synchronous detector and filter **404** is converted to digital form by analog-to-digital converter **405** and forwarded to microcontroller **406**. Thus, microcontroller **406** can obtain a digital value representing the capacitance seen by any row or column of electrode elements (or electrode if measured separately) selected by multiplexer **402**. Buttons **407**, which can be auxiliary pushbuttons or switches situated near array **400**, are also connected to microcontroller **406**. Buttons **407** can be used, for example, for the same purposes as the buttons on a computer mouse. Microcontroller **406** sends data to utilizing means, such as a personal computer (not shown) over lead **420**. A particular device that can be used for A/D converter **405** and microcontroller **406** is the 87C552 circuit made by Intel Corporation, which includes both an A/D converter and a microprocessor.

FIG. **5** is a circuit diagram of each integrating amplifier and bootstrap circuit **401**. The RF signal from RF oscillator **408** drives the base of transistor Q1 and the bootstrap circuit comprised of resistor **501** and capacitor **502**. Current source **503** provides a constant DC bias current through transistor Q1. An electrode in array **100** is connected to the emitter of transistor Q1. The RF current to an electrode is determined by the capacitance seen by the electrode; thus, an increase in capacitance caused by the proximity of an object, such as a finger, causes in increase in such current. Such an increase is reflected as a change in the RF current flowing from the collector of transistor Q1. The collector of transistor Q1 is connected to the input node of integrating amplifier **505** via coupling capacitor **506**. For a change in capacitance, ΔC, at the electrode, the change in the amplitude of the output signal from amplifier **505** will be approximately $A(\Delta C/C_f)$, where A is the amplitude of the RF signal from oscillator **408** and C_f is the value of integrating capacitor **507**. Resistor **508** provides a bias current for amplifier **505** and resistor **504** provides bias current for transistor Q1.

The effects of electrode-to-electrode capacitances, wiring capacitances and other extraneous capacitances are minimized by driving all electrodes and guard plane **411** in unison with the same RF signal from RF oscillator **408**. The bootstrap circuit serves to minimize any signal due to the finite impedance of the biasing circuit of transistor Q1. The base-to-collector capacitance of transistors Q1 and other stray capacitances in the circuit can be compensated for by adjusting trim resistor **109** shown in FIG. **1**.

In using the position sensor of the invention as a computer mouse or trackball to control a cursor, movement of the mouse or trackball is emulated by touching array **100** with finger **102**, or some other object, and stroking finger **102** over array **100** to move the cursor. Changes in position of the finger with respect to array **100** are reflected in corresponding changes in position of the cursor. Thus, for such an application, microcontroller **406** sends data over lead **420** relating to changes in position. FIG. **6** is a flow chart of the operation of microcontroller **406** in such an application.

Referring to FIG. **6**, microcomputer **406** reads the initial capacitance values for all the elements in array **100** and stores such values (step **601**). Such initial values should reflect the state of array **100** without a finger or other object being nearby, accordingly, it may be desirable to repeat step **601** a number of times and then to select the minimum capacitance values read as the initial values, thereby compensating for the effect of any objects moving close to array **100** during the initialization step. After initialization, all capacitance values are periodically read and the initial values subtracted to yield a remainder value for each element (step **602**). If one or more of the remainders exceeds a preset threshold (step **603**), indicating that an object is close to or touching array **100**, then the x and y coordinates of the centroid of capacitance for such object can be calculated from such remainders (step **604**). For applications in which the electrodes of array **100** are connected in rows and columns, as shown in FIG. **2** and FIG. **3**, such calculation can be performed as follows:

$$x = \frac{\sum_{n_x=1}^{u_x} n_x V(n_x)}{\sum_{n_x=1}^{u_x} V(n_x)} \tag{1}$$

$$y = \frac{\sum_{n_y=1}^{u_y} n_y V(n_y)}{\sum_{n_y=1}^{u_y} V(n_y)} \tag{2}$$

where:

u_x is the number of columns, $V(n_x)$ is the remainder value for column n_x, u_y is the number of rows and $V(n_y)$ is the remainder value for row n_y. To avoid spurious operation, it may be desirable to require that two or more measurements exceed the preset threshold. The threshold can be set to some percentage of the range of A/D converter **405**, for example 10–15% of such range. Note that the value of x can neither be less than 1 nor more than u_x and the value of y can neither be less than 1 nor more than u_y.

For applications in which the capacitance values for the electrode **101** in array **100** are measured separately, the x and y values of the centroid can also be calculated using equations (1) and (2) by adding all the capacitances measured for a row or column to obtain the value of V for such row or column. Such addition has the same effect as if the electrodes were connected together in a row or column.

When set, the "T" flag indicates that remainders were above the threshold during the previous iteration through step **603**. Such flag is set during step **606** and cleared during step **607**. Thus, after the first iteration through step **603**, indicating a new stroke of finger **102** on array **100**, the "T" flag is set and the x and y values just calculated are stored. During each subsequent iteration during such stroke, the changes in x and y(dx and dy) are calculated (step **608**) as follows:

$$dx = x_c - x_p \tag{3}$$

$$dy = y_c - y_p \tag{4}$$

where x_c and y_c are the values just calculated in step **605** and x_p and y_p are the values calculated and stored (step **610**) during the previous iteration.

It may be desirable to remove jitter from the least-significant bit in the values of dx and dy calculated (step **609**). This can be accomplished by incrementing negative values by 1 and decrementing positive values by 1, leaving zero values without change.

The values calculated for x and y are stored (step **610**) for use in calculating dx and dy during the next iteration. Then, if other inputs, such as buttons **407**, are connected to microcontroller **406**, the state of such inputs is read (step **611**). Finally, if x and y have changed (dx≠0 or dy≠0) or the state of buttons **407** has changed (step **612**), data relating to such changes is sent over line **420** to the computer or other utilizing means to which sensor **400** is connected (step **613**). Such data typically includes dx, dy and the current state of the buttons, which corresponds to that sent to a computer by a conventional computer mouse or trackball. Finally the states of such other inputs are stored (step **614**) for use during the next iteration.

Typically the cycle time through the above-described steps will be about 20 milliseconds, depending on the time constant of the filter in circuit **404**. After each change of multiplexer **402**, microcontroller **406** is programmed to wait approximately 2 milliseconds for the output of circuit **404** to settle.

It will be clear that the absolute values of x and y can be included in the data sent over line **420** to utilizing means, if desired. For example, capacitive input sensor **400** can be adapted for use as a general purpose input pad for entering handwritten information. For such an application, it may be desirable to increase the number of electrodes to improve definition, but even a 4×4 matrix for use with finger input can produce useful input data because of the interpolating effect of the centroid-finding calculations performed in step **604**.

Instead of using buttons **407** for additional input when array sensor **100** is used as a computer mouse, it may be desirable to sense different finger pressures. For example, to perform a "click and drag" operation, a typical use of a computer mouse, a heavier finger pressure can be used on array **100** than when an ordinary cursor movement is desired. Clearly finger pressures can be sensed by electromechanical or other means, but differences in the capacitances sensed by sensor **400** can also be used for this purpose.

The magnitudes of the capacitance values sensed by array **100** are somewhat related to finger pressure because of the compressibility of the fingertip when contacting array **100**. Higher finger pressure will cause higher capacitance values to be sensed. This effect can be enhanced by replacing the insulating layer (not shown) on array **100** with a compressible insulating layer. Different finger pressures can be set by defining one or more additional thresholds for use in step **603**. An ordinary touch would cause the remainders to exceed only the first threshold; a heavier touch would cause at least one remainder to exceed a higher threshold, which could then be used to indicate a different button state.

FIG. **7** is a diagram showing how an array **100** can be used as a keyboard in accordance with the invention. Again, array **100** is shown as a 4×4 matrix of electrodes, but with a keyboard pattern overlay superimposed on the matrix. The dotted lines indicate such matrix. Such a keyboard pattern can be printed on the insulating layer covering the electrodes. Note that the individual "keys" in the keyboard do not necessarily correspond to the underlying electrodes. The x and y coordinates are shown for reference purposes. Since the values obtained for x and y in a 4×4 matrix using equations (1) and (2) will range from 1 to 4, this range is shown on the coordinates.

The identity of a key touched is determined from the x and y values computed for the centroid of capacitance resulting from the touch. For example, using the x and y coordinates shown in FIG. **7**, a "5" can be defined as a touch with $[1.7 \leq x \leq 2.3, 2.3 \leq y \leq 2.7]$; a "0" can be defined as a touch with $[1 \leq x \leq 2.3, 1 \leq y \leq 1.3]$; and a "+" can be defined as a touch with $[3.7 \leq x \leq 4, 2.4 \leq y \leq 3.5]$. These ranges are chosen to leave guard bands between adjacent keys. Such a range for each key on the keyboard is stored in microprocessor **406**.

FIG. **8** is a flow chart showing operation of microcontroller **406** when the capacitive position sensor of the invention is used as a keyboard. Steps **801**, **802**, **803** and **805** are similar to steps **601**, **602**, **603** and **604**, respectively, in FIG. **6**. In step **805**, the identity of the key touched is determined from the stored ranges and the values of x and y calculated in step **806**. In step **807**, the identity of the key touched is sent to utilizing means. The "T" flag is set in step **808**, cleared in step **809** and tested in step **804**. Such flag assures that the key identity is sent to utilizing means only once.

It should be clear that the various ways described above of using the capacitive position sensor of the invention can be combined. For example, a combination mouse-keyboard can be implemented in which one portion of array **100** is used as a mouse responsive to finger strokes and a second portion is used as a keyboard responsive to finger touches. Alternatively, array **100** can be adapted to operate in different modes: the first mode as a mouse, the second as a keyboard. Switching between modes can be accomplished, for example, with one of buttons **407**, or with extra pressure in a specified region of array **100**. Thus, where space is at a premium, such as in a portable computer, the capacitive position sensor of the invention can be used as part of the keyboard and also as a mouse.

The invention has been shown and described with reference to particular embodiments. However, it will be understood by those skilled in the art that various changes may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A sensor for capacitively sensing the position in a continuous range of positions of an object on a surface of an input device, which comprises:

an array of electrodes on said surface;

an insulating layer covering said electrodes;

means connected to said electrodes for measuring a capacitance value for each said electrode;

means responsive to said measuring means for comparing said capacitance values with a first preset threshold and, if at least one of said capacitance values exceeds said first preset threshold, for calculating the position of a centroid of capacitance for said array from said measured capacitance values, said first preset threshold being set at a capacitance value that is exceeded for a given electrode only when said object is close to or touching said given electrode, said centroid of capacitance being the first moment of the distribution of said capacitance values in said array and representing substantially the position of said object on said surface; and

means responsive to said calculating means and connected to utilizing means for sending said centroid of capacitance position to said utilizing means.

2. The sensor of claim **1** in which said array is a two-dimensional array and said electrodes are arranged in rows and columns.

3. The sensor of claim **2** wherein said input device is a keyboard, said sensor further comprising:

means for designating portions of the surface of said keyboard to represent different keys; and

said calculating means comprises:

means for storing a range of coordinates for each key in said keyboard;

means for comparing said centroid of capacitance position with said ranges of coordinates and selecting the range of coordinates in which said centroid of capacitance position falls, and

said sending means comprises means for sending the identity of the key associated with said selected range of coordinates to said utilizing means.

4. The sensor of claim **2** wherein each said electrode comprises:

at each intersection of a row and a column, a first electrode element connected to other first electrode elements in said row and a second electrode element connected to other second electrode elements in said column,

and wherein said means for measuring a capacitance value for each electrode is adapted to measure the capacitance value for each row of said first electrode elements and the capacitance value for each column of said second electrode elements.

5. The sensor of claim **4** wherein said first and second electrode elements at each intersection are interdigitated.

6. The sensor of claim **1** wherein said calculating means periodically calculates changes in said centroid of capacitance position and said sending means periodically sends said changes to said utilizing means.

7. The sensor of claim **1** which further comprises:

means responsive to said measuring means for comparing said capacitance values with a second preset threshold and for indicating to said utilizing means when said second preset threshold is exceeded, said second preset threshold being set at a capacitance value higher than said first preset threshold.

8. The sensor of claim **1** wherein said measuring means comprises:

means connected to said electrodes for supplying the same RF signal in unison to each said electrode,

means connected to said electrodes for sensing RF currents flowing between said electrodes and said object in response to said RF signal, and

means connected to said RF current sensing means for converting said RF currents into signals representative of said capacitance values for each said electrode.

9. The sensor of claim **8**, which further comprises:

a guard plane substantially parallel to said electrodes, and said means for supplying an RF signal further comprises:

means connected to said guard plane for supplying said RF signal to said guard plane in unison with the RF signals supplied to said electrodes.

10. A touch-sensitive input device for a computer, which comprises:

an array of electrodes on a surface of said input device, said electrodes being arranged in rows and columns;

an insulating layer covering said electrodes;

means connected to said electrodes for measuring a capacitance value for each said electrode;

means responsive to said measuring means for comparing said capacitance values with a first preset threshold and, if at least one of said capacitance values exceeds said first preset threshold, for calculating the coordinates of a centroid of capacitance for said array from said measured capacitance values, said centroid of capacitance corresponding to the position of a finger or other object touching said surface, said first preset threshold being set at a capacitance value that is exceeded for a given electrode only when said finger or other object is close to or touching said surface in the vicinity of said given electrode, said centroid of capacitance being the first moment of the distribution of said capacitance values in said array and representing substantially the position of said object in a continuous range of positions on said surface; and

means responsive to said calculating means and connected to said computer for sending information to said computer indicative of or derived from said calculated coordinates.

* * * * *

EXHIBIT D

US005565658A

United States Patent [19]

Gerpheide et al.

[11] **Patent Number: 5,565,658**

[45] **Date of Patent: Oct. 15, 1996**

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[54] **CAPACITANCE-BASED PROXIMITY WITH INTERFERENCE REJECTION APPARATUS AND METHODS**

[75] Inventors: **George E. Gerpheide; Michael D. Layton**, both of Salt Lake City, Utah

[73] Assignee: **Cirque Corporation**, Salt Lake City, Utah

[21] Appl. No.: **351,008**

[22] Filed: **Dec. 7, 1994**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 193,275, Feb. 8, 1994, Pat. No. 5,478,170, which is a continuation of Ser. No. 914,043, Jul. 13, 1992, Pat. No. 5,305,017.

[51] **Int. Cl.**^{6} **G08C 21/00**

[52] **U.S. Cl.** **178/19**; 345/174

[58] **Field of Search** 178/18, 19, 20; 345/168, 173, 174; 328/5; 342/16

[56] **References Cited**

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4,371,746	2/1983	Pepper, Jr.	178/18
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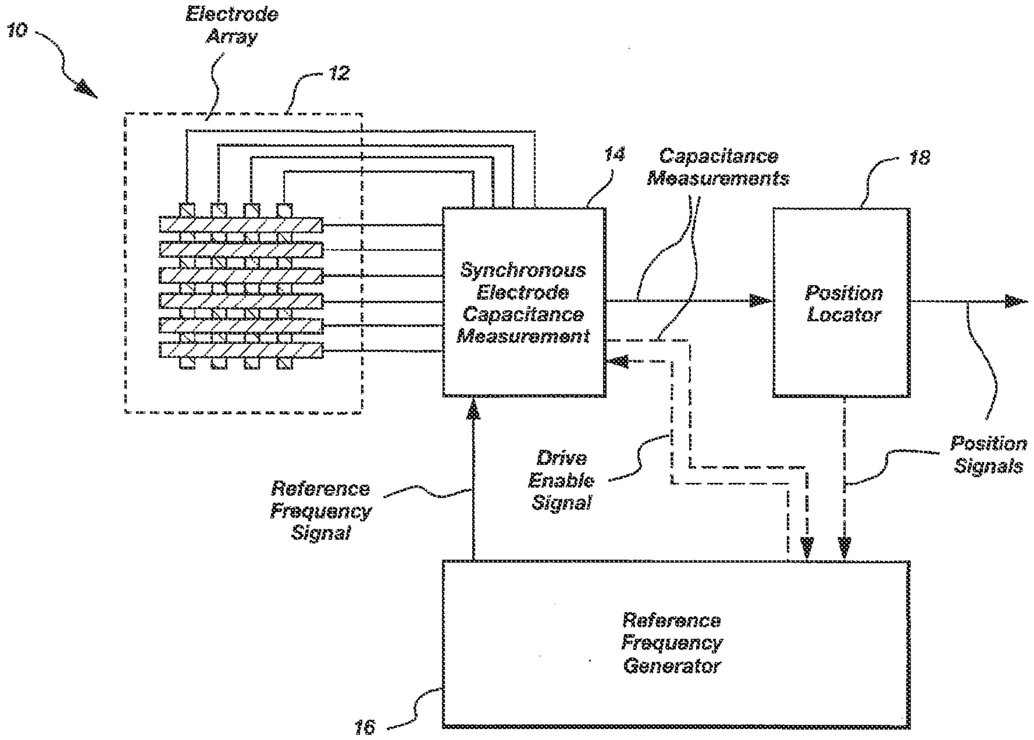
5,053,757	10/1991	Meadows	178/18 X
5,305,017	4/1994	Gerpheide	345/174

Primary Examiner—Stephen Chin
Assistant Examiner—Paul Loomis
Attorney, Agent, or Firm—Thorpe, North & Western

[57] **ABSTRACT**

Apparatus and method for a capacitance-based proximity sensor with interference rejection. A pair of electrode arrays establish a capacitance on a touch detection pad, the capacitance varying with movement of a conductive object near the pad. The capacitance variations are measured synchronously with a reference frequency signal to thus provide a measure of the position of the object. Electrical interference is rejected by producing a reference frequency signal which is not coherent with the interference.

14 Claims, 8 Drawing Sheets



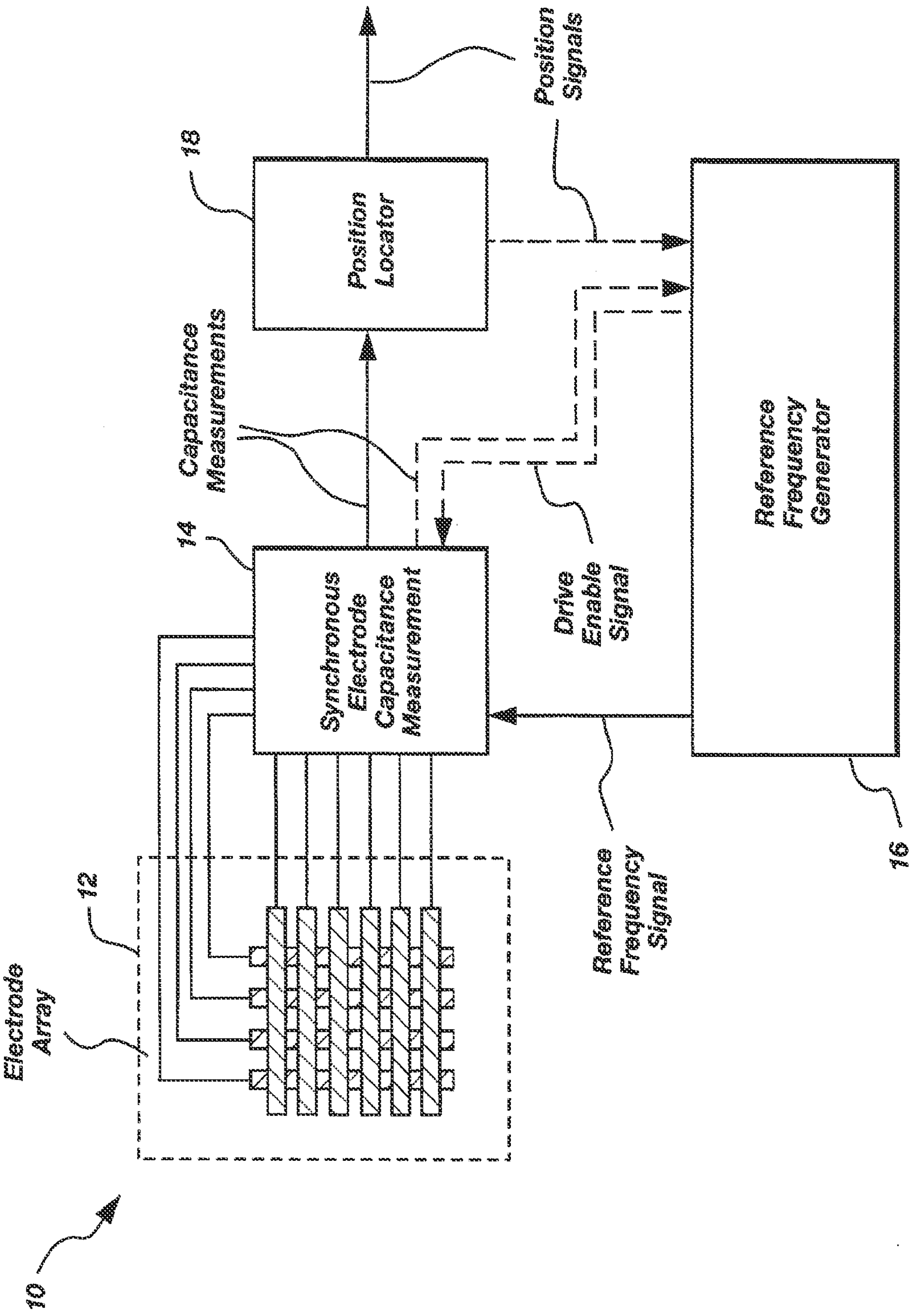

10
Electrode Array
12
Synchronous Electrode Capacitance Measurement
14
Capacitance Measurements
Position Locator
18
Position Signals
Drive Enable Signal
Reference Frequency Signal
Reference Frequency Generator
16

Fig. 1

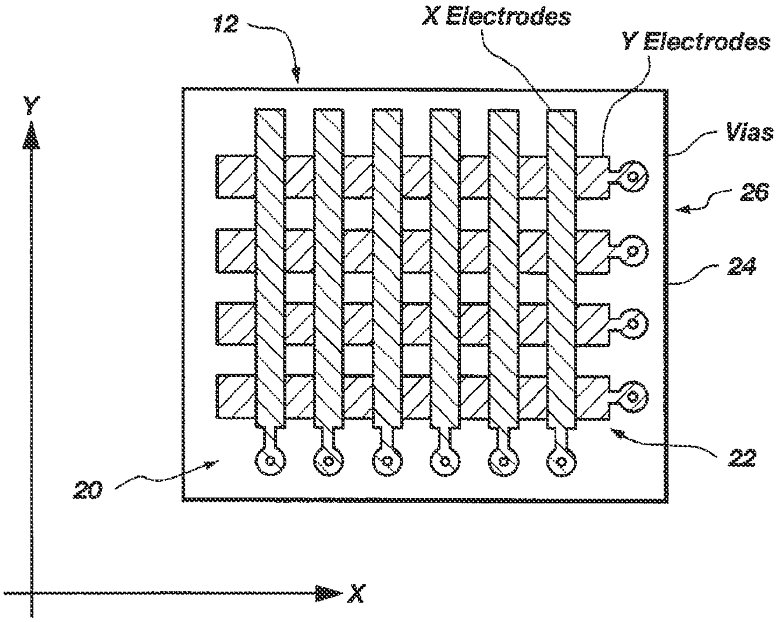

12
X Electrodes
Y Electrodes
Vias
26
24
22
20
Y
X

Fig. 2a

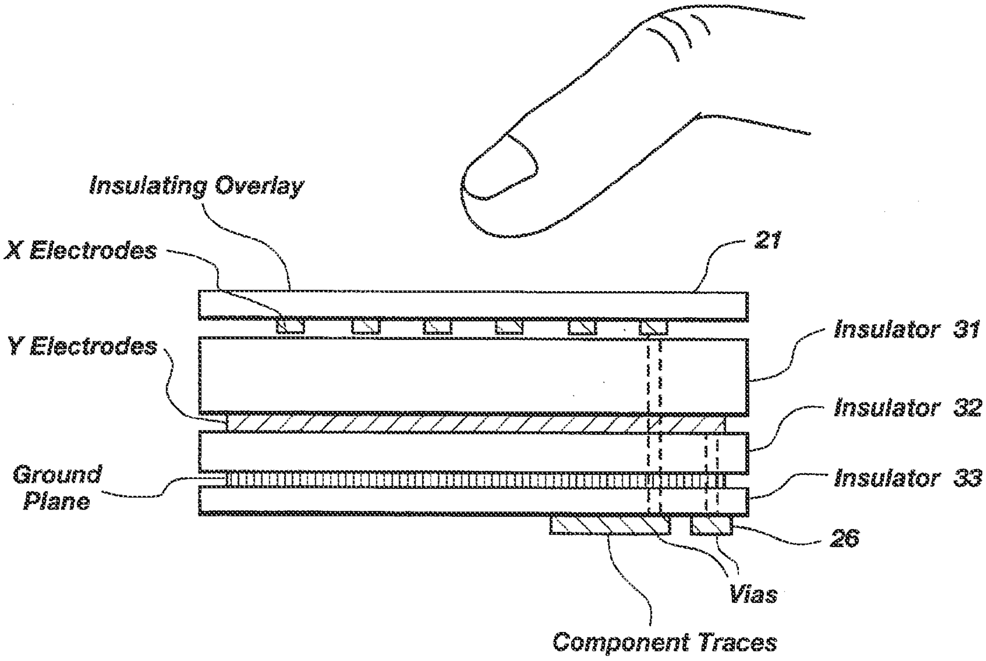

Insulating Overlay
X Electrodes
21
Y Electrodes
Insulator 31
Insulator 32
Ground Plane
Insulator 33
26
Vias
Component Traces

Fig. 2b

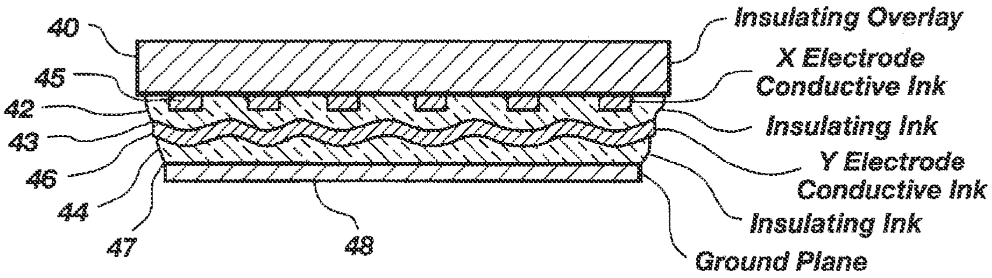

40
45
42
43
46
44
47
48
Insulating Overlay
X Electrode
Conductive Ink
Insulating Ink
Y Electrode
Conductive Ink
Insulating Ink
Ground Plane

Fig. 3a

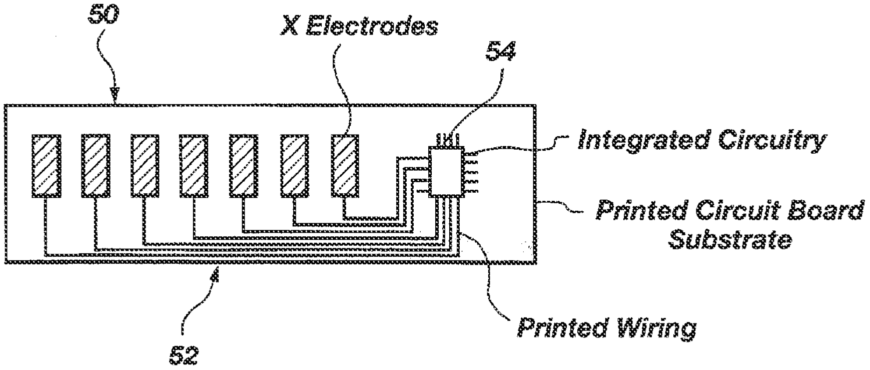

50
X Electrodes
54
Integrated Circuitry
Printed Circuit Board
Substrate
Printed Wiring
52

Fig. 3b

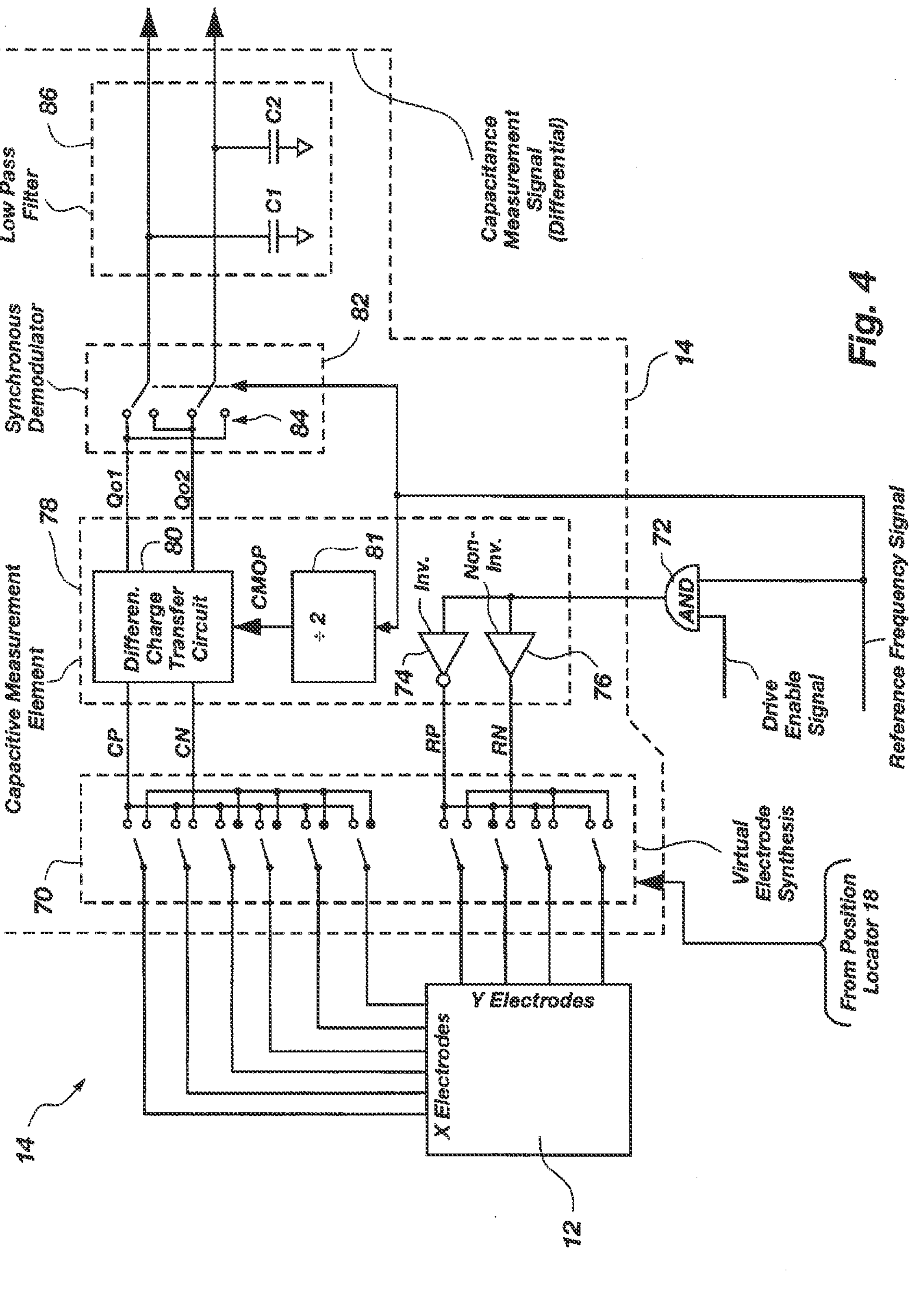

Capacitive Measurement Element
78
Low Pass Filter
86
Synchronous Demodulator
82
84
Differen. Charge Transfer Circuit
80
CMOP
÷ 2
81
Qo1
Qo2
CP
CN
RP
RN
Inv.
Non-Inv.
74
76
72
AND
C1
C2
Capacitance Measurement Signal (Differential)
14
70
Virtual Electrode Synthesis
Drive Enable Signal
Reference Frequency Signal
From Position Locator 18
X Electrodes
Y Electrodes
12
14

Fig. 4

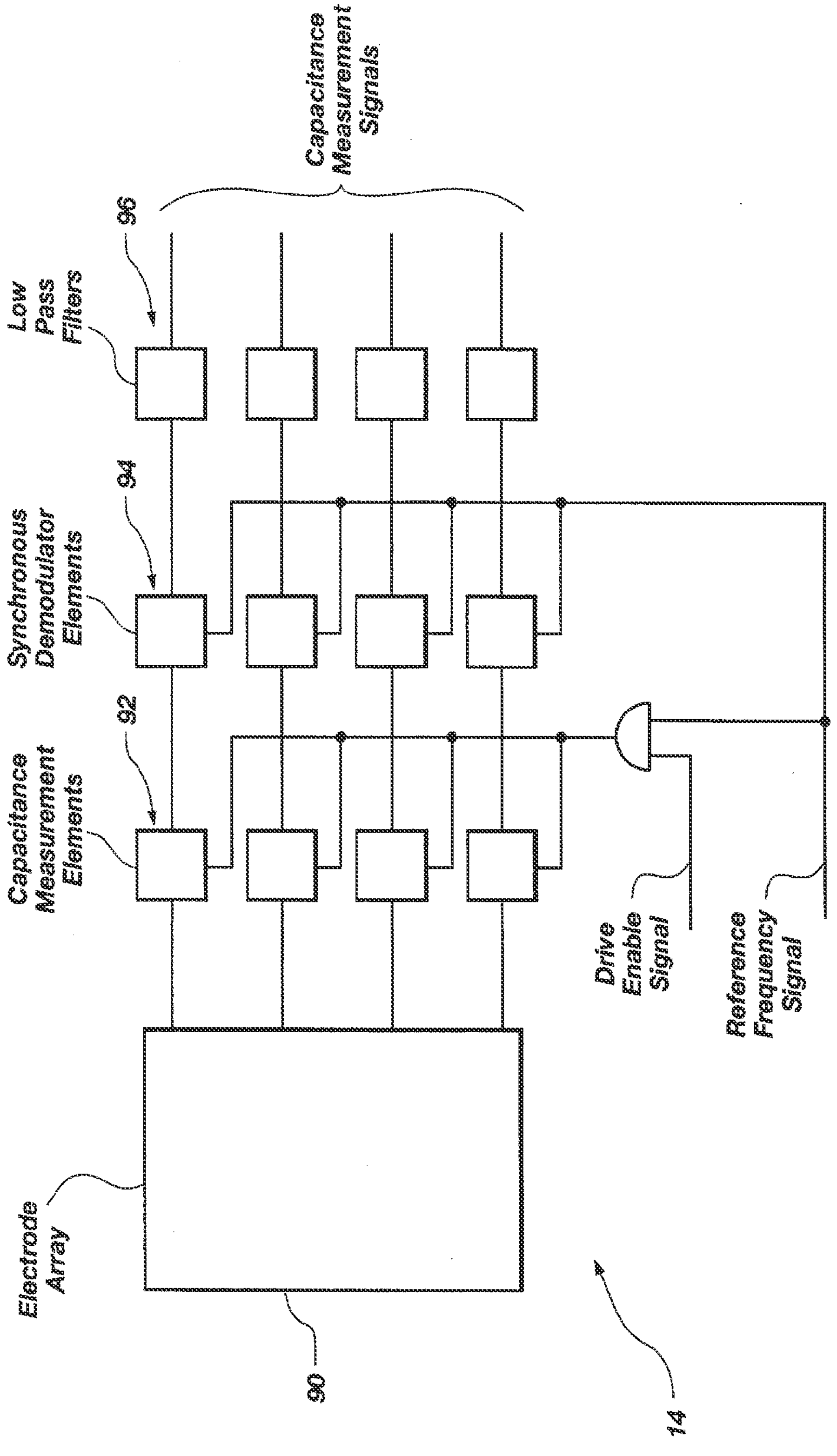

Capacitance Measurement Signals
96
Low Pass Filters
94
Synchronous Demodulator Elements
92
Capacitance Measurement Elements
Drive Enable Signal
Reference Frequency Signal
Electrode Array
90
14

Fig. 5

Fig. 6a

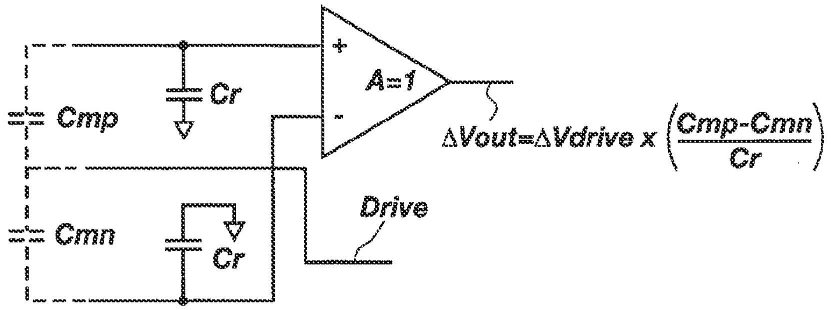


Fig. 6b

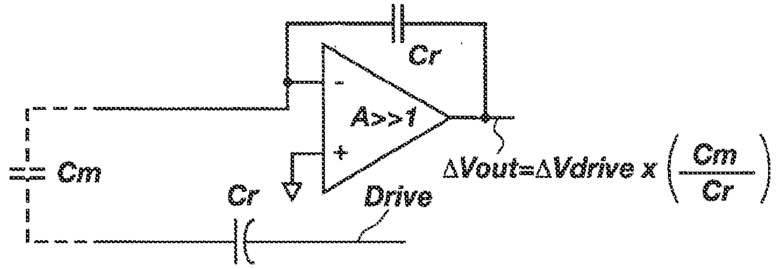


Fig. 6c

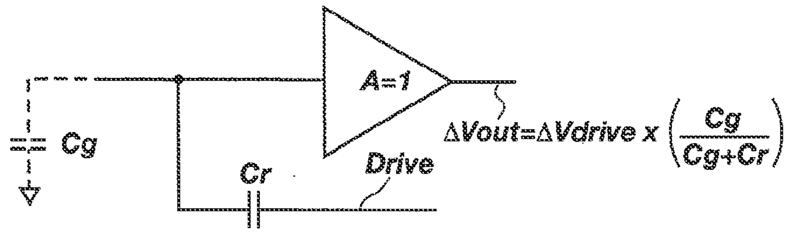
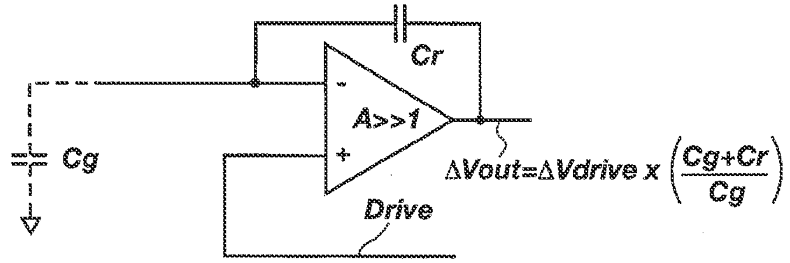


Fig. 6d



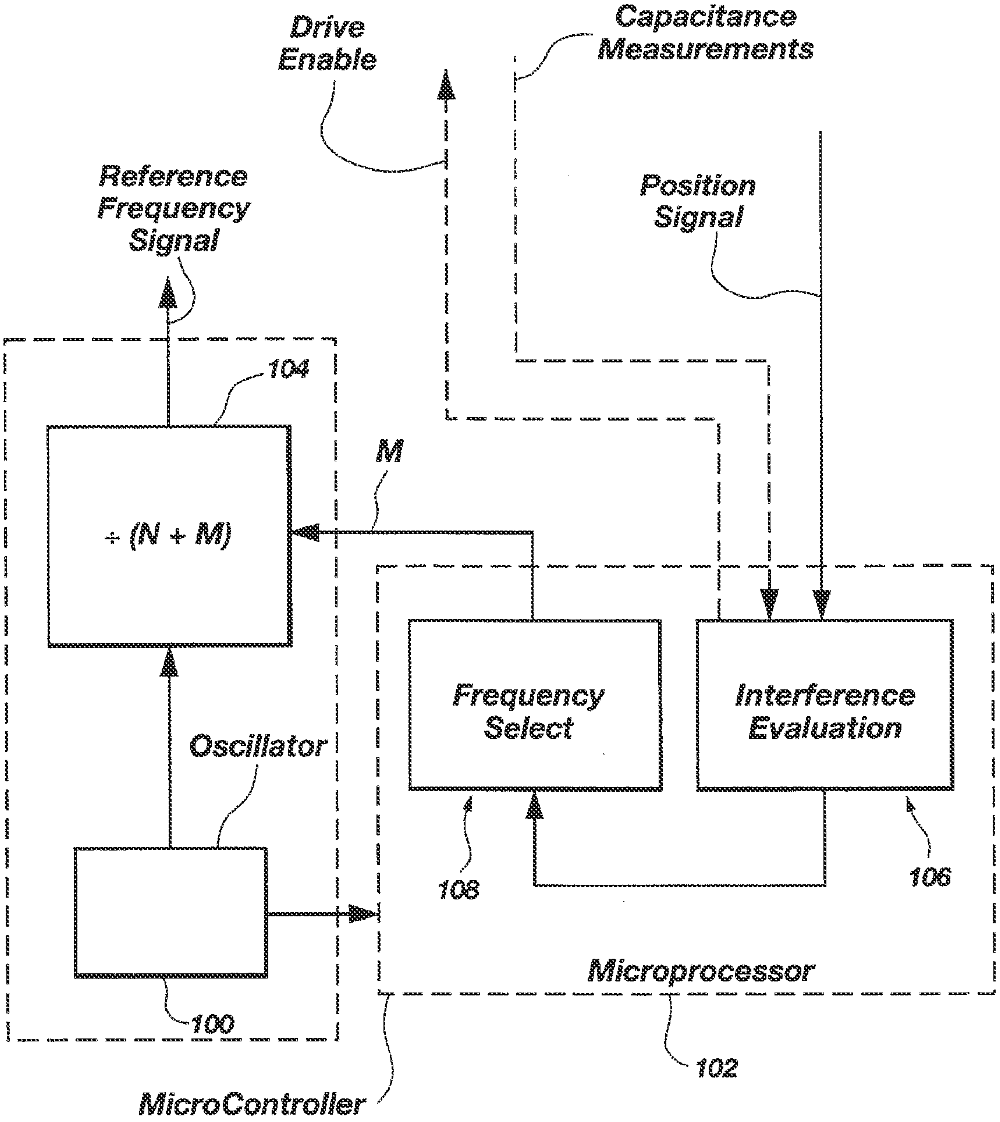

Drive Enable
Capacitance Measurements
Reference Frequency Signal
Position Signal
104
M
÷ (N + M)
Frequency Select
Interference Evaluation
Oscillator
108
106
Microprocessor
100
102
MicroController

Fig. 7

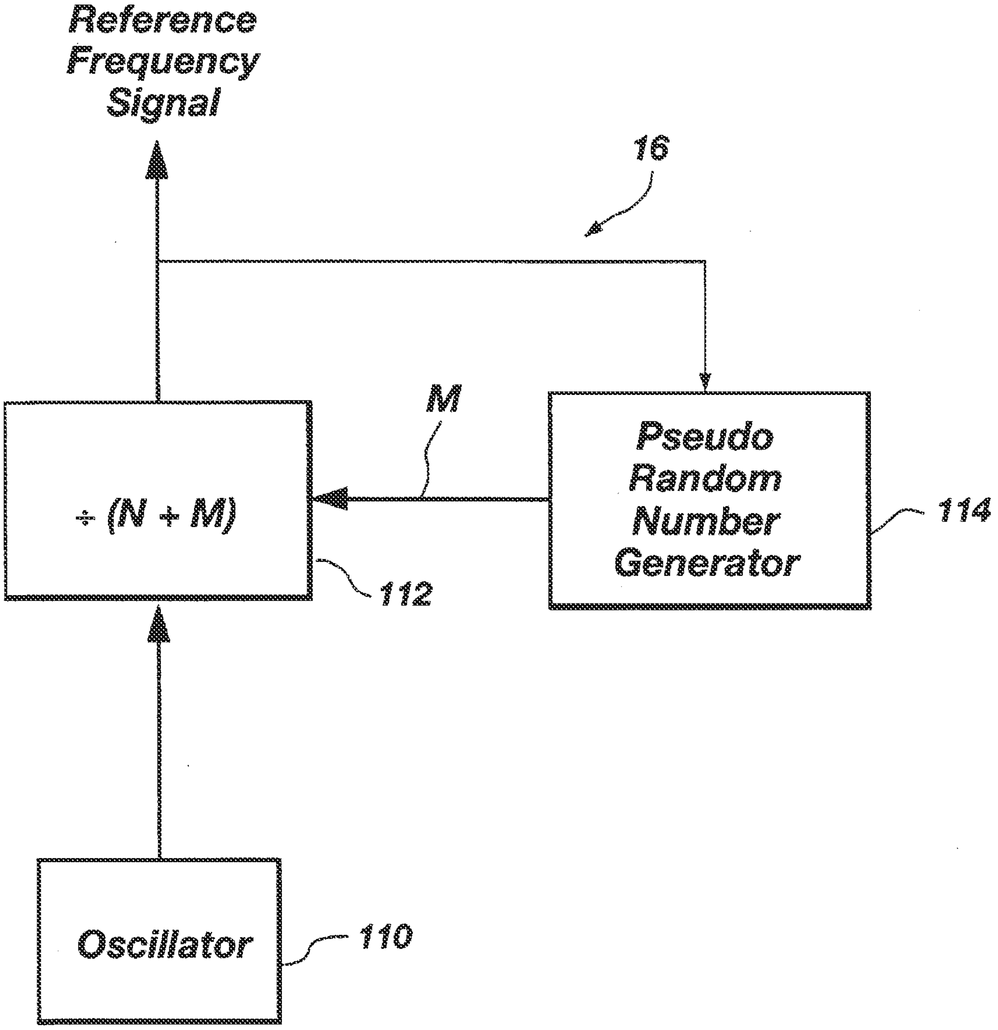

Reference
Frequency
Signal
16
M
÷ (N + M)
112
Pseudo
Random
Number
Generator
114
Oscillator
110

Fig. 8

CAPACITANCE-BASED PROXIMITY WITH INTERFERENCE REJECTION APPARATUS AND METHODS

The following patent is a continuation-in-part patent of U.S. patent application Ser. No. 08/193,275, filed Feb. 8, 1994, now U.S. Pat. No. 5,478,170, which is a continuation of Ser. No. 914,043, filed Jul. 13, 1992, now U.S. Pat. No. 5,305,017.

This invention relates generally to apparatus and methods for touch sensitive input devices, and more particularly, to apparatus and methods for capacitance-based touch detection wherein electrical interference is effectively rejected from the detection system.

BACKGROUND OF THE INVENTION

Numerous prior art devices and systems exist by which tactile sensing is used to provide data input to a data processor. Such devices are used in place of common pointing devices (such as a "mouse" or stylus) to provide data input by finger positioning on a pad or display device. These devices sense finger position by a capacitive touch pad wherein scanning signals are applied to the pad and variations in capacitance caused by a finger touching or approaching the pad are detected. By sensing the finger position at successive times, the motion of the finger can be detected. This sensing apparatus has application for controlling a computer screen cursor. More generally it can provide a variety of electrical equipment with information corresponding to finger movements, gestures, positions, writing, signatures and drawing motions.

In U.S. Pat. No. 4,698,461, Meadows et al., a touch surface is covered with a layer of invariant resistivity. Panel scanning signals are applied to excite selected touch surface edges so as to establish an alternating current voltage gradient across the panel surface. When the surface is touched, a touch current flows from each excited edge through the resistive surface and is then coupled to a user's finger (by capacitance or conduction), through a user's body, and finally coupled by the user's body capacitance to earth ground potential. Different scanning sequences and modes of voltage are applied to the edges, and in each case the currents are measured. It is possible to determine the location of touch by measuring these currents. In particular, the physical parameter which indicates touch location is the resistance from the edges to the point of touch on the surface. This resistance varies as the touch point is closer or farther from each edge. For this system, the term "capacitive touch pad" may be a misnomer because capacitance is involved as a means of coupling current from the surface touch point through the user's finger but is not the parameter indicative of finger position. A disadvantage of this invention is that accurate touch location measurement depends on uniform resistivity of the surface. Fabricating such a uniformly resistive surface layer can be difficult and expensive, and require special fabrication methods and equipment.

The panel of the Meadows '461 patent also includes circuitry for "nulling", or offsetting to zero, the touch currents which are present when the panel is not touched. This nulling can be accomplished while the panel operates, and allows touches which generate a relatively weak signal, such as from a gloved finger, to be more accurately determined. The Meadows '461 panel also includes circuitry for automatically shifting the frequency of panel scanning signals away from spectra of spurious signals, such as those developed by cathode-ray tube transformers, which may be present in the environment. The panel seeks to avoid interference from the spurious signals, which could happen if the frequency of scanning was nearly equal to that of the spurious signals. A microcontroller determines whether the scanning frequency should be shifted by monitoring the rate at which adjustments are required in nulling of the touch currents, as described above. The only means described for generating frequency control signals is based on this nulling adjustment.

U.S. Pat. No. 4,922,061, Meadows et al., is similar to the Meadows '461 patent in that the touch panel determines touch location based on variations in resistance, not capacitance. This is particularly evident from FIG. 2 where the resistances from edge to touch point are shown as Kx times Rx, where Kx is corresponds to the distance indicated by **76A**. The apparatus uses a measurement signal of a frequency that varies in a substantially random manner, thus reducing susceptibility to interference from spurious electromagnetic spectra.

U.S. Pat. No. 4,700,022, Salvador, describes an array of detecting conductive strips, each laid between resistive emitting strips. The finger actually makes electrical contact from an emitting strip to detecting strip. Touch location is determined from resistance variation (as with Meadows '461 and '061 above) in the strip contacted by the finger. Averages are taken of a certain number of synchronous samples. A design formula is presented to choose a sampling frequency so that it is not a multiple of the most undesired predetermined interfering signal. No suggestion is made that sampling frequency is adjusted or adapts automatically.

In U.S. Pat. No. 5,305,017, Gerpheide, touch location is determined by true capacitance variation, instead of resistance variation, using a plurality of electrode strips forming virtual electrodes. This approach eliminates the necessity of a coating having uniform resistance across a display screen. However, such a capacitance-based detection device may suffer from electrical background interference from its surroundings, which is coupled onto the sensing electrodes and interferes with position detection. These spurious signals cause troublesome interference with the detection of finger positioning. The device operator may even act as an antenna for electrical interference which may cause a false charge injection or depletion from the detecting electrodes.

Accordingly, there is a need for a touch detection system which has the following characteristics:

(1) the touch location is determined without the need of resistance variation so as to avoid the high cost of requiring uniform resistance during fabrication;

(2) the touch location is measured in a manner independent of resistance of the electrodes or their connecting wiring, thus broadening the range of materials and processes which may be used for fabrication; and

(3) electrical interference signals are rejected and eliminated from the detection system regardless of their frequency and without requiring possibly expensive nulling apparatus.

SUMMARY OF THE INVENTION

The present invention employs a touch location device having true capacitance variation by using insulated electrode arrays to form virtual electrodes. The capacitance variation is measured by means independent of the resistance of the electrodes, so as to eliminate that parameter as a fabrication consideration. The electrical interference is eliminated regardless of frequency to provide a clear detection signal.

An illustrative embodiment of the present invention includes an electrode array for developing capacitances which vary with movement of an object (such as finger, other body part, conductive stylus, etc.) near the array, a synchronous capacitance measurement element which measures variation in the capacitances, such measurements being synchronized with a reference frequency signal, and a reference frequency signal generator for generating a reference frequency signal which is not coherent with electrical interference which could otherwise interfere with capacitance measurements and thus position location.

Interference rejection is carried out by generating a reference frequency signal whose frequency is different from the interference frequency. Alternately, the reference signal is generated with random frequencies so as not to be coherent with the interference frequencies and thus the electrical interference is effectively rejected.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a capacitance variation position measuring device made in accordance with the principles of the present invention;

FIG. 2A is a plan view of one illustrative embodiment of the electrode array shown in FIG. 1;

FIG. 2B is a side, cross-sectional view of one illustrative embodiment of the electrode array of FIG. 2A;

FIG. 3A is a side, cross-sectional view of another embodiment of the electrode array of FIG. 1;

FIG. 3B is a plan view of the electrode array of FIG. 3A;

FIG. 4 is a schematic of one embodiment of the synchronous electrode capacitance measurement device of FIG. 1;

FIG. 5 is a schematic of another embodiment of the synchronous electrode capacitance measurement device of FIG. 1;

FIGS. 6A–6D are circuit diagrams of alternative embodiments of the capacitance measurement elements shown in FIGS. 4 and 5;

FIG. 7 is a block diagram of one embodiment of the reference frequency generator shown in FIG. 1; and

FIG. 8 is a block diagram showing an alternative embodiment of the reference frequency generator shown in FIG. 1.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 shows the essential elements of a capacitance variation finger (or other conductive body or non-body part) position sensing system **10**, made in accordance with the invention. An electrode array **12** includes a plurality of layers of conductive electrode strips. The electrodes and the wiring connecting them to the device may have substantial resistance, which permits a variety of materials and processes to be used for fabricating them. The electrodes are electrically insulated from one another. Mutual capacitance exists between each two of the electrodes, and stray capacitance exists between each of the electrodes and ground. A finger positioned in proximity to the array alters these mutual and stray capacitance values. The degree of alteration depends on the position of the finger with respect to electrodes. In general, the alteration is greater when the finger is closer to the electrode in question.

A synchronous electrode capacitance measurement unit **14** is connected to the electrode array **12** and determines selected mutual and/or stray capacitance values associated with the electrodes. To minimize interference, a number of measurements are performed by unit **14** with timing synchronized to a reference frequency signal provided by reference frequency generator **16**. The desired capacitance value is determined by integrating, averaging, or in more general terms, by filtering the individual measurements made by unit **14**. In this way, interference in the measurement is substantially rejected except for spurious signals having strong frequency spectra near the reference frequency.

The reference frequency generator **16** attempts to automatically select and generate a reference frequency which is not coherent with the most undesirable frequency of spurious signals. This approach substantially eliminates interference even though its frequency is likely to be initially unknown and may even change during operation.

A position locator **18** processes the capacitance measurement signal from the synchronous electrode capacitance measurement unit **14** and provides position signals for use by a host computer, for example, and to the reference frequency generator **16**. The position locator unit **18** determines finger position signals based on the capacitance measurements. Several different systems are commonly known in the art for determining finger position based on measurements of capacitance associated with electrodes in an array. Position locators may provide one-dimensional sensing (such as for a volume slider control), two-dimensional sensing with contact determination (such as for computer cursor control), or full three-dimensional sensing (such as for games and three-dimensional computer graphics.) An example of a prior art position locator unit is shown in the Gerpheide '017 patent mentioned above, as units 40 and 50 of FIG. 1 of the patent.

Electrode Array

FIG. 2A illustrates the electrodes in a preferred electrode array **12**, together with a coordinate axes defining X and Y directions. One embodiment includes sixteen X electrodes and twelve Y electrodes, but for clarity of illustration, only six X electrodes **20** and four Y electrodes **22** are shown. It is apparent to one skilled in the art how to extend the number of electrodes. The array is preferably fabricated as a multilayer printed circuit board **24**. The electrodes are etched electrically conductive strips, connected to vias **26** which in turn connect them to other layers in the array. Illustratively, the array **12** is approximately 65 millimeters in the X direction and 49 millimeters in the Y direction. The X electrodes are approximately 0.7 millimeters wide on 3.3 millimeter centers. The Y electrodes are approximately three millimeters wide on 3.3 millimeter centers.

FIG. *2b* illustrates the electrode array **12** from a side, cross-sectional view. An insulating overlay **21** is an approximately 0.2 millimeters thick clear polycarbonate sheet with a texture on the top side which is comfortable to touch. Wear resistance may be enhanced by adding a textured clear hard coating over the top surface. The overlay bottom surface may be silk-screened with ink to provide graphics designs and colors.

The X electrodes **20**, Y electrodes **22**, ground plane **25** and component traces **27** are etched copper traces within a multilayer printed circuit board. The ground plane **25** covers the entire array area and shields the electrodes from electrical interference which may be generated by the parts of the circuitry. The component traces **27** connect the vias **26** and hence the electrodes **20**, **22**, to other circuit components of FIG. **1**. Insulator **31**, insulator **32** and insulator **33** are fiberglass-epoxy layers within the printed circuit board **24**. They have respective thicknesses of approximately 1.0 millimeter, 0.2 millimeters and 0.1 millimeters. Dimensions may be varied considerably as long as consistency is maintained. However, all X electrodes **20** must be the same size, as must all Y electrodes **22**.

One skilled in the art will realize that a variety of techniques and materials can be used to form the electrode array. For example, FIG. 3A illustrates an alternative embodiment in which the electrode array includes an insulating overlay **40** as described above. Alternate layers of conductive ink **42** and insulating ink **43** are applied to the reverse surface by a silk screen process. The X electrodes **45** are positioned between the insulating overlay **40** and X electrode conductive ink layer **42**. Another insulating ink layer **43** is applied below layer **42**. The Y electrodes **46** are positioned between insulating ink layer **43** and conductive ink layer **44**. Another insulating ink layer **47** is applied below conductive ink layer **44**, and ground plane **48** is affixed to Y electrode conductive ink layer **47**. Each layer is approximately 0.01 millimeters thick.

The resulting array is thin and flexible, which allows it to be formed into curved surfaces. In use it would be laid over a strong, solid support. In other examples, the electrode array may utilize a flexible printed circuit board, such as a flex circuit, or stampings of sheet metal or metal foil.

A variety of electrode geometries and arrangements are possible for finger position sensing. One example is shown in FIG. 3*b*. This is an array of parallel electrode strips **50** for one-dimensional position sensing which could be useful as a "slider volume control" or "toaster darkness control". Other examples include a grid of diamonds, or sectors of a disk.

It is desired that the electrode array of the present invention be easily fabricated by economical and widely available printed circuit board processes. It is also desired to allow use of various overlay materials selected for texture and low friction, upon which logo art work and coloration can be economically printed. A further preference is that the overlay may be custom printed separately from fabrication of the electrode-containing part of the array. This allows an economical standardized mass production of that part of the array, and later affixing of the custom printed overlay.

Synchronous Electrode Capacitance Measurement

FIG. **4** shows one embodiment of the synchronous electrode capacitance measurement unit **14** in more detail. The key elements of the synchronous electrode capacitance measurement unit **14** are (a) an element for producing a voltage change in the electrode array synchronously with a reference signal, (b) an element producing a signal indicative of the displacement charge thereby coupled between electrodes of the electrode array, (c) an element for demodulating this signal synchronously with the reference signal, and (d) an element for low pass filtering the demodulated signal. Unit **14** is coupled to the electrode array, preferably through a multiplexor or switches. The capacitances to be measured in this embodiment are mutual capacitances between electrodes but could be stray capacitances of electrodes to ground or algebraic sums (that is sums and differences) of such mutual or stray capacitances.

FIG. 4 shows one specific embodiment of a synchronous electrode capacitance measurement unit **14** connected to the electrode array **12**, in which algebraic sums of mutual capacitances between electrodes are measured. The components are grouped into four main functional blocks. A virtual electrode synthesis block **70** connects each of the X electrodes to one of the wires CP or CN, and each of the Y electrodes to one of the wires RP or RN. The electrodes are selectively connected to the wires by switches , preferably CMOS switches under control of the position locator apparatus **18** (FIG. **1**) to select appropriate electrodes for capacitance measurement. (See Gerpheide '017 which describes such electrode selection by signal S of FIG. 1 of the patent.) All electrodes connected to the CP wire at any one time are considered to form a single "positive virtual X electrode". Similarly, the electrodes connected to CN, RP, and RN form a "negative virtual X electrode", a "positive virtual Y electrode", and a "negative virtual Y electrode", respectively.

The reference frequency signal is preferably a digital logic signal from the reference frequency generator **16** (FIG. **1**). The reference frequency signal is supplied to unit **14** via an AND gate **72** also having a "drive enable" input, supplied by the reference frequency generator **16** (FIG. **1**). The AND gate output feeds through inverter **74** and noninverting buffer **76** to wires RP and RN respectively which are part of a capacitive measurement element **78**. In the preferred embodiment, the drive enable signal is always TRUE, to pass the reference frequency signal. In further preferred embodiments, it is asserted FALSE by the reference frequency generator when interference evaluation is to be performed as described later. When the drive enable signal is FALSE, the drive signal stays at a constant voltage level. When the drive signal is TRUE, it is a copy of the reference frequency signal.

The capacitance measurement element **78** contains a differential charge transfer circuit **80** as illustrated in FIG. 4 of Gerpheide, U.S. Pat. 5,349,303, incorporated herein by reference. Capacitors Cs1 and Cs2 of FIG. 4 of that patent correspond to the stray capacitances of the positive and negative virtual electrodes to ground. The CHOP signal of that FIG. 4 is conveniently supplied in the present invention as a square wave signal having half the frequency of the reference frequency signal, as generated by the divide-by-2 circuit **81** shown herein. As described in the Gerpheide '303 patent, the circuit maintains CP and CN (lines 68 and 72 therein) at a constant virtual ground voltage.

The capacitance measurement element **78** also contains a non-inverting drive buffer **76** which drives RN and negative virtual Y electrodes to change voltage levels copying the drive enable signal transitions. The inverting buffer **74** drives RP and the positive virtual Y electrodes to change voltage levels opposite the drive enable signal transitions. Since CP and CN are maintained at virtual ground, these voltage changes are the net voltage changes across the mutual capacitances which exist between virtual Y and virtual X electrodes. Charges proportional to these voltage changes multiplied by the appropriate capacitance values are thereby coupled onto nodes CP and CN (the "coupled charges"). The charge transfer circuit therefore supplies a proportional differential charges at outputs Qo1 and Qo2, which are proportional to the coupled charges and thus to the capacitances.

In short, this differential charge is a proportionality factor K times the "balance" L, which is a combination of these capacitances given by the equation:

$$L=M(xp,yn)+M(xn,yp)-M(xp,yp)-M(xn,yn)$$

where M(a,b) is the notation for the mutual capacitance between virtual electrode "a" and virtual electrode "b". Changes in balance are indicative of finger position relative to virtual electrode position as described in Gerpheide, U.S. Pat. No. 5,305,017. The proportionality factor K has a sign which is the same as the drive enable signal transition direction.

Referring again to FIG. 4, the synchronous electrode capacitance measurement element **78** is connected via lines carrying charges Qo1 and Qo2 to a synchronous demodulator **82** which may be a double-pole double-throw CMOS switch **84** controlled by the reference frequency signal. The synchronous demodulator **82**, which among other things functions to rectify the charges Qo1 and Qo2, is connected to a low-pass filter **86** which may be a pair of capacitors C1, C2 configured as an integrator for differential charges. (An integrator illustratively is a low pass filter with 6 db per octave frequency roll off.) Charges Qo1 and Qo2 are integrated onto capacitors C1 and C2, respectively, when the reference frequency signal has just transitioned positive, and K is positive. The charges are integrated onto opposite capacitors when K is negative. In this way, a differential charge proportional to the balance L is accumulated on C1 and C2.

FIG. **5** shows another embodiment of the synchronous electrode capacitance measurement unit **14**. In this embodiment, each electrode in an electrode array **90** is connected to a dedicated capacitance measurement element **92**, each of which is connected to a synchronous demodulator **94** and then to a low pass filter **96**. This configuration has the advantage of continuously providing capacitance measurements for each electrode, whereas the prior preferred embodiment measures a single configuration of electrodes at any one time. The disadvantage of the embodiment of FIG. **5** is the greater expense which may be associated with the duplicated elements. This is a common tradeoff between providing multiple elements to process measurements at the same time versus multiplexing a single element to process measurements sequentially. There is obviously a wide spectrum of variations applying this trade off.

Also, many of the elements can be implemented in digital form using analog-digital converters and digital signal processing. While the preferred embodiments currently use substantial analog processing, future digital processing costs may be expected to become relatively cheaper.

FIG. **6** provides a number of preferred alternatives for the capacitance measurement element **78** (FIG. **4**) or **92** (FIG. **5**). FIGS. **6**A and **6**B show circuits adapted for measuring mutual capacitances between electrodes (which may be physical or virtual electrodes), represented by Cmp, Cmn, and Cm. FIGS. **6**C and **6**D show circuits adapted for measuring electrode capacitance to ground represented by Cg. Each of these provides an output voltage change indicative of the capacitance being measured. These voltage changes are given by the following formulas:

For FIG. **6**A:

$$\Delta Vout=\Delta Vdrive\times(Cmp-Cmn)/Cr$$

For FIG. **6**B:

$$\Delta Vout=\Delta Vdrive\times Cm/Cr$$

For FIG. **6**C:

$$\Delta Vout=\Delta Vdrive\times Cg/(Cg+Cr)$$

For FIG. **6**D:

$$\Delta Vout=\Delta Vdrive\times(Cg+Cr)/Cg$$

The formulas depend on a known reference capacitance represented by Cr and a known drive voltage change represented by ΔVdrive. Further capacitance measurement elements may be based on charge balance techniques as described in Meyer, U.S. Pat. No. 3,857,092. Synchronous demodulators may be implemented using an analog or digital multiplier, or a "double-balanced mixer" integrated circuit (such as part number LM1496) from National Semiconductor Company. There are different implementations known in the art for low pass filter elements, such as switched capacitor integrators and filters, high-order analog filters, and digital filters.

Reference Frequency Generator

FIG. **7** illustrates a preferred embodiment of reference frequency generator **16** (FIG. **1**). The generator observes position signals to evaluate the extent of interference at some reference frequency. In the event that substantial interference is detected, the generator **16** selects a different frequency for further measurements. The generator **16** seeks to always select a reference frequency away from frequencies which have been found to result in measurement interference, as described below.

The generator **16** includes an oscillator **100** which is, for example, set at four MHz, driving a microcontroller **102** and a divide-by-(M+N) circuit **104**. Value N is a fixed constant, approximately 50. Value M is specified by the microcontroller **102** to be, for example, one of four values in the range 61 KHz to 80 KHz as specified by the microcontroller **102**.

The microcontroller **102** performs the functions of interference evaluation **106** and frequency selection **108**. It may perform other functions associated with the system such as position location. The preferred interference evaluation function **106** produces a measure of the interference in the position signals generated by the position location unit **18** (FIG. **1**). This is based on the principle that interference produces a spurious, relatively large magnitude high-frequency component of a position signal, and operates according to the following code description. It assumes position data points X, Y, and Z occur approximately every ten milliseconds. In brief, it calculates an interference measure, IM, as the sum of the absolute values of the second differences of X and Y together with the absolute values of the first differences of Z over 32 data points. Differencing a stream of data has the effect of applying a high-pass filter to it.

In detail, for each data point the interference evaluation function **106** executes the following steps, where ABS() means the absolute value function:

```
XD=X--XLAST        ;computes first differences
YD=Y--YLAST
ZD=Z-ZLAST
XDD=XD-XDLAST             ;computes second differences
YDD=YD-YLAST
IM = IM + ABS(XDD) + ABS(YDD) + ABS(Z)       ;sum
IF EVERY 32ND SAMPLE
    {EXECUTE FREQUENCY SELECT FUNCTION 108
    (See description below)
    IM = 0}
```

-continued

```
XLAST=X          ;move current values to last
YLAST=Y
ZLAST=Z
XDLAST=XD
YDLAST=YD
```

In another embodiment, the interference evaluation function **106** is not based on position signals. Instead the function asserts the drive enable signal described above to a FALSE state and reads a resulting synchronous capacitance measurement. This measures charge coupled to the electrodes when no voltage is being driven across the electrodes by the apparatus. Such charge must be the result of interference, and so this interference (from spurious signals) is directly measured. This is another way to generate the interference measure, IM.

The preferred frequency select function **108** generates a table of historical interference measurements for each frequency which may be selected. On system initialization, each entry is set to zero. Thereafter, the frequency select function is activated approximately every 32 data points by the interference evaluation function **106**. The current interference measure, IM, is entered as the entry for the currently selected frequency in the table. Then all table entries are scanned. The frequency having the lowest interference measure entry is selected as the new current frequency, and the corresponding M value is sent to the divide-by-(M+N) element **104**. Approximately every 80 seconds, every entry in the table is decremented by an amount corresponding to approximately 0.05 mm of position change. In this way, if a frequency is flagged as "bad" by having strong interference one time, it will not be flagged as "bad" permanently.

The functions described above for the different embodiments could be carried out by a microprocessor such as part no. MC 68HC705P6 manufactured by Motorola, Inc. serving as the microcontroller **102**.

FIG. **8** shows an alternate preferred embodiment of the reference frequency generator **16** (FIG. **1**). It generates a reference frequency signal that varies randomly. Each cycle of the signal has a different and substantially random period. It is extremely unlikely that a spurious signal would coherently follow the same sequence of random variation. Hence the spurious signal is substantially rejected by capacitance measurements synchronous to the reference frequency. The degree of rejection is not as great as in the former embodiment, but the generator is simpler because interference evaluation and frequency selection functions are not needed.

The generator of FIG. **8** includes an oscillator **110** and a divide-by-(N+M) circuit **112**. The value M supplied to the divider comes from a pseudo-random number generator (PRNG) **114** which generates numbers in the range 0 to 15. Each cycle of the reference frequency clocks the PRNG **114** to produce a new number. PRNGs are well known in the art.

For either embodiment in FIGS. **7** or **8**, the range of values for M in relation to the value of N can be increased or decreased to give a greater or lesser range of possible frequencies. The value of N or the oscillator frequency can be adjusted to change the maximum possible frequency. A phase-locked frequency synthesizer such as the Motorola MC145151-2, or a voltage controlled oscillator driven by a D/A converter, could also preferably be employed instead of the divide-by-(M+N) circuit.

It should be understood that other variations of the preferred embodiments described above fall within the scope of this invention. Such variations include different electrode array geometry, such as a grid of strips, a grid of diamonds, parallel strips and various other shapes. Also included are different variations of electrode array fabrication, such as printed circuit board (PCB), flex PCB, silk screen, sheet or foil metal stampings. Variations of the kinds of capacitance utilized are included, such as full balance (see Gerpheide '017), stray, mutual, half balance.

The above description has provided certain preferred embodiments in accordance with this invention. It is apparent by those skilled in the art that various modifications can be made within the spirit and scope of the invention, which are included within the scope of the following claims.

What is claimed is:

1. A capacitance-based proximity sensor for locating the position of an object while rejecting a frequency of electrical interference, comprising:

(a) an electrode array for forming capacitances which vary with movements of the object,

(b) measurement means coupled to the electrode array for measuring the capacitances synchronously with a reference signal, and

(c) generator means for supplying a reference signal to the measurement means, said reference signal having a frequency which is not coherent with the frequency of electrical interference, wherein the generator means comprises means for evaluating the electrical interference and for producing the reference signal, and wherein the evaluating means includes means for storing a table of frequencies of selected reference signals and measures of electrical interference IM for each of these frequencies, and for producing a reference signal whose frequency has the lowest IM associated therewith.

2. A capacitance-based proximity sensor for locating the position of an object while rejecting electrical interference, comprising:

(a) an electrode array for forming capacitances which vary with movements of the object,

(b) measurement means coupled to the electrode array for measuring the capacitances synchronously with a reference signal,

(c) object locator means responsive to the measurement means for producing a position signal, having a high frequency component, indicating the position of the object relative to the electrode array,

(d) generator means for supplying a reference signal to the measurement means, said reference signal having a frequency which is not coherent with the frequency of the electrical interference, and wherein said generator means comprises

evaluation means responsive to the object locator means for determining the magnitude of the high frequency component of the position signal, and

means responsive to the evaluation means for changing the frequency of the reference signal when the magnitude of the high frequency component of the position signal exceeds a predetermined value.

3. A capacitance-based proximity sensor for locating the position of an object while rejecting electrical interference, comprising:

(a) an electrode array for forming capacitances which vary with movements of the object,

(b) measurement means coupled to the electrode array for measuring the capacitances synchronously with a reference signal, wherein said measurement means comprises driver means for developing, synchronously with the reference signal, voltage changes on the electrode array,

charge measuring means for measuring, synchronously with the reference signal, charges coupled to the electrode array and thus capacitance,

means for selectively inhibiting the driver means from developing voltage changes, the coupled charge measurements made during inhibition of the driver means representing the interference measure IM, and

(c) generator means for supplying a reference signal to the measurement means, said reference signal having a frequency which is not coherent with the frequency of the electrical interference, wherein said generator means includes means for changing the frequency of the reference signal when the interference measure IM exceeds a predetermined level.

4. The proximity sensor as in claim 3 wherein the generator means further includes means for storing a table of frequencies of reference signals and associated interference measures IM made for reference signals with each of such frequencies, and for producing a reference signal whose frequency has the lowest interference measure IM associated therewith.

5. A capacitance-based proximity sensor for locating the position of an object while rejecting electrical interference, comprising:

(a) an electrode array for forming capacitances which vary with movements of the object, wherein the electrode array comprises a plurality of first electrode strips spaced apart from each other in a first array, and a plurality of second electrode strips spaced apart from each other and in close proximity with the first electrode strips;

(b) measurement means coupled to the electrode array for measuring the capacitances synchronously with a reference signal, and

(c) generator means for supplying a reference signal to the measurement means, said reference signal having a frequency which is not coherent with the frequency of the electrical interference.

6. The proximity sensor of claim 5 wherein the measurement means includes

driver means for developing, synchronously with the reference signal, voltage changes on the electrode array,

a charge transfer means coupled to the electrode array for producing synchronously with the frequency of the reference signal, measurement signals representing charges coupled onto the electrode array as a result of the voltage changes,

synchronous demodulator means coupled to the charge transfer means for rectifying the measurement signals synchronously with the reference signal, and

low pass filter means coupled to the synchronous demodulator means for producing signals representing the average DC values of the rectified signals, and thus representing the capacitances of the electrode array.

7. The proximity sensor of claim 6 wherein the measurement means includes a plurality of capacitance measurement elements, each being connected to a respective electrode strip.

8. The proximity sensor of claim 7 further comprising a plurality of synchronous demodulation elements, each connected to a respective capacitance measurement element.

9. The proximity sensor of claim 1 further including a position locator means connected to the output of the measurement means for providing a position signal representative of the location of the object relative to the electrode array.

10. The detection system of claim 1 wherein the electrode array comprises first and second electrode sets spaced from each other to develop a capacitance for the touch pad.

11. The detection system of claim 10 wherein the first and second set of electrodes are generally orthogonal to each other to form virtual electrodes to provide capacitance.

12. The detection system of claim 1 wherein the measuring means comprises a capacitive measurement element coupled to the electrode array, a synchronous demodulator coupled to the capacitive measurement element, and a low-pass filter coupled to the demodulator.

13. A method of sensing the position of an object on an electrode array comprising the steps of:

(a) generating capacitances on the array which vary with movement of the object,

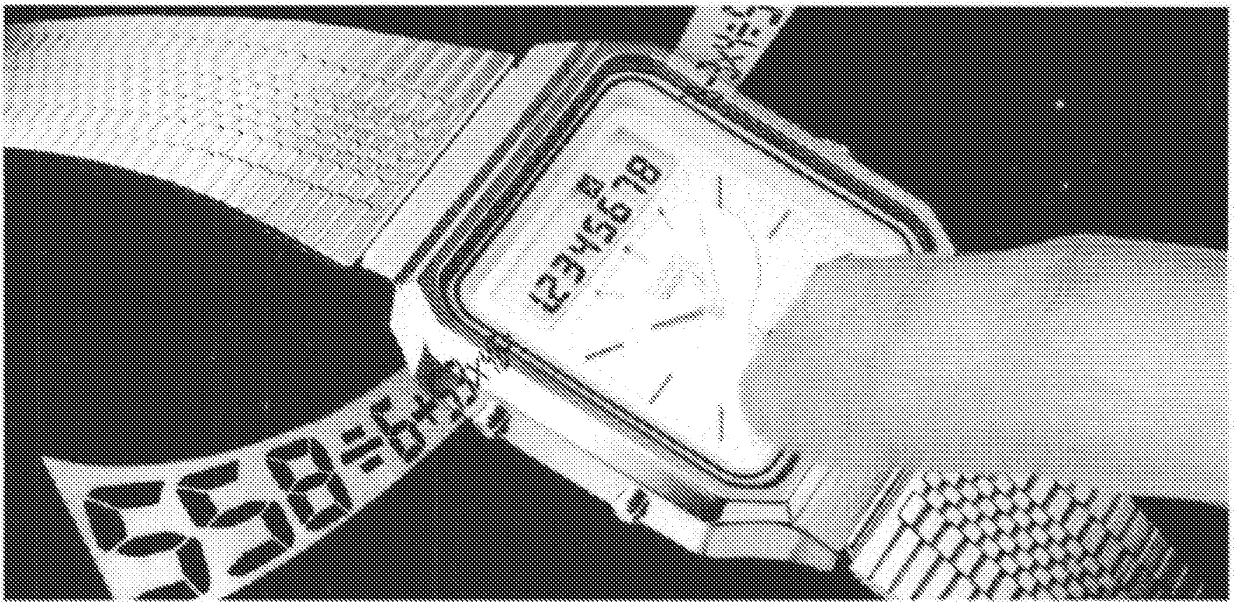
(b) measuring the capacitances on the array synchronously with the frequency of a reference signal, and

(c) generating a reference signal having a frequency which is not coherent with the frequencies of the electrical interference affecting the capacitances by evaluating the electrical interference, storing a table of frequencies of selected reference signals and measures of electrical interference IM for each of these frequencies, and for producing a reference signal whose frequency has the lowest IM associated therewith.

14. The method of claim 13 and further including producing a signal indicating the position of the object relative to the electrode array.

* * * * *

EXHIBIT E



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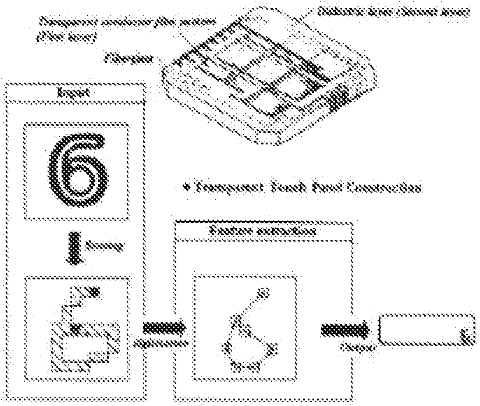

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AT-550 FP-1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

U.S. Patent No.:	5,796,183 B1	§	Docket No.:	5796183RX2
Issued:	August 18, 1998	§	Inventors:	Hourmand et al.
Filed:	January 31, 1996	§	Patent Owner:	UUSI, LLC
Control No.	TBD	§	Examiner:	TBD

For: Capacitive Responsive Electronic Switching Circuit

Mail Stop *Ex Parte* Reexam
Attn: Central Reexamination Unit
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT ACCOMPANYING REQUEST FOR *EX PARTE* REEXAMINATION UNDER 35 U.S.C. §§ 302-307

Dear Sir:

Patent Owner UUSI, LLC respectfully submits the following amendments and remarks in conjunction with its contemporaneous request for *Ex Parte* Reexamination, pursuant to the provisions of 35 U.S.C. §§ 302–307 (2002), of claims 18 and 27 of United States Patent No. 5,796,183 C1 (the "`183 Patent"). The Patent Owner respectfully requests the following amendments and remarks be entered and respectfully requests consideration of amended claims 18 and 27 and newly added claims 40-105.

I. LISTING OF THE `183 PATENT CLAIMS UNDER REEXAMINATION

A listing of each claim for which reexamination has been requested is provided below. Reexamination of claims 18 and 27 is requested contemporaneously with this amendment. Accordingly, please amend claims 18 and 27 and cancel claim 35 as provided below. In addition, please add new claims 40-105 as follows.

18. (Amended) A capacitive responsive electronic switching circuit comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad;

the plurality of small sized input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said touch terminals when proximal or touched by the operator to provide a control output signal,

wherein said predefined frequency of said oscillator and said signal output frequencies are selected to decrease a first impedance of said dielectric substrate relative to a second impedance of any contaminate that may create an electrical path on said dielectric substrate between said adjacent areas defined by the plurality of small sized input touch terminals, and wherein said detector circuit compares a sensed body capacitance change to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.

27. (Amended) A capacitive responsive electronic switching circuit for a controlled keypad device comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;

the first and second input touch terminals defining areas for an operator to provide an input by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled keypad device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

35. (Cancelled) [[The capacitive responsive electronic switching circuit as defined in claim 27, wherein when the second touch terminal is not touched on its defining area by the operator to provide input, the control output signal is prevented.]]

40. (New) The capacitive responsive electronic switching circuit as defined in claim 18, wherein each signal output frequency selectively provided to each row of the plurality of small sized input touch terminals of the keypad has a same Hertz value.

41. (New) The capacitive responsive electronic switching circuit as defined in claim 18, wherein each signal output frequency selectively provided to each row of the plurality of small sized input touch terminals of the keypad is selected from a plurality of Hertz values.

42. (New) The capacitive responsive electronic switching circuit as defined in claim 41, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.

43. (New) The capacitive responsive electronic switching circuit as defined in claim 41, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.

44. (New) The capacitive responsive electronic switching circuit as defined in claim 41, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.

45. (New) A capacitive responsive electronic switching circuit comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies directly to a plurality of small sized input touch terminals of a keypad;

the plurality of small sized input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said touch terminals when proximal or touched by the operator to provide a control output signal,

wherein said predefined frequency of said oscillator and said signal output frequencies are selected to decrease a first impedance of said dielectric substrate relative to a second impedance of any contaminate that may create an electrical path on said dielectric substrate between said adjacent areas defined by the plurality of small sized input touch terminals, and wherein said detector circuit compares a sensed body capacitance change to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.

46. (New) The capacitive responsive electronic switching circuit as defined in claim 45, wherein the sensed body capacitance change to ground proximate the input touch terminal is caused by the operator’s body capacitance decreasing an input touch terminal signal on the detector circuit, and wherein the sensed body capacitance change to ground is compared to a second threshold level to generate the control output signal.

47. (New) The capacitive responsive electronic switching circuit as defined in claim 45, wherein the sensed body capacitance change to ground proximate the input touch terminal is caused by the operator’s body capacitance decreasing an input touch terminal signal amplitude on the detector circuit, and wherein the sensed body capacitance change to ground is compared to a second threshold level to generate the control output signal.

48. (New) The capacitive responsive electronic switching circuit as defined in claim 45, wherein the signal output frequencies have a same Hertz value.

49. (New) The capacitive responsive electronic switching circuit as defined in claim 45, wherein each signal output frequency is selected from a plurality of Hertz values.

50. (New) The capacitive responsive electronic switching circuit as defined in claim 49, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.

51. (New) The capacitive responsive electronic switching circuit as defined in claim 49, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.

52. (New) The capacitive responsive electronic switching circuit as defined in claim 49, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.

53. (New) The capacitive responsive electronic switching circuit as defined in claim 45, wherein a peak voltage of the signal output frequencies is greater than a supply voltage.

54. (New) The capacitive responsive electronic switching circuit as defined in claim 53, wherein the supply voltage is a battery supply voltage.

55. (New) The capacitive responsive electronic switching circuit as defined in claim 53, wherein the supply voltage is a voltage regulator supply voltage.

56. (New) A capacitive responsive electronic switching circuit comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad, and wherein a peak voltage of the signal output frequencies is greater than a supply voltage;

the plurality of small sized input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said touch terminals when proximal or touched by the operator to provide a control output signal,

wherein said predefined frequency of said oscillator and said signal output frequencies are selected to decrease a first impedance of said dielectric substrate relative to a second impedance of any contaminate that may create an electrical path on said dielectric substrate between said adjacent areas defined by the plurality of small sized input touch terminals, and wherein said detector circuit compares a sensed body capacitance change to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.

57. (New) The capacitive responsive electronic switching circuit as defined in claim 56, wherein the sensed body capacitance change to ground proximate the input touch terminal is caused by the operator’s body capacitance decreasing an input touch terminal signal on the detector circuit, and wherein the sensed body capacitance change to ground is compared to a second threshold level to generate the control output signal.

58. (New) The capacitive responsive electronic switching circuit as defined in claim 56, wherein the sensed body capacitance change to ground proximate the input touch terminal is caused by the operator’s body capacitance decreasing an input touch terminal signal amplitude on the detector circuit, and wherein the sensed body capacitance change to ground is compared to a second threshold level to generate the control output signal.

59. (New) The capacitive responsive electronic switching circuit as defined in claim 56, wherein each signal output frequency selectively provided to each row of the plurality of small sized input touch terminals of the keypad has a same Hertz value.

60. (New) The capacitive responsive electronic switching circuit as defined in claim 56, wherein each signal output frequency selectively provided to each row of the plurality of small sized input touch terminals of the keypad is selected from a plurality of Hertz values.

61. (New) The capacitive responsive electronic switching circuit as defined in claim 60, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.

62. (New) The capacitive responsive electronic switching circuit as defined in claim 60, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.

63. (New) The capacitive responsive electronic switching circuit as defined in claim 60, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.

64. (New) The capacitive responsive electronic switching circuit as defined in claim 56, wherein the supply voltage is a battery supply voltage.

65. (New) The capacitive responsive electronic switching circuit as defined in claim 56, wherein the supply voltage is a voltage regulator supply voltage.

66. (New) The capacitive responsive electronic switching circuit as defined in claim 27, wherein each signal output frequency selectively provided to each row of the closely spaced array of input touch terminals of the keypad has a same Hertz value.

67. (New) The capacitive responsive electronic switching circuit as defined in claim 27, wherein each signal output frequency selectively provided to each row of the closely spaced array of input touch terminals of the keypad is selected from a plurality of Hertz values.

68. (New) The capacitive responsive electronic switching circuit as defined in claim 67, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.

69. (New) The capacitive responsive electronic switching circuit as defined in claim 67, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.

70. (New) The capacitive responsive electronic switching circuit as defined in claim 67, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.

71. (New) The capacitive responsive electronic switching circuit as defined in claim 27, wherein the detector circuit is configured to inhibit the control output signal unless the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

72. (New) A capacitive responsive electronic switching circuit for a controlled keypad device comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies directly to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;

the first and second input touch terminals defining areas for an operator to provide an input by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled keypad device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

73. (New) The capacitive responsive electronic switching circuit as defined in claim 72, wherein the signal output frequencies have a same Hertz value.

74. (New) The capacitive responsive electronic switching circuit as defined in claim 72, wherein each signal output frequency is selected from a plurality of Hertz values.

75. (New) The capacitive responsive electronic switching circuit as defined in claim 74, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.

76. (New) The capacitive responsive electronic switching circuit as defined in claim 74, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.

77. (New) The capacitive responsive electronic switching circuit as defined in claim 74, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.

78. (New) The capacitive responsive electronic switching circuit as defined in claim 72, wherein said detector circuit is configured to generate said control output signal only when the operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.

79. (New) The capacitive responsive electronic switching circuit as defined in claim 72, further comprising an indicator for indicating the detector circuit has determined that the operator is proximal or touches said second touch terminal.

80. (New) The capacitive responsive electronic switching circuit as defined in claim 72, wherein the detector circuit is configured to inhibit the control output signal unless the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

81. (New) The capacitive responsive electronic switching circuit as defined in claim 72, wherein a peak voltage of the signal output frequencies is greater than a supply voltage.

82. (New) The capacitive responsive electronic switching circuit as defined in claim 81, wherein the supply voltage is a battery supply voltage.

83. (New) The capacitive responsive electronic switching circuit as defined in claim 81, wherein the supply voltage is a voltage regulator supply voltage.

84. (New) A capacitive responsive electronic switching circuit for a controlled keypad device comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals, wherein a peak voltage of the signal output frequencies is greater than a supply voltage;

the first and second input touch terminals defining areas for an operator to provide an input by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled keypad device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

85. (New) The capacitive responsive electronic switching circuit as defined in claim 84, wherein the signal output frequencies have a same Hertz value.

86. (New) The capacitive responsive electronic switching circuit as defined in claim 84, wherein each signal output frequency is selected from a plurality of Hertz values.

87. (New) The capacitive responsive electronic switching circuit as defined in claim 86, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.

88. (New) The capacitive responsive electronic switching circuit as defined in claim 86, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.

89. (New) The capacitive responsive electronic switching circuit as defined in claim 86, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.

90. (New) The capacitive responsive electronic switching circuit as defined in claim 84, wherein the supply voltage is a battery supply voltage.

91. (New) The capacitive responsive electronic switching circuit as defined in claim 84, wherein the supply voltage is a voltage regulator supply voltage.

92. (New) The capacitive responsive electronic switching circuit as defined in claim 84, wherein said detector circuit is configured to generate said control output signal only when the operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.

93. (New) The capacitive responsive electronic switching circuit as defined in claim 84, further comprising an indicator for indicating the detector circuit has determined that the operator is proximal or touches said second touch terminal.

94. (New) The capacitive responsive electronic switching circuit as defined in claim 84, wherein the detector circuit is configured to inhibit the control output signal unless the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

95. (New) A capacitive responsive electronic switching circuit for a controlled keypad device comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals, and wherein a peak voltage of the signal output frequencies is greater than a supply voltage;

the first and second input touch terminals defining areas for an operator to provide an input by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled keypad device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

96. (New) The capacitive responsive electronic switching circuit as defined in claim 95, wherein each signal output frequency selectively provided to each row of the closely spaced array of input touch terminals of the keypad has a same Hertz value.

97. (New) The capacitive responsive electronic switching circuit as defined in claim 95, wherein each signal output frequency selectively provided to each row of the closely spaced array of input touch terminals of the keypad is selected from a plurality of Hertz values.

98. (New) The capacitive responsive electronic switching circuit as defined in claim 97, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.

99. (New) The capacitive responsive electronic switching circuit as defined in claim 97, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.

100. (New) The capacitive responsive electronic switching circuit as defined in claim 97, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.

101. (New) The capacitive responsive electronic switching circuit as defined in claim 95, wherein the supply voltage is a battery supply voltage.

102. (New) The capacitive responsive electronic switching circuit as defined in claim 95, wherein the supply voltage is a voltage regulator supply voltage.

103. (New) The capacitive responsive electronic switching circuit as defined in claim 95, wherein said detector circuit is configured to generate said control output signal only when the operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.

104. (New) The capacitive responsive electronic switching circuit as defined in claim 95, further comprising an indicator for indicating the detector circuit has determined that the operator is proximal or touches said second touch terminal.

105. (New) The capacitive responsive electronic switching circuit as defined in claim 95, wherein the detector circuit is configured to inhibit the control output signal unless the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

II. STATUS OF THE CLAIMS

Claims 1-17, 19-26, 28-34, and 36-39 are unamended with respect to the first Ex Parte Reexamination Certificate No. 5,796,183 C1 issued April 29, 2013. Claim 35 has been cancelled herein. Claims 18 and 27 have been amended, and claims 40-105 are newly added. The present amendment neither enlarges the scope of the claims of the patent nor introduces new matter.

III. DISCUSSION OF CLAIMS AND PRIOR ART REFERENCES

Patent Owner has filed a Request for Ex Parte Reexamination contemporaneously with this amendment submitting that a substantial new question of patentability of claim 18 is raised by the combination of U.S. Patent No. 5,463,388 ("Boie") and U.S. Patent No. 5,565,658 ("Gerpheide") and a substantial new question of patentability of claim 27 is raised by the combination of Boie, Gerpheide and the advertisement entitled "Now…The Invisible Casio Calculator Watch" ("Casio").

Patent Owner is amending claims 18 and 27, canceling claim 35, and adding new claims 40-105 in this amendment. Accordingly, Patent Owner respectfully requests consideration of amended claims 18 and 27 and new claims 40-105. The present amendment neither enlarges the scope of the claims of the patent nor introduces new matter.

A. REFERENCES OF INTEREST

Reference 1:	Boie et al., U.S. Patent No. 5,463,388, filed on January 29, 1993 and issued on October 31, 1995 ("Boie"), which qualifies as 35 U.S.C. § 102(a)-type prior art.
Reference 2:	Gerpheide et al., U.S. Patent No. 5,565,658, filed on December 7, 1994 and issued on October 15, 1996 ("Gerpheide"), which qualifies as 35 U.S.C. § 102(e)-type prior art.
Reference 3:	Casio advertisement entitled "Now… The Invisible Casio Calculator Watch," published in Popular Science by On the Run in 1984 ("Casio"), which qualifies as 35 U.S.C. § 102(b)-type prior art.

Reference 4: Lee, thesis entitled "A Fast Multiple-Touch-Sensitive Input Device," and published October 1984 ("Lee"), which qualifies as 35 U.S.C. § 102(b)-type prior art.

References 1-3 above are discussed in detail in the Request for Ex Parte Reexamination filed herewith, which discussion is incorporated herein by reference. A discussion of reference 4 (Lee) follows.

Lee generally relates to "the design and implementation of a fast-scanning multiple-touch-sensitive input device." *See, e.g.*, Lee, Abstract. Lee describes the hardware of his device as consisting of a sensor matrix board, row and column selection registers, A/D converting circuits and a dedicated CPU. *See id.* Figure 3.4, reproduced below, illustrates a block diagram of the hardware.

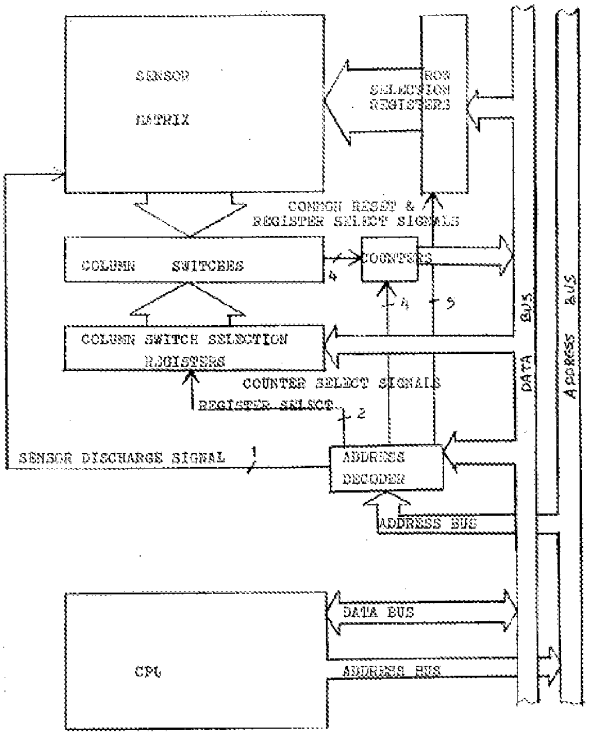

Fig. 3.4 Block diagram of the hardware.

Lee, Figure 3.4

Lee describes the operation of the row and column selection registers as follows:

> The design of the sensor matrix is based on the technique of capacitance measurement between a finger tip and a metal plate. The row selection registers select one or more rows by setting the corresponding bits to a high state in order to charge up the sensors while the column selection registers select one or more columns by turn on corresponding analog switches to discharge the sensors through timing resistors. The intersecting region of the selected rows and the selected columns represents the selected sensors as a unit.

Id. at 3-1. Figure 3.1(a) shows a model of a selected sensor in the sensor matrix and Figure 3.1(b) shows the timing diagram for discharging time measurement of a selected sensor as shown in Figure 3.1(a). Figure 3.2 illustrates a small section of a sensor matrix according to Lee.

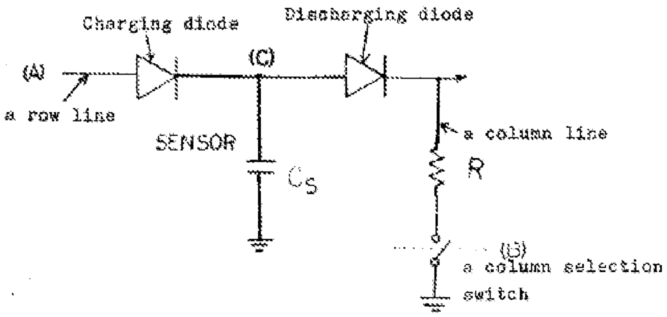

Fig. 3.1 a. A model of a selected sensor in the sensor matrix

Lee, Figure 3.1(a)

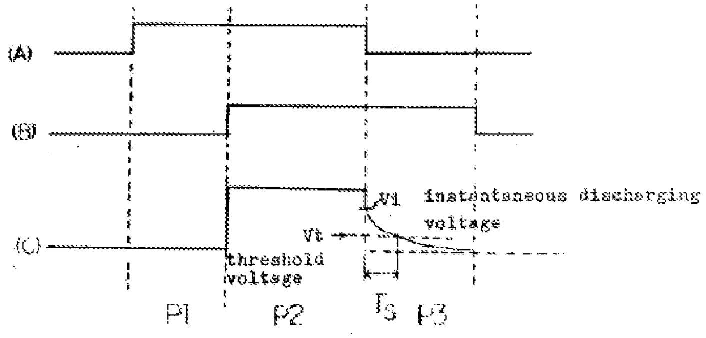

Fig. 3.1 b. The timing diagram for discharging time measurement of a selected sensor as shown above.

Lee, Figure 3.1(b)

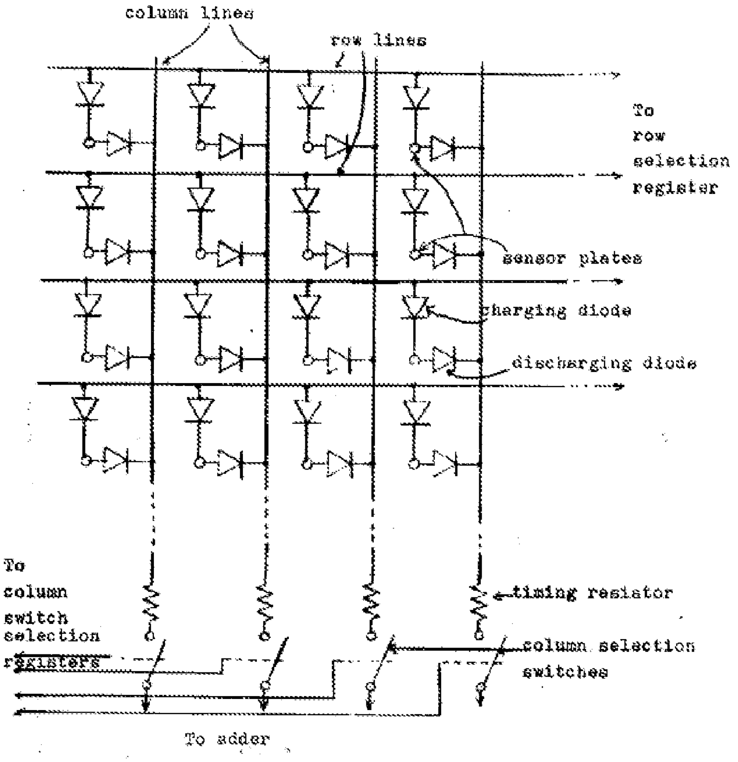

Fig. 3.2 A small section of sensor matrix.

Lee, Figure 3.2

Lee describes the interface between the CPU and the sensor matrix as follows:

> The CPU selects the row or rows of a sensor group, initiating charging of all the associated sensors. After a charging interval, the CPU discharges the selected column or columns corresponding to a sensor group by connecting a group of discharge resistors whose current is summed via a high slew rate operational amplifier.

Id. at 3-10. As illustrated by the data bus of Figure 3.4, Lee teaches the CPU selects or deselects the row(s) by sending binary signals to the selected row(s). *See, e.g.*, *id.* at Figs. 3.1(a), 3.1(b), and 3.4. Lee does not disclose sending frequencies to the selected rows.

B. DISCUSSION OF CLAIMS

Independent Claim 18

Independent claim 18 as amended herein recites "a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad." None of the cited references, alone or in combination, teaches or suggests these limitations.

Rather, Boie discloses that "RF oscillator 408 provides an RF signal, for example, 100 kilohertz, to circuits 401, synchronous detector and filter 404 via inverter 410, and guard plane 411." Boie, col. 3:67-col. 4:2. Boie further discloses that "[t]he effects of electrode-to-electrode capacitances, wiring capacitances and other extraneous capacitances arc minimized by driving all electrodes and guard plane 411 in unison with the same RF signal from RF oscillator 408." *Id.* at col. 4:58-60; *see id.* at Fig. 4. Thus, Boie discloses driving the electrodes of electrode array 100 and guard plane 411 with a single RF signal. Boie does not teach or suggest a microcontroller providing signal output frequencies to these components, wherein a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad.

Neither Gerpheide nor Lee cures the deficiencies of Boie. While Gerpheide teaches a reference frequency generator 16 "observes position signals to evaluate the extent of interference at some reference frequency" and that in "the event that substantial interference is detected, the generator 16 selects a different frequency for further measurements," Gerpheide does not teach that a microcontroller provides these frequencies selectively to each row of the input touch terminals. *See, e.g.*, *id.* at col. 8:22-30; Fig. 7. Rather, in Gerpheide, the "reference frequency signal is supplied to unit 14 via an AND gate 72.... The AND gate output feeds through inverter 74 and noninverting buffer 76 to wires RP and RN respectively which are part of a capacitive measurement element 78." *See id.* at col. 6:19-26; Fig. 4. Thus, the output of AND gate 72 is sent to every row of electrode array 12 via one of inverter 74 and noninverting buffer 76 at the same time. Therefore, Gerpheide does not disclose a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad.

Likewise, Lee does not teach or suggest that a <u>signal output frequency</u> is selectively provided to each row of a plurality of small sized input touch terminals of a keypad. Rather, Lee teaches the CPU selects or deselects row(s) by sending binary signals to the selected row(s). *See, e.g.*, *id.* at Figs. 3.1(a), 3.1(b), and 3.4. In contrast, claim 18 recites selectively providing a signal output frequency to each row of the touch terminals.

Accordingly, Boie in combination with Gerpheide and/or Lee does not disclose all of the elements of claim 18, and therefore claim 18 is patentable over these references.

New claims 40-44 depend from claim 18 and add further limitations. Patent Owner respectfully submits that these dependent claims are allowable by reason of depending from an allowable claim as well as for adding new limitations.

Independent Claim 27

Independent claim 27 as amended herein recites "the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals." None of the cited references, alone or in combination, teaches or suggests these limitations.

Rather, Boie discloses that "RF oscillator 408 provides an RF signal, for example, 100 kilohertz, to circuits 401, synchronous detector and filter 404 via inverter 410, and guard plane 411." Boie, col. 3:67-col. 4:2. Boie further discloses that "[t]he effects of electrode-to-electrode capacitances, wiring capacitances and other extraneous capacitances arc minimized by driving all electrodes and guard plane 411 in unison with the same RF signal from RF oscillator 408." *Id.* at col. 4:58-60; *see id.* at Fig. 4. Thus Boie discloses driving the electrodes of electrode array 100 and guard plane 411 with a single RF signal. Boie does not teach or suggest the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals.

None of Gerpheide, Lee or Casio cures the deficiencies of Boie. While Gerpheide teaches a reference frequency generator 16 "observes position signals to evaluate the extent of interference at some reference frequency" and that in "the event that substantial interference is detected, the generator 16 selects a different frequency for further measurements," Gerpheide does not teach that a microcontroller provides these frequencies selectively to each row of the input touch terminals. *See, e.g., id.* at col. 8:22-30; Fig. 7. Rather, in Gerpheide, the "reference frequency signal is supplied to unit 14 via an AND gate 72…. The AND gate output feeds through inverter 74 and noninverting buffer 76 to wires RP and RN respectively which are part of a capacitive measurement element 78." *See id.* at col. 6:19-26; Fig. 4. Thus, the output of AND gate 72 is sent to every row of electrode array 12 via one of inverter 74 and noninverting buffer 76 at the same time. Therefore, Gerpheide does not disclose a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad.

Likewise, Lee does not teach or suggest that a <u>signal output frequency</u> is selectively provided to each row of a plurality of small sized input touch terminals of a keypad. Rather, Lee teaches the CPU selects or deselects row(s) by sending binary signals to the selected row(s). *See,* *e.g.*, *id.* at Figs. 3.1(a), 3.1(b), and 3.4. In contrast, claim 27 recites selectively providing a signal output frequency to each row of the touch terminals.

Casio discloses input touch terminals comprising first and second input touch terminals, *see, e.g.*, Figure, but fails to provide any teaching with respect to the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a closely spaced array of input touch terminals of a keypad.

Accordingly, Boie in combination with Gerpheide, Lee and/or Casio does not disclose all of the elements of claim 27, and therefore claim 27 is patentable over these references.

New claims 66-71 depend from claim 27 and add further limitations. Patent Owner respectfully submits that these dependent claims are allowable by reason of depending from an allowable claim as well as for adding new limitations.

Independent Claim 45

Independent claim 45 recites "a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies directly to a plurality of small sized input touch terminals of a keypad." None of the cited references, alone or in combination, teaches or suggests these limitations.

Rather, Boie discloses that "RF oscillator 408 provides an RF signal, for example, 100 kilohertz, to circuits 401, synchronous detector and filter 404 via inverter 410, and guard plane 411." Boie, col. 3:67-col. 4:2. Boie further discloses that "[t]he effects of electrode-to-electrode capacitances, wiring capacitances and other extraneous capacitances arc minimized by driving all electrodes and guard plane 411 in unison with the same RF signal from RF oscillator 408." *Id.* at col. 4:58-60; *see id.* at Fig. 4. Thus, Boie discloses driving the electrodes of electrode array 100 and guard plane 411 with a single RF signal sent from oscillator 408. Therefore, Boie does not teach or suggest a microcontroller selectively providing signal output frequencies directly to a plurality of small sized input touch terminals of a keypad.

Neither Gerpheide nor Lee cures the deficiencies of Boie. While Gerpheide teaches a reference frequency generator 16 "observes position signals to evaluate the extent of interference at some reference frequency" and that in "the event that substantial interference is detected, the generator 16 selects a different frequency for further measurements," Gerpheide does not teach that a microcontroller provides these frequencies directly to a plurality of small sized input touch terminals. *See, e.g.*, *id.* at col. 8:22-30; Fig. 7. Rather, in Gerpheide, the microprocessor provides value M, i.e., a selected frequency, to a divide-by-(M+N) circuit 104 which then outputs the reference frequency signal to AND gate 72. *See, e.g.*, *id.* at col. 8:31-38; col. 6:19-26; Figs. 4 and 7. Thereafter, the output of AND gate 72 is sent to electrode array 12 via one of inverter 74 and noninverting buffer 76. *See, e.g.*, *id.* at col. 6:19-26; Fig. 4. Therefore, Gerpheide does not disclose the microcontroller selectively providing signal output frequencies directly to a plurality of small sized input touch terminals of a keypad.

Lee does not teach or suggest that <u>signal output frequencies</u> are directly provided from a microcontroller to the plurality of small sized input touch terminals of a keypad. Rather, Lee teaches the CPU selects or deselects row(s) by sending binary signals to the selected row(s). *See, e.g.*, *id.* at Figs. 3.1(a), 3.1(b), and 3.4. In contrast, claim 45 recites a microcontroller selectively provides signal output frequencies directly to the touch terminals.

Accordingly, Boie in combination with Gerpheide and/or Lee does not disclose all of the elements of claim 45, and therefore claim 45 is patentable over these references.

New claims 46-55 depend from claim 45 and add further limitations. Patent Owner respectfully submits that these dependent claims are allowable by reason of depending from an allowable claim as well as for adding new limitations.

Independent Claim 56

Independent claim 56 recites "a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad, and wherein a peak voltage of the signal output frequencies is greater than a supply voltage." None of the cited references, alone or in combination, teaches or suggests these limitations.

As discussed above with respect to claims 18 and 27, the cited references, either alone or in combination, fail to teach or suggest the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad. Moreover, none of the cited references teaches or suggests wherein a peak voltage of the signal output frequencies is greater than a supply voltage.

Accordingly, Boie in combination with Gerpheide and/or Lee does not disclose all of the elements of claim 56, and therefore claim 56 is patentable over these references.

New claims 57-65 depend from claim 56 and add further limitations. Patent Owner respectfully submits that these dependent claims are allowable by reason of depending from an allowable claim as well as for adding new limitations.

Independent Claim 72

Independent claim 72 recites "a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies directly to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals." None of the cited references, alone or in combination, teaches or suggests these limitations.

Rather, Boie discloses that "RF oscillator 408 provides an RF signal, for example, 100 kilohertz, to circuits 401, synchronous detector and filter 404 via inverter 410, and guard plane 411." Boie, col. 3:67-col. 4:2. Boie further discloses that "[t]he effects of electrode-to-electrode capacitances, wiring capacitances and other extraneous capacitances arc minimized by driving all electrodes and guard plane 411 in unison with the same RF signal from RF oscillator 408." *Id.* at col. 4:58-60; *see id.* at Fig. 4. Thus, Boie discloses driving the electrodes of electrode array 100 and guard plane 411 with a single RF signal sent from oscillator 408. Therefore, Boie does not teach or suggest a microcontroller selectively providing signal output frequencies directly to a closely spaced array of input touch terminals of a keypad.

None of Gerpheide, Lee or Casio cures the deficiencies of Boie. While Gerpheide teaches a reference frequency generator 16 "observes position signals to evaluate the extent of interference at some reference frequency" and that in "the event that substantial interference is detected, the generator 16 selects a different frequency for further measurements," Gerpheide does not teach that a microcontroller provides these frequencies directly to a closely spaced array of input touch terminals. *See, e.g., id.* at col. 8:22-30; Fig. 7. Rather, in Gerpheide, the microprocessor provides value M, i.e., a selected frequency, to a divide-by-(M+N) circuit 104 which then outputs the reference frequency signal to AND gate 72. *See, e.g.*, *id.* at col. 8:31-38;

col. 6:19-26; Figs. 4 and 7. Thereafter, the output of AND gate 72 is sent to electrode array 12 via one of inverter 74 and noninverting buffer 76. *See, e.g.*, *id.* at col. 6:19-26; Fig. 4. Therefore, Gerpheide does not disclose the microcontroller selectively providing signal output frequencies directly to a closely spaced array of input touch terminals of a keypad.

Lee does not teach or suggest that <u>signal output frequencies</u> are directly provided from a microcontroller to the plurality of small sized input touch terminals of a keypad. Rather, Lee teaches the CPU selects or deselects row(s) by sending binary signals to the selected row(s). *See, e.g.*, *id.* at Figs. 3.1(a), 3.1(b), and 3.4. In contrast, claim 72 recites a microcontroller selectively provides signal output frequencies directly to the touch terminals.

Casio discloses input touch terminals comprising first and second input touch terminals, *see, e.g.*, Figure, but fails to provide any teaching with respect to the microcontroller selectively providing signal output frequencies directly to a closely spaced array of input touch terminals of a keypad.

Accordingly, Boie in combination with Gerpheide, Lee and/or Casio does not disclose all of the elements of claim 72, and therefore claim 72 is patentable over these references.

New claims 73-83 depend from claim 72 and add further limitations. Patent Owner respectfully submits that these dependent claims are allowable by reason of depending from an allowable claim as well as for adding new limitations.

Independent Claim 84

Independent claim 84 recites "the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals, wherein a peak voltage of the signal output frequencies is greater than a supply voltage."

None of the cited references, alone or in combination, teaches or suggests at least wherein a peak voltage of the signal output frequencies is greater than a supply voltage. Accordingly, Boie in combination with Gerpheide, Casio and/or Lee does not disclose all of the elements of claim 84, and therefore claim 84 is patentable over these references.

New claims 85-94 depend from claim 84 and add further limitations. Patent Owner respectfully submits that these dependent claims are allowable by reason of depending from an allowable claim as well as for adding new limitations.

Independent Claim 95

Independent claim 95 recites "a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals, and wherein a peak voltage of the signal output frequencies is greater than a supply voltage." None of the cited references, alone or in combination, teaches or suggests these limitations.

As discussed above with respect to claims 18, 27 and 56, the cited references, either alone or in combination, fail to teach or suggest a signal output frequency is selectively provided to each row of a closely spaced array of input touch terminals of a keypad. Moreover, none of the cited references teaches or suggests wherein a peak voltage of the signal output frequencies is greater than a supply voltage.

Accordingly, Boie in combination with Gerpheide, Casio and/or Lee does not disclose all of the elements of claim 95, and therefore claim 95 is patentable over these references.

New claims 96-105 depend from claim 95 and add further limitations. Patent Owner respectfully submits that these dependent claims are allowable by reason of depending from an allowable claim as well as for adding new limitations.

IV. SUPPORT FOR CLAIM AMENDMENTS AND NEW CLAIMS

Support for each of the amendments to claims 18 and 27 and for each of the new claims 40-105 may be found throughout the `183 Patent, and particular support may be found, for example, as set forth in the charts below.

A. Amended Claim 18

`183 Patent Claim Language	**`183 Patent Support**
18. A capacitive responsive electronic switching circuit comprising:	--
an oscillator providing a periodic output signal having a predefined frequency;	--
a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad;	See Figures 4, 11; and Claims 8, 12, 16. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads." Col. 6:1-3. The `183 Patent discloses "Although the

`183 Patent Claim Language	`183 Patent Support
	preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27. The `183 Patent discloses "Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6. Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5 volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8.

`183 Patent Claim Language	`183 Patent Support
	Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 12:6-33. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies." Col. 14:22-25. The `183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components similar to those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of the first embodiment in that it includes an array of touch circuits designated as 900_1 through 900_{nm}, which, as shown, include both the touch circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface

`183 Patent Claim Language	**`183 Patent Support**
	(typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.
the plurality of small sized input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and	--
a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said touch terminals when proximal or touched by the operator to provide a control output signal,	--
wherein said predefined frequency of said oscillator and said signal output frequencies are selected to decrease a first impedance of said dielectric substrate relative to a second impedance of any contaminate that may create an electrical path on said dielectric substrate between said adjacent areas defined by the plurality of small sized input touch terminals, and wherein said detector circuit compares a sensed body capacitance change to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.	--

B. Amended Claim 27

`183 Patent Claim Language	**`183 Patent Support**
27. A capacitive responsive electronic switching circuit for a controlled keypad device comprising:	--

`183 Patent Claim Language	**`183 Patent Support**
an oscillator providing a periodic output signal having a predefined frequency;	--
a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;	See Figures 4, 11; and Claims 8, 12, 16. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads." Col. 6:1-3. The `183 Patent discloses "Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27. The `183 Patent discloses "Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via

`183 Patent Claim Language	`183 Patent Support
	line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6. Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5 volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8. Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 12:6-33. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies." Col. 14:22-25.  The `183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components

`183 Patent Claim Language	`183 Patent Support
	similar to those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of the first embodiment in that it includes an array of touch circuits designated as 900_1 through 900_{nm}, which, as shown, include both the touch circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.
the first and second input touch terminals defining areas for an operator to provide an input by proximity and touch; and	--
a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by	--

`183 Patent Claim Language	`183 Patent Support
the operator to provide a control output signal for actuation of the controlled keypad device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.	

C. New Claim 40

`183 Patent Claim Language	`183 Patent Support
40. The capacitive responsive electronic switching circuit as defined in claim 18, wherein each signal output frequency selectively provided to each row of the plurality of small sized input touch terminals of the keypad has a same Hertz value.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the

`183 Patent Claim Language	`183 Patent Support
	preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

D. New Claim 41

`183 Patent Claim Language	`183 Patent Support

`183 Patent Claim Language	`183 Patent Support
41. The capacitive responsive electronic switching circuit as defined in claim 18, wherein each signal output frequency selectively provided to each row of the plurality of small sized input touch terminals of the keypad is selected from a plurality of Hertz values.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or

`183 Patent Claim Language	`183 Patent Support
	above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

E. New Claim 42

`183 Patent Claim Language	`183 Patent Support
42. The capacitive responsive electronic switching circuit as defined in claim 41, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance

`183 Patent Claim Language	`183 Patent Support
	of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent

`183 Patent Claim Language	`183 Patent Support
	to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

F. New Claim 43

`183 Patent Claim Language	`183 Patent Support
43. The capacitive responsive electronic switching circuit as defined in claim 41, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads

`183 Patent Claim Language	`183 Patent Support
	59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain

`183 Patent Claim Language	**`183 Patent Support**
	bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

G. New Claim 44

`183 Patent Claim Language	**`183 Patent Support**
44. The capacitive responsive electronic switching circuit as defined in claim 41, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.	See Fig. 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the

`183 Patent Claim Language	`183 Patent Support
	frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 11:1-27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

H. New Claim 45

For ease of analysis, new independent claim 45 is shown below with pseudo-amendments illustrating the differences between new claim 45 and claim 18 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
45. A capacitive responsive electronic switching circuit comprising:	See Claim 18.
an oscillator providing a periodic output signal having a predefined frequency;	See Claim 18.
a microcontroller using the	See Figures 4, 11; and Claims 8, 12, 16.

`183 Patent Claim Language	`183 Patent Support
periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies <u>directly</u> to a plurality of small sized input touch terminals of a keypad;	The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads." Col. 6:1-3. The `183 Patent discloses "Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27. The `183 Patent discloses "Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6.

`183 Patent Claim Language	`183 Patent Support
	Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5 volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8. Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 12:6-33. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies." Col. 14:22-25.  The `183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components similar to those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of

`183 Patent Claim Language	`183 Patent Support
	the first embodiment in that it includes an array of touch circuits designated as 900_1 through 900_{nm}, which, as shown, include both the touch circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.
the plurality of small sized input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and	See Claim 18.
a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said touch terminals when proximal or touched by the operator to provide a control output signal,	See Claim 18.
wherein said predefined frequency of said oscillator and said signal output	See Claim 18.

`183 Patent Claim Language	`183 Patent Support
frequencies are selected to decrease a first impedance of said dielectric substrate relative to a second impedance of any contaminate that may create an electrical path on said dielectric substrate between said adjacent areas defined by the plurality of small sized input touch terminals, and wherein said detector circuit compares a sensed body capacitance change to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.	

I. New Claim 46

For ease of analysis, new dependent claim 46 is shown below with pseudo-amendments illustrating the differences between new claim 46 and claim 33 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
46. The capacitive responsive electronic switching circuit as defined in claim 45, ~~further comprising~~ wherein ~~said detector circuit compares~~ the sensed body capacitance change <u>to ground proximate the input touch terminal is</u> caused by the <u>operator's</u> body capacitance decreasing an input touch terminal signal on the detector <u>circuit, and wherein the sensed body capacitance change</u> to ground ~~when proximate to the input touch terminal~~ <u>is compared</u> to a second threshold level to generate the control output signal.	See Claims 1, 18, 28, and 33. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold

`183 Patent Claim Language	`183 Patent Support
	value. The details of touch circuit 400 are described below with reference to FIG. 8." Col. 12:24-28. The `183 Patent discloses "As can be seen, at 1 kHz, the capacitive impedance of the glass is much greater than the nominal 1 MΩ of the water bridge across the pads. As a result, at 1 kHz, there would be little difference in the impedance paths to ground of the two adjacent pads when either is touched. This would result in the voltage on both pads being pulled towards ground by comparable amounts. Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Col. 10:54 – Col. 11:9. The `183 Patent discloses "As stated above, the operator's body includes a capacitance to ground, which may range in a typical person from between 20 to 300 pF. The base terminal of transistor 410 is coupled to it's [sic] emitter by resistor 412 such that unless capacitance is present by the user touching the touch pad 450, transistor 410 will not be forward biased and will not conduct. Thus, when touch pad 450 is not

`183 Patent Claim Language	`183 Patent Support
	touched, the output signal at the collector terminal of transistor 410 and across pulse stretcher circuit 417 will be zero volts. When, however, a person touches the touch pad 450, that person's body capacitance to ground couples the base of transistor 410 to ground 103 through resistor 413, thereby forward biasing transistor 410 into conduction. This charges capacitor 418 providing a positive DC voltage with respect to the line 301 and causes the output of the Schmitt trigger 420 to go low. Diode 414 is coupled across the base to emitter junction of transistor 410 to clamp the base emitter reverse bias voltage to –0.7V and also reduce the forward recovery and turn-on time. Col. 15:29-47.

J. New Claim 47

For ease of analysis, new dependent claim 47 is shown below with pseudo-amendments illustrating the differences between new claim 47 and claim 34 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
47. The capacitive responsive electronic switching circuit as defined in claim 45, ~~further comprising~~ wherein ~~said detector circuit compares~~ the sensed body capacitance change to ground proximate the input touch terminal is caused by the operator's body capacitance decreasing an input touch terminal signal amplitude on the detector circuit, and wherein the sensed body capacitance change to ground ~~when proximate to the input touch terminal~~ is compared to a second threshold level to generate the control output signal.	See Claims 1, 18, 28, and 34. The `183 Patent discloses "Another method for implementing capacitive touch switches relies on the change in capacitive coupling between a touch terminal and ground. Systems utilizing such a method are described in U.S. Pat. No. 4,758,735 and U.S. Pat. No. 5,087,825. With this methodology the detection circuit consists of an oscillator (or AC line voltage derivative) providing a signal to a touch terminal whose voltage is then monitored by a detector. The touch terminal is driven in electrical series with other components that function in part as a charge pump. The touch of an operator then provides a capacitive short to ground via the operator's own body capacitance that lowers the amplitude of oscillator voltage seen at the touch terminal." Col. 3:44-56.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8." Col. 12:24-28. The `183 Patent discloses "As can be seen, at 1 kHz, the capacitive impedance of the glass is much greater than the nominal 1 MΩ of the water bridge across the pads. As a result, at 1 kHz, there would be little difference in the impedance paths to ground of the two adjacent pads when either is touched. This would result in the voltage on both pads being pulled towards ground by comparable amounts. Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ

`183 Patent Claim Language	**`183 Patent Support**
	or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Col. 10:54 – Col. 11:9. The `183 Patent discloses "As stated above, the operator's body includes a capacitance to ground, which may range in a typical person from between 20 to 300 pF. The base terminal of transistor 410 is coupled to it's [sic] emitter by resistor 412 such that unless capacitance is present by the user touching the touch pad 450, transistor 410 will not be forward biased and will not conduct. Thus, when touch pad 450 is not touched, the output signal at the collector terminal of transistor 410 and across pulse stretcher circuit 417 will be zero volts. When, however, a person touches the touch pad 450, that person's body capacitance to ground couples the base of transistor 410 to ground 103 through resistor 413, thereby forward biasing transistor 410 into conduction. This charges capacitor 418 providing a positive DC voltage with respect to the line 301 and causes the output of the Schmitt trigger 420 to go low. Diode 414 is coupled across the base to emitter junction of transistor 410 to clamp the base emitter reverse bias voltage to –0.7V and also reduce the forward recovery and turn-on time. Col. 15:29-47.

K. New Claim 48

`183 Patent Claim Language	**`183 Patent Support**
48. The capacitive responsive electronic switching circuit as defined in claim 45, wherein the signal output	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably

`183 Patent Claim Language	`183 Patent Support
frequencies have a same Hertz value.	at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended

`183 Patent Claim Language	`183 Patent Support
	touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

L. New Claim 49

`183 Patent Claim Language	`183 Patent Support
49. The capacitive responsive electronic switching circuit as defined in claim 45, wherein each signal output frequency is selected from a plurality of Hertz values.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low

`183 Patent Claim Language	`183 Patent Support
	detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however,

`183 Patent Claim Language	`183 Patent Support
	oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

M. New Claim 50

`183 Patent Claim Language	`183 Patent Support
50. The capacitive responsive electronic switching circuit as defined in claim 49, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of

`183 Patent Claim Language	`183 Patent Support
	inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

N. New Claim 51

`183 Patent Claim Language	`183 Patent Support
51. The capacitive responsive electronic switching circuit as defined in claim 49, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at

`183 Patent Claim Language	`183 Patent Support
	or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

O. New Claim 52

`183 Patent Claim Language	`183 Patent Support
52. The capacitive responsive electronic switching circuit as defined in claim 49, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.	See Fig. 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "At 800 kHz, the impedance of the glass drops to 200 kΩ or lower

`183 Patent Claim Language	`183 Patent Support
	giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 11:1-27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

P. New Claim 53

`183 Patent Claim Language	`183 Patent Support
53. The capacitive responsive electronic switching circuit as defined in claim 45, wherein a peak voltage of the signal output frequencies is greater than a supply voltage.	See Figures 4, 5; Claims 27 and 37. The `183 Patent discloses "Having provided a basis for the use of higher frequencies, the basic construction of the electronic switching circuit constructed in accordance with a first embodiment of the present invention is now described with reference to FIG. 4. The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5. Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6." Col. 11:60 – Col. 12:13. The `183 Patent discloses "Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator

`183 Patent Claim Language	`183 Patent Support
	200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s)." Col. 18:43-49. The `183 Patent discloses "A preferred circuit for implementing a voltage regulator 100 is shown in FIG. 5. Voltage regulator 100 preferably includes an AC/DC convertor 110 for generating 29 V to 36 V unregulated DC on line 119. This unregulated DC power is supplied to a 5 V DC regulator 120 and to a 26 V DC regulator 130. AC/DC convertor 110 includes diodes 112, 114, 116, and 118, which rectify the supplied 24 V AC power provided on power lines 101 and 102." Col. 12:50-57; see also Col. 12:57 – Col. 13:31. The `183 Patent discloses "The oscillator circuitry shown in FIG. 6 is very stable over the temperature range of -40° C. to 105° C. The output of the touch switch circuitry drops at a rate of approximately 40 mV/°C. when temperature falls below 0° C. If application requires operation at low temperatures (-40° C.), the following three methods may be used to increase the output of the switch: increase the oscillator's regulated supply voltage, increase the resistance of resistor 416, and use a higher gain transistor 410. All of these methods would increase sensitivity at high temperatures." Col. 16:33-41.

Q. New Claim 54

`183 Patent Claim Language	`183 Patent Support
54. The capacitive responsive electronic switching circuit as defined in claim 53, wherein the supply voltage is a battery supply voltage.	The `183 Patent discloses "It will be apparent to those skilled in the art, that various components of voltage regulator 100 may be added or excluded depending upon the source of power available to power the oscillator 200. For example, if the available power is a 110 V AC

`183 Patent Claim Language	`183 Patent Support
	60 Hz commercial power line, a transformer may be added to convert the 100 V AC power to 24 V AC. Alternatively, if a DC batter is used, the AC/DC convertor among other components may be eliminated." Col 13:23-31.

R. New Claim 55

`183 Patent Claim Language	`183 Patent Support
55. The capacitive responsive electronic switching circuit as defined in claim 53, wherein the supply voltage is a voltage regulator supply voltage.	Figures 4, 5, 11, and 12. The `183 Patent discloses "The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5." Col. 11:64 – Col. 12:5; see also Col. 12:50 – Col. 13:31.

S. New Claim 56

For ease of analysis, new independent claim 56 is shown below with pseudo-amendments illustrating the differences between new claim 56 and claim 18 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
56. A capacitive responsive electronic switching circuit comprising:	See Claim 18.
an oscillator providing a periodic output signal having a predefined frequency;	See Claim 18.
a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing	See Figures 4, 5, 11; and Claims 8, 12, 16, 27 and 37.

`183 Patent Claim Language	`183 Patent Support
signal output frequencies, wherein a signal output frequency is selectively provided to each row of a plurality of small sized input touch terminals of a keypad, and wherein a peak voltage of the signal output frequencies is greater than a supply voltage;	The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads." Col. 6:1-3.  The `183 Patent discloses "Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27. The `183 Patent discloses "Having provided a basis for the use of higher frequencies, the basic construction of the electronic switching circuit constructed in accordance with a first embodiment of the present invention is now described with reference to FIG. 4. The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC

`183 Patent Claim Language	`183 Patent Support
	voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5. Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6. Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5 volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8. Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 11:60 – 12:33.

`183 Patent Claim Language	**`183 Patent Support**
	The `183 Patent discloses "A preferred circuit for implementing a voltage regulator 100 is shown in FIG. 5. Voltage regulator 100 preferably includes an AC/DC convertor 110 for generating 29 V to 36 V unregulated DC on line 119. This unregulated DC power is supplied to a 5 V DC regulator 120 and to a 26 V DC regulator 130. AC/DC convertor 110 includes diodes 112, 114, 116, and 118, which rectify the supplied 24 V AC power provided on power lines 101 and 102." Col. 12:50-57; see also Col. 12:57 – Col. 13:31. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies." Col. 14:22-25. The `183 Patent discloses "The oscillator circuitry shown in FIG. 6 is very stable over the temperature range of -40° C. to 105° C. The output of the touch switch circuitry drops at a rate of approximately 40 mV/°C. when temperature falls below 0° C. If application requires operation at low temperatures (-40° C.), the following three methods may be used to increase the output of the switch: increase the oscillator's regulated supply voltage, increase the resistance of resistor 416, and use a higher gain transistor 410. All of these methods would increase sensitivity at high temperatures." Col. 16:33-41. The `183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components similar to those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of

`183 Patent Claim Language	`183 Patent Support
	the first embodiment in that it includes an array of touch circuits designated as 900_1 through 900_{nm}, which, as shown, include both the touch circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.
the plurality of small sized input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and	See Claim 18.
a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said touch terminals when proximal or touched by the operator to provide a control output signal,	See Claim 18.
wherein said predefined frequency of said oscillator and said signal output	See Claim 18.

`183 Patent Claim Language	`183 Patent Support
frequencies are selected to decrease a first impedance of said dielectric substrate relative to a second impedance of any contaminate that may create an electrical path on said dielectric substrate between said adjacent areas defined by the plurality of small sized input touch terminals, and wherein said detector circuit compares a sensed body capacitance change to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.	

T. New Claim 57

For ease of analysis, new dependent claim 57 is shown below with pseudo-amendments illustrating the differences between new claim 57 and claim 33 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
57. The capacitive responsive electronic switching circuit as defined in claim 56, ~~further comprising~~ wherein ~~said detector circuit compares~~ the sensed body capacitance change to ground proximate the input touch terminal is caused by the operator's body capacitance decreasing an input touch terminal signal on the detector circuit, and wherein the sensed body capacitance change to ground ~~when proximate to the input touch terminal~~ is compared to a second threshold level to generate the control output signal.	See Claims 1, 18, 28, and 33. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold

`183 Patent Claim Language	`183 Patent Support
	value. The details of touch circuit 400 are described below with reference to FIG. 8." Col. 12:24-28. The `183 Patent discloses "As can be seen, at 1 kHz, the capacitive impedance of the glass is much greater than the nominal 1 MΩ of the water bridge across the pads. As a result, at 1 kHz, there would be little difference in the impedance paths to ground of the two adjacent pads when either is touched. This would result in the voltage on both pads being pulled towards ground by comparable amounts. Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Col. 10:54 – Col. 11:9. The `183 Patent discloses "As stated above, the operator's body includes a capacitance to ground, which may range in a typical person from between 20 to 300 pF. The base terminal of transistor 410 is coupled to it's [sic] emitter by resistor 412 such that unless capacitance is present by the user touching the touch pad 450, transistor 410 will not be forward biased and will not conduct. Thus, when touch pad 450 is not

`183 Patent Claim Language	`183 Patent Support
	touched, the output signal at the collector terminal of transistor 410 and across pulse stretcher circuit 417 will be zero volts. When, however, a person touches the touch pad 450, that person's body capacitance to ground couples the base of transistor 410 to ground 103 through resistor 413, thereby forward biasing transistor 410 into conduction. This charges capacitor 418 providing a positive DC voltage with respect to the line 301 and causes the output of the Schmitt trigger 420 to go low. Diode 414 is coupled across the base to emitter junction of transistor 410 to clamp the base emitter reverse bias voltage to –0.7V and also reduce the forward recovery and turn-on time. Col. 15:29-47.

U. New Claim 58

For ease of analysis, new dependent claim 58 is shown below with pseudo-amendments illustrating the differences between new claim 58 and claim 34 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
58. The capacitive responsive electronic switching circuit as defined in claim 56, ~~further comprising~~ wherein ~~said detector circuit compares~~ the sensed body capacitance change to ground proximate the input touch terminal is caused by the operator's body capacitance decreasing an input touch terminal signal amplitude on the detector circuit, and wherein the sensed body capacitance change to ground ~~when proximate to the input touch terminal~~ is compared to a second threshold level to generate the control output signal.	See Claims 1, 18, 28, and 34. The `183 Patent discloses "Another method for implementing capacitive touch switches relies on the change in capacitive coupling between a touch terminal and ground. Systems utilizing such a method are described in U.S. Pat. No. 4,758,735 and U.S. Pat. No. 5,087,825. With this methodology the detection circuit consists of an oscillator (or AC line voltage derivative) providing a signal to a touch terminal whose voltage is then monitored by a detector. The touch terminal is driven in electrical series with other components that function in part as a charge pump. The touch of an operator then provides a capacitive short to ground via the operator's own body capacitance that lowers the amplitude of oscillator voltage seen at the touch terminal." Col. 3:44-56.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8." Col. 12:24-28. The `183 Patent discloses "As can be seen, at 1 kHz, the capacitive impedance of the glass is much greater than the nominal 1 MΩ of the water bridge across the pads. As a result, at 1 kHz, there would be little difference in the impedance paths to ground of the two adjacent pads when either is touched. This would result in the voltage on both pads being pulled towards ground by comparable amounts. Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ

`183 Patent Claim Language	`183 Patent Support
	or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Col. 10:54 – Col. 11:9. The `183 Patent discloses "As stated above, the operator's body includes a capacitance to ground, which may range in a typical person from between 20 to 300 pF. The base terminal of transistor 410 is coupled to it's [sic] emitter by resistor 412 such that unless capacitance is present by the user touching the touch pad 450, transistor 410 will not be forward biased and will not conduct. Thus, when touch pad 450 is not touched, the output signal at the collector terminal of transistor 410 and across pulse stretcher circuit 417 will be zero volts. When, however, a person touches the touch pad 450, that person's body capacitance to ground couples the base of transistor 410 to ground 103 through resistor 413, thereby forward biasing transistor 410 into conduction. This charges capacitor 418 providing a positive DC voltage with respect to the line 301 and causes the output of the Schmitt trigger 420 to go low. Diode 414 is coupled across the base to emitter junction of transistor 410 to clamp the base emitter reverse bias voltage to –0.7V and also reduce the forward recovery and turn-on time. Col. 15:29-47.

V. New Claim 59

`183 Patent Claim Language	`183 Patent Support
59. The capacitive responsive electronic switching circuit as defined in claim 56, wherein each signal output frequency selectively provided to each row of the plurality of small sized input	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably

`183 Patent Claim Language	**`183 Patent Support**
touch terminals of the keypad has a same Hertz value.	at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended

`183 Patent Claim Language	`183 Patent Support
	touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

W. New Claim 60

`183 Patent Claim Language	`183 Patent Support
60. The capacitive responsive electronic switching circuit as defined in claim 56, wherein each signal output frequency selectively provided to each row of the plurality of small sized input touch terminals of the keypad is selected from a plurality of Hertz values.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low

`183 Patent Claim Language	`183 Patent Support
	detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however,

`183 Patent Claim Language	`183 Patent Support
	oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

X. New Claim 61

`183 Patent Claim Language	`183 Patent Support
61. The capacitive responsive electronic switching circuit as defined in claim 60, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of

`183 Patent Claim Language	`183 Patent Support
	inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

Y. New Claim 62

`183 Patent Claim Language	`183 Patent Support
62. The capacitive responsive electronic switching circuit as defined in claim 60, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at

`183 Patent Claim Language	`183 Patent Support
	or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

Z. New Claim 63

`183 Patent Claim Language	`183 Patent Support
63. The capacitive responsive electronic switching circuit as defined in claim 60, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.	See Fig. 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "At 800 kHz, the impedance of the glass drops to 200 kΩ or lower

`183 Patent Claim Language	`183 Patent Support
	giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 11:1-27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

AA. New Claim 64

`183 Patent Claim Language	`183 Patent Support
64. The capacitive responsive electronic switching circuit as defined in claim 56, wherein the supply voltage is a battery supply voltage.	The `183 Patent discloses "It will be apparent to those skilled in the art, that various components of voltage regulator 100 may be added or excluded depending upon the source of power available to power the oscillator 200. For example, if the available power is a 110 V AC 60 Hz commercial power line, a transformer may be added to convert the 100 V AC power to 24 V AC. Alternatively, if a DC batter is used, the AC/DC convertor among other components may be eliminated." Col 13:23-31.

BB. New Claim 65

`183 Patent Claim Language	`183 Patent Support
65. The capacitive responsive electronic switching circuit as defined in claim 56, wherein the supply voltage is a voltage regulator supply voltage.	Figures 4, 5, 11, and 12. The `183 Patent discloses "The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5." Col. 11:64 – Col. 12:5; see also Col. 12:50 – Col. 13:31.

CC. New Claim 66

`183 Patent Claim Language	`183 Patent Support
66. The capacitive responsive electronic switching circuit as defined in claim 27, wherein each signal output frequency selectively provided to each row of the closely spaced array of input touch terminals of the keypad has a same Hertz value.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at

`183 Patent Claim Language	`183 Patent Support
	or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

DD. New Claim 67

`183 Patent Claim Language	`183 Patent Support
67. The capacitive responsive electronic switching circuit as defined in claim 27, wherein each signal output frequency selectively provided to each row of the closely spaced array of input touch terminals of the keypad is selected from a plurality of Hertz values.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to

`183 Patent Claim Language	`183 Patent Support
	approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

EE. New Claim 68

`183 Patent Claim Language	`183 Patent Support
68. The capacitive responsive electronic switching circuit as defined in claim 67, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to

`183 Patent Claim Language	**`183 Patent Support**
	ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of

`183 Patent Claim Language	**`183 Patent Support**
	oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

FF. New Claim 69

`183 Patent Claim Language	**`183 Patent Support**
69. The capacitive responsive electronic switching circuit as defined in claim 67, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components

`183 Patent Claim Language	**`183 Patent Support**
	and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

GG. New Claim 70

`183 Patent Claim Language	**`183 Patent Support**
70. The capacitive responsive electronic switching circuit as defined in claim 67, wherein the plurality of Hertz	See Fig. 11. The `183 Patent discloses "The touch detection

`183 Patent Claim Language	`183 Patent Support
values comprises Hertz values greater than 800 kHz.	circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 11:1-27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the

`183 Patent Claim Language	`183 Patent Support
	resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

HH. New Claim 71

`183 Patent Claim Language	`183 Patent Support
71. The capacitive responsive electronic switching circuit as defined in claim 27, wherein the detector circuit is configured to inhibit the control output signal unless the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.	See Figures 19, 20A-C; and Claims 28 and 35. The `183 Patent discloses "In another embodiment a method to prevent inadvertent so actuations is to require a multi-step process. Referring to FIG. 19, a device is shown having a first palm button 2201, a second palm button 2202, and an indicator light 2205. Palm button 2201 has to be activated first and then button 2202 has to be activated within a 2 second time window before a desired actuation can occur." Col. 22:49-55. The `183 Patent discloses "In a variation of the multi-step process, two touch plates within a housing (one vertical and one horizontal) are used to provide a two-step turn-on. Referring to FIGS. 20A-C, the first step to actuate the output relay 2310, is initiated when the operator inserts his hands and touches the vertical touch sensor 2301 with the dorsal side of the hands. A yellow LED 2304 on top of the device show the successful completion of the first step. The second step is to flip the hand over and touch the horizontal touch sensor 2302 with the palmar

`183 Patent Claim Language	**`183 Patent Support**
	side of the hand. A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310. The flipping action of the hand in the second step causes the forearm muscles to flex, thereby reducing stiffness and fatigue. Also, the hands, and arms can rest on the run bar until the machine cycle is complete. The second step of the two-step turn-on must occur within some predetermined time (for example 2 seconds) after the release of vertical touch sensor or the first step must be repeated." Col. 23:19-36.

II. New Claim 72

For ease of analysis, new independent claim 72 is shown below with pseudo-amendments illustrating the differences between new claim 72 and claim 27 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	**`183 Patent Support**
72. A capacitive responsive electronic switching circuit for a controlled keypad device comprising:	See Claim 27.
an oscillator providing a periodic output signal having a predefined frequency;	See Claim 27.
a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies <u>directly</u> to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;	See Figures 4, 11; and Claims 8, 12, 16. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col.

`183 Patent Claim Language	`183 Patent Support
	5:49-57. The `183 Patent discloses "In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads." Col. 6:1-3. The `183 Patent discloses "Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27. The `183 Patent discloses "Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6. Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5 volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed

`183 Patent Claim Language	`183 Patent Support
	below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8. Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 12:6-33. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies." Col. 14:22-25.  The `183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components similar to those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of the first embodiment in that it includes an array of touch circuits designated as 900_1 through 900_{nm}, which, as shown, include both the touch circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between

`183 Patent Claim Language	`183 Patent Support
	the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.
the first and second input touch terminals defining areas for an operator to provide an input by proximity and touch; and	See Claim 27.
a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled keypad device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.	See Claim 27.

JJ. New Claim 73

`183 Patent Claim Language	`183 Patent Support
73. The capacitive responsive electronic switching circuit as defined in claim 72, wherein the signal output	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably

`183 Patent Claim Language	**`183 Patent Support**
frequencies have a same Hertz value.	at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended

`183 Patent Claim Language	`183 Patent Support
	touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

KK. New Claim 74

`183 Patent Claim Language	`183 Patent Support
74. The capacitive responsive electronic switching circuit as defined in claim 72, wherein each signal output frequency is selected from a plurality of Hertz values.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low

`183 Patent Claim Language	`183 Patent Support
	detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however,

`183 Patent Claim Language	`183 Patent Support
	oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

LL. New Claim 75

`183 Patent Claim Language	`183 Patent Support
75. The capacitive responsive electronic switching circuit as defined in claim 74, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of

`183 Patent Claim Language	`183 Patent Support
	inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

MM. New Claim 76

`183 Patent Claim Language	`183 Patent Support
76. The capacitive responsive electronic switching circuit as defined in claim 74, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at

`183 Patent Claim Language	`183 Patent Support
	or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

NN. New Claim 77

`183 Patent Claim Language	`183 Patent Support
77. The capacitive responsive electronic switching circuit as defined in claim 74, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.	See Fig. 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "At 800 kHz, the impedance of the glass drops to 200 kΩ or lower

`183 Patent Claim Language	`183 Patent Support
	giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 11:1-27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

OO. New Claim 78

For ease of analysis, new dependent claim 78 is shown below with pseudo-amendments illustrating the differences between new claim 78 and claim 28 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
78. The capacitive responsive electronic switching circuit as defined in claim 72, wherein said detector circuit ~~generates~~ is configured to generate said control output signal only when the operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.	See Claims 27 and 28.

PP. New Claim 79

For ease of analysis, new dependent claim 79 is shown below with pseudo-amendments illustrating the differences between new claim 79 and claim 36 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
79. The capacitive responsive electronic switching circuit as defined in claim 72, ~~and~~ further ~~including~~ comprising an indicator for indicating ~~when said~~ the detector circuit ~~determines~~ has determined that the operator is	See Claims 32 and 36. The `183 Patent discloses "The microprocessor also allows the use of visual indicators such as LEDs or annunciators such as a bell or tone generator to confirm the actuation of a given

`183 Patent Claim Language	`183 Patent Support
proximal or touches said second touch terminal.	touch switch or switches. This is particularly useful in cases where a sequence of actuations is required before an action occurs. The feedback to the operator provided by a visual or audio indicator activated by the microprocessor in response to intermediate touches in a required sequence can minimize time lost and/or frustration on the part of the operator due to failed actuations from partial touches or wrong actuations from touching the wrong pad in a given required sequence or combination of touches." Col. 6:31-42. The `183 Patent discloses "A further option is to provide one or more LEDs 2205 or audible annunciators for visual or audible feedback to the operator. Specifically, in FIG. 19 the LED 2205 will come on when button 2201 has been successfully activated to cue the operator that it is time to move to button 2202. Where required a second LED with a different color than the first (yellow for the first LED and red for the second) can be provided to provide visual confirmation that the second button 2202 has been activated or that the required combination of the two buttons has been activated. Two different audible tone or sound generators could also be used in lieu of the LEDs to provide feedback to the operator." Col. 23:1-12. The `183 Patent discloses "A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310." Col. 23:28-30.

QQ. New Claim 80

`183 Patent Claim Language	`183 Patent Support
80. The capacitive responsive electronic switching circuit as defined in claim 72, wherein the detector circuit is configured to inhibit the control output signal unless the operator is proximal or touches said second touch terminal after	See Figures 19, 20A-C; and Claims 28 and 35. The `183 Patent discloses "In another embodiment a method to prevent inadvertent so actuations is to require a multi-step process. Referring to FIG. 19, a device is shown having a

`183 Patent Claim Language	`183 Patent Support
the operator is proximal or touches said first touch terminal.	first palm button 2201, a second palm button 2202, and an indicator light 2205. Palm button 2201 has to be activated first and then button 2202 has to be activated within a 2 second time window before a desired actuation can occur." Col. 22:49-55. The `183 Patent discloses "In a variation of the multi-step process, two touch plates within a housing (one vertical and one horizontal) are used to provide a two-step turn-on. Referring to FIGS. 20A-C, the first step to actuate the output relay 2310, is initiated when the operator inserts his hands and touches the vertical touch sensor 2301 with the dorsal side of the hands. A yellow LED 2304 on top of the device show the successful completion of the first step. The second step is to flip the hand over and touch the horizontal touch sensor 2302 with the palmar side of the hand. A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310. The flipping action of the hand in the second step causes the forearm muscles to flex, thereby reducing stiffness and fatigue. Also, the hands, and arms can rest on the run bar until the machine cycle is complete. The second step of the two-step turn-on must occur within some predetermined time (for example 2 seconds) after the release of vertical touch sensor or the first step must be repeated." Col. 23:19-36.

RR. New Claim 81

`183 Patent Claim Language	`183 Patent Support
81. The capacitive responsive electronic switching circuit as defined in claim 72, wherein a peak voltage of the signal output frequencies is greater than a supply voltage.	See Figures 4, 5; Claims 27 and 37. The `183 Patent discloses "Having provided a basis for the use of higher frequencies, the basic construction of the electronic switching circuit constructed in accordance with a first embodiment of the present invention is now described with reference to FIG. 4. The electronic switching circuit includes a voltage

`183 Patent Claim Language	`183 Patent Support
	regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5. Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6." Col. 11:60 – Col. 12:13. The `183 Patent discloses "Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s)." Col. 18:43-49. The `183 Patent discloses "A preferred circuit for implementing a voltage regulator 100 is shown in FIG. 5. Voltage regulator 100 preferably includes an AC/DC convertor 110 for generating 29 V to 36 V unregulated DC on line 119. This unregulated DC power is supplied to a 5 V DC regulator 120 and to a 26 V DC regulator 130. AC/DC convertor 110 includes diodes 112, 114, 116, and 118, which rectify the supplied 24 V AC power provided on power lines 101 and 102." Col. 12:50-57; see also Col. 12:57 – Col. 13:31.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent discloses "The oscillator circuitry shown in FIG. 6 is very stable over the temperature range of -40° C. to 105° C. The output of the touch switch circuitry drops at a rate of approximately 40 mV/°C. when temperature falls below 0° C. If application requires operation at low temperatures (-40° C.), the following three methods may be used to increase the output of the switch: increase the oscillator's regulated supply voltage, increase the resistance of resistor 416, and use a higher gain transistor 410. All of these methods would increase sensitivity at high temperatures." Col. 16:33-41.

SS. New Claim 82

`183 Patent Claim Language	`183 Patent Support
82. The capacitive responsive electronic switching circuit as defined in claim 81, wherein the supply voltage is a battery supply voltage.	The `183 Patent discloses "It will be apparent to those skilled in the art, that various components of voltage regulator 100 may be added or excluded depending upon the source of power available to power the oscillator 200. For example, if the available power is a 110 V AC 60 Hz commercial power line, a transformer may be added to convert the 100 V AC power to 24 V AC. Alternatively, if a DC batter is used, the AC/DC convertor among other components may be eliminated." Col 13:23-31.

TT. New Claim 83

`183 Patent Claim Language	`183 Patent Support
83. The capacitive responsive electronic switching circuit as defined in claim 81, wherein the supply voltage is a voltage regulator supply voltage.	Figures 4, 5, 11, and 12. The `183 Patent discloses "The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105.

`183 Patent Claim Language	`183 Patent Support
	Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5." Col. 11:64 – Col. 12:5; see also Col. 12:50 – Col. 13:31.

UU. New Claim 84

For ease of analysis, new independent claim 84 is shown below with pseudo-amendments illustrating the differences between new claim 84 and claim 27 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
84. A capacitive responsive electronic switching circuit for a controlled keypad device comprising:	See Claim 27.
an oscillator providing a periodic output signal having a predefined frequency;	See Claim 27.
a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals<u>, wherein a peak voltage of the signal output frequencies is greater than a supply voltage</u>;	See Figures 4, 5, 11; and Claims 8, 12, 16, 27 and 37. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads." Col. 6:1-3.

`183 Patent Claim Language	`183 Patent Support
	The `183 Patent discloses "Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27. The `183 Patent discloses "Having provided a basis for the use of higher frequencies, the basic construction of the electronic switching circuit constructed in accordance with a first embodiment of the present invention is now described with reference to FIG. 4. The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5. Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6. Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5

`183 Patent Claim Language	`183 Patent Support
	volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8. Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 11:60 – 12:33. The `183 Patent discloses "A preferred circuit for implementing a voltage regulator 100 is shown in FIG. 5. Voltage regulator 100 preferably includes an AC/DC convertor 110 for generating 29 V to 36 V unregulated DC on line 119. This unregulated DC power is supplied to a 5 V DC regulator 120 and to a 26 V DC regulator 130. AC/DC convertor 110 includes diodes 112, 114, 116, and 118, which rectify the supplied 24 V AC power provided on power lines 101 and 102." Col. 12:50-57; see also Col. 12:57 – Col. 13:31. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output

`183 Patent Claim Language	`183 Patent Support
	frequencies." Col. 14:22-25. The `183 Patent discloses "The oscillator circuitry shown in FIG. 6 is very stable over the temperature range of -40° C. to 105° C. The output of the touch switch circuitry drops at a rate of approximately 40 mV/°C. when temperature falls below 0° C. If application requires operation at low temperatures (-40° C.), the following three methods may be used to increase the output of the switch: increase the oscillator's regulated supply voltage, increase the resistance of resistor 416, and use a higher gain transistor 410. All of these methods would increase sensitivity at high temperatures." Col. 16:33-41. The `183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components similar to those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of the first embodiment in that it includes an array of touch circuits designated as 900_1 through 900_{nm}, which, as shown, include both the touch circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc.

`183 Patent Claim Language	`183 Patent Support
	can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.
the first and second input touch terminals defining areas for an operator to provide an input by proximity and touch; and	See Claim 27.
a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled keypad device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.	See Claim 27.

VV. New Claim 85

`183 Patent Claim Language	`183 Patent Support
85. The capacitive responsive electronic switching circuit as defined in claim 84, wherein the signal output frequencies have a same Hertz value.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to

`183 Patent Claim Language	`183 Patent Support
	approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27.

`183 Patent Claim Language	**`183 Patent Support**
	The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

WW. New Claim 86

`183 Patent Claim Language	**`183 Patent Support**
86. The capacitive responsive electronic switching circuit as defined in claim 84, wherein each signal output frequency is selected from a plurality of Hertz values.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to

`183 Patent Claim Language	`183 Patent Support
	ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of

`183 Patent Claim Language	**`183 Patent Support**
	oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

XX. New Claim 87

`183 Patent Claim Language	**`183 Patent Support**
87. The capacitive responsive electronic switching circuit as defined in claim 86, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components

`183 Patent Claim Language	**`183 Patent Support**
	and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

YY. New Claim 88

`183 Patent Claim Language	**`183 Patent Support**
88. The capacitive responsive electronic switching circuit as defined in claim 86, wherein the plurality of Hertz	See Figure 11. The `183 Patent discloses "The touch detection

`183 Patent Claim Language	`183 Patent Support
values comprises Hertz values greater than 100 kHz.	circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance

`183 Patent Claim Language	`183 Patent Support
	paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

ZZ. New Claim 89

`183 Patent Claim Language	`183 Patent Support
89. The capacitive responsive electronic switching circuit as defined in claim 86, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.	See Fig. 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as

`183 Patent Claim Language	`183 Patent Support
	illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 11:1-27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily

`183 Patent Claim Language	`183 Patent Support
	vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

AAA. New Claim 90

`183 Patent Claim Language	`183 Patent Support
90. The capacitive responsive electronic switching circuit as defined in claim 84, wherein the supply voltage is a battery supply voltage.	The `183 Patent discloses "It will be apparent to those skilled in the art, that various components of voltage regulator 100 may be added or excluded depending upon the source of power available to power the oscillator 200. For example, if the available power is a 110 V AC 60 Hz commercial power line, a transformer may be added to convert the 100 V AC power to 24 V AC. Alternatively, if a DC batter is used, the AC/DC convertor among other components may be eliminated." Col 13:23-31.

BBB. New Claim 91

`183 Patent Claim Language	`183 Patent Support
91. The capacitive responsive electronic switching circuit as defined in claim 84, wherein the supply voltage is a voltage regulator supply voltage.	Figures 4, 5, 11, and 12. The `183 Patent discloses "The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5." Col. 11:64 – Col. 12:5; see also Col. 12:50 – Col. 13:31.

CCC. New Claim 92

For ease of analysis, new dependent claim 92 is shown below with pseudo-amendments illustrating the differences between new claim 92 and claim 28 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
92. The capacitive responsive electronic switching circuit as defined in claim 84, wherein said detector circuit ~~generates~~ is configured to generate said control output signal only when the operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.	See Claims 27 and 28.

DDD. New Claim 93

For ease of analysis, new dependent claim 93 is shown below with pseudo-amendments illustrating the differences between new claim 93 and claim 36 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
93. The capacitive responsive electronic switching circuit as defined in claim 84, ~~and~~ further ~~including~~ comprising an indicator for indicating ~~when said~~ the detector circuit ~~determines~~ has determined that the operator is proximal or touches said second touch terminal.	See Claims 32 and 36. The `183 Patent discloses "The microprocessor also allows the use of visual indicators such as LEDs or annunciators such as a bell or tone generator to confirm the actuation of a given touch switch or switches. This is particularly useful in cases where a sequence of actuations is required before an action occurs. The feedback to the operator provided by a visual or audio indicator activated by the microprocessor in response to intermediate touches in a required sequence can minimize time lost and/or frustration on the part of the operator due to failed actuations from partial touches or wrong actuations from touching the wrong pad in a

`183 Patent Claim Language	`183 Patent Support
	given required sequence or combination of touches." Col. 6:31-42. The `183 Patent discloses "A further option is to provide one or more LEDs 2205 or audible annunciators for visual or audible feedback to the operator. Specifically, in FIG. 19 the LED 2205 will come on when button 2201 has been successfully activated to cue the operator that it is time to move to button 2202. Where required a second LED with a different color than the first (yellow for the first LED and red for the second) can be provided to provide visual confirmation that the second button 2202 has been activated or that the required combination of the two buttons has been activated. Two different audible tone or sound generators could also be used in lieu of the LEDs to provide feedback to the operator." Col. 23:1-12. The `183 Patent discloses "A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310." Col. 23:28-30.

EEE. New Claim 94

`183 Patent Claim Language	`183 Patent Support
94. The capacitive responsive electronic switching circuit as defined in claim 84, wherein the detector circuit is configured to inhibit the control output signal unless the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.	See Figures 19, 20A-C; and Claims 28 and 35. The `183 Patent discloses "In another embodiment a method to prevent inadvertent so actuations is to require a multi-step process. Referring to FIG. 19, a device is shown having a first palm button 2201, a second palm button 2202, and an indicator light 2205. Palm button 2201 has to be activated first and then button 2202 has to be activated within a 2 second time window before a desired actuation can occur." Col. 22:49-55. The `183 Patent discloses "In a variation of the multi-step process, two touch plates within a housing (one vertical and one horizontal) are

`183 Patent Claim Language	`183 Patent Support
	used to provide a two-step turn-on. Referring to FIGS. 20A-C, the first step to actuate the output relay 2310, is initiated when the operator inserts his hands and touches the vertical touch sensor 2301 with the dorsal side of the hands. A yellow LED 2304 on top of the device show the successful completion of the first step. The second step is to flip the hand over and touch the horizontal touch sensor 2302 with the palmar side of the hand. A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310. The flipping action of the hand in the second step causes the forearm muscles to flex, thereby reducing stiffness and fatigue. Also, the hands, and arms can rest on the run bar until the machine cycle is complete. The second step of the two-step turn-on must occur within some predetermined time (for example 2 seconds) after the release of vertical touch sensor or the first step must be repeated." Col. 23:19-36.

FFF. New Claim 95

For ease of analysis, new independent claim 95 is shown below with pseudo-amendments illustrating the differences between new claim 95 and claim 27 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
95. A capacitive responsive electronic switching circuit for a controlled keypad device comprising:	See Claim 27.
an oscillator providing a periodic output signal having a predefined frequency;	See Claim 27.
a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies, wherein a signal output frequency is selectively provided to each row of a closely spaced	See Figures 4, 5, 11; and Claims 8, 12, 16, 27 and 37. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably

`183 Patent Claim Language	`183 Patent Support
array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals, and wherein a peak voltage of the signal output frequencies is greater than a supply voltage;	at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard." Col. 5:49-57. The `183 Patent discloses "In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads." Col. 6:1-3. The `183 Patent discloses "Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad." Col. 11:19-27. The `183 Patent discloses "Having provided a basis for the use of higher frequencies, the basic construction of the electronic switching circuit constructed in accordance with a first embodiment of the present invention is now described with reference to FIG. 4. The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200

`183 Patent Claim Language	`183 Patent Support
	with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5. Upon being powered by voltage regulator 100, oscillator 200 generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator 200 is supplied via line 201 to a floating common generator 300, a touch pad shield plate 460, a touch circuit 400, and a microcontroller 500. Oscillator 200 is described below with reference to FIG. 6. Floating common generator 300 receives the 26 V peak square wave from oscillator 200 and outputs a regulated floating common that is 5 volts below the square wave output from oscillator 200 and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit 400 and microcontroller 500 via line 301 such that the output square wave from oscillator 200 and floating common output from floating common generator 300 provide power to touch circuit 400 and microcontroller 500. Details of floating common generator 300 are discussed below with reference to FIG. 7. Touch circuit 400 senses capacitance from a touch pad 450 via line 451 and outputs a signal to microcontroller 500 via line 401 upon detecting a capacitance to ground at touch pad 450 that exceeds a threshold value. The details of touch circuit 400 are described below with reference to FIG. 8. Upon receiving an indication from touch circuit 400 that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad 450, microcontroller 500 outputs a signal to a load-controlling microcontroller 600 via line 501, which is preferably a two way optical coupling bus." Col. 11:60 – 12:33. The `183 Patent discloses "A preferred circuit for implementing a voltage regulator 100 is

\`183 Patent Claim Language	\`183 Patent Support
	shown in FIG. 5. Voltage regulator 100 preferably includes an AC/DC convertor 110 for generating 29 V to 36 V unregulated DC on line 119. This unregulated DC power is supplied to a 5 V DC regulator 120 and to a 26 V DC regulator 130. AC/DC convertor 110 includes diodes 112, 114, 116, and 118, which rectify the supplied 24 V AC power provided on power lines 101 and 102." Col. 12:50-57; see also Col. 12:57 – Col. 13:31. The \`183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies." Col. 14:22-25. The \`183 Patent discloses "The oscillator circuitry shown in FIG. 6 is very stable over the temperature range of -40° C. to 105° C. The output of the touch switch circuitry drops at a rate of approximately 40 mV/°C. when temperature falls below 0° C. If application requires operation at low temperatures (-40° C.), the following three methods may be used to increase the output of the switch: increase the oscillator's regulated supply voltage, increase the resistance of resistor 416, and use a higher gain transistor 410. All of these methods would increase sensitivity at high temperatures." Col. 16:33-41. The \`183 Patent discloses "A multiple touch pad circuit constructed in accordance with the second embodiment is shown in FIG. 11. In the second embodiment of FIG. 11, components similar to those in the first embodiment in FIG. 4 are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of the first embodiment in that it includes an array of touch circuits designated as 900_1 through 900_{nm}, which, as shown, include both the touch

`183 Patent Claim Language	`183 Patent Support
	circuit 400 shown in FIGS. 4 and 8 and the input touch terminal pad 451 (FIG. 4). Microcontroller 500 selects each row of the touch circuits 900_1 to 900_{nm} by providing the signal from oscillator 200 to selected rows of touch circuits. In this manner, microcontroller 500 can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length 451 between the touch pad 450 and the base to the detection transistor 410 to a minimum, the detection circuits 900 are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps." Col. 18:34-59.
the first and second input touch terminals defining areas for an operator to provide an input by proximity and touch; and	See Claim 27.
a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled keypad device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said	See Claim 27.

`183 Patent Claim Language	`183 Patent Support
first touch terminal.	

GGG. New Claim 96

`183 Patent Claim Language	`183 Patent Support
96. The capacitive responsive electronic switching circuit as defined in claim 95, wherein each signal output frequency selectively provided to each row of the closely spaced array of input touch terminals of the keypad has a same Hertz value.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass

`183 Patent Claim Language	`183 Patent Support
	becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

HHH. New Claim 97

`183 Patent Claim Language	`183 Patent Support
97. The capacitive responsive electronic switching circuit as defined in claim 95, wherein each signal output frequency selectively provided to each row of the closely spaced array of input touch terminals of the keypad is selected	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a

`183 Patent Claim Language	**`183 Patent Support**
from a plurality of Hertz values.	[sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be

`183 Patent Claim Language	`183 Patent Support
	possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

III. New Claim 98

`183 Patent Claim Language	`183 Patent Support
98. The capacitive responsive electronic switching circuit as defined in claim 97, wherein the plurality of Hertz values comprises Hertz values greater than 50 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads

`183 Patent Claim Language	`183 Patent Support
	by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50

`183 Patent Claim Language	`183 Patent Support
	kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

JJJ. New Claim 99

`183 Patent Claim Language	`183 Patent Support
99. The capacitive responsive electronic switching circuit as defined in claim 97, wherein the plurality of Hertz values comprises Hertz values greater than 100 kHz.	See Figure 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad 59 being twice that of the touched pad 57. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of

`183 Patent Claim Language	`183 Patent Support
	operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. Col. 10:60 – Col. 11:27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

KKK. New Claim 100

`183 Patent Claim Language	`183 Patent Support
100. The capacitive responsive electronic switching circuit as defined in claim 97, wherein the plurality of Hertz values comprises Hertz values greater than 800 kHz.	See Fig. 11. The `183 Patent discloses "The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a [sic] skin oils and water. Col. 5:49-53. The `183 Patent discloses "At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad 57 and adjacent pads 59. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the

`183 Patent Claim Language	`183 Patent Support
	touch pad. Col. 11:1-27. The `183 Patent discloses "As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator 200 may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator 200 is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. Col. 14:22-28. The `183 Patent disclosed "The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application." Col. 14:65 – Col. 15:1.

LLL. New Claim 101

`183 Patent Claim Language	`183 Patent Support
101. The capacitive responsive electronic switching circuit as defined in claim 95, wherein the supply voltage is a battery supply voltage.	The `183 Patent discloses "It will be apparent to those skilled in the art, that various components of voltage regulator 100 may be added or excluded depending upon the source of power available to power the oscillator 200. For example, if the available power is a 110 V AC 60 Hz commercial power line, a transformer may be added to convert the 100 V AC power to 24 V AC. Alternatively, if a DC batter is used, the AC/DC convertor among other components may be eliminated." Col 13:23-31.

MMM. New Claim 102

`183 Patent Claim Language	`183 Patent Support
102. The capacitive responsive electronic switching circuit as defined in claim 95, wherein the supply voltage is a	Figures 4, 5, 11, and 12. The `183 Patent discloses "The electronic switching circuit includes a voltage regulator 100 including input lines 101 and 102 for

`183 Patent Claim Language	`183 Patent Support
voltage regulator supply voltage.	receiving a 24 V AC line voltage and a line 103 for grounding the circuit. Voltage regulator 100 converts the received AC voltage to a DC voltage and supplies a regulated 5 V DC power to an oscillator 200 via lines 104 and 105. Voltage regulator also supplies oscillator 200 with 26 V DC power via line 106. The details of voltage regulator 100 are discussed below with reference to FIG. 5." Col. 11:64 – Col. 12:5; see also Col. 12:50 – Col. 13:31.

NNN. New Claim 103

For ease of analysis, new dependent claim 103 is shown below with pseudo-amendments illustrating the differences between new claim 103 and claim 28 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
103. The capacitive responsive electronic switching circuit as defined in claim 95, wherein said detector circuit ~~generates~~ is configured to generate said control output signal only when the operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.	See Claims 27 and 28.

OOO. New Claim 104

For ease of analysis, new dependent claim 104 is shown below with pseudo-amendments illustrating the differences between new claim 104 and claim 36 of the `183 Patent following the first reexamination proceeding.

`183 Patent Claim Language	`183 Patent Support
104. The capacitive responsive electronic switching circuit as defined in claim 95, ~~and~~ further ~~including~~	See Claims 32 and 36. The `183 Patent discloses "The microprocessor

`183 Patent Claim Language	**`183 Patent Support**
comprising an indicator for indicating ~~when said~~ the detector circuit ~~determines~~ has determined that the operator is proximal or touches said second touch terminal.	also allows the use of visual indicators such as LEDs or annunciators such as a bell or tone generator to confirm the actuation of a given touch switch or switches. This is particularly useful in cases where a sequence of actuations is required before an action occurs. The feedback to the operator provided by a visual or audio indicator activated by the microprocessor in response to intermediate touches in a required sequence can minimize time lost and/or frustration on the part of the operator due to failed actuations from partial touches or wrong actuations from touching the wrong pad in a given required sequence or combination of touches." Col. 6:31-42. The `183 Patent discloses "A further option is to provide one or more LEDs 2205 or audible annunciators for visual or audible feedback to the operator. Specifically, in FIG. 19 the LED 2205 will come on when button 2201 has been successfully activated to cue the operator that it is time to move to button 2202. Where required a second LED with a different color than the first (yellow for the first LED and red for the second) can be provided to provide visual confirmation that the second button 2202 has been activated or that the required combination of the two buttons has been activated. Two different audible tone or sound generators could also be used in lieu of the LEDs to provide feedback to the operator." Col. 23:1-12. The `183 Patent discloses "A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310." Col. 23:28-30.

PPP. New Claim 105

`183 Patent Claim Language	**`183 Patent Support**
105. The capacitive responsive electronic switching circuit as defined in claim 95, wherein the detector circuit is	See Figures 19, 20A-C; and Claims 28 and 35. The `183 Patent discloses "In another

`183 Patent Claim Language	`183 Patent Support
configured to inhibit the control output signal unless the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.	embodiment a method to prevent inadvertent so actuations is to require a multi-step process. Referring to FIG. 19, a device is shown having a first palm button 2201, a second palm button 2202, and an indicator light 2205. Palm button 2201 has to be activated first and then button 2202 has to be activated within a 2 second time window before a desired actuation can occur." Col. 22:49-55. The `183 Patent discloses "In a variation of the multi-step process, two touch plates within a housing (one vertical and one horizontal) are used to provide a two-step turn-on. Referring to FIGS. 20A-C, the first step to actuate the output relay 2310, is initiated when the operator inserts his hands and touches the vertical touch sensor 2301 with the dorsal side of the hands. A yellow LED 2304 on top of the device show the successful completion of the first step. The second step is to flip the hand over and touch the horizontal touch sensor 2302 with the palmar side of the hand. A red LED 2305 on top of the device shows the completion of the two step turn-on and activation of output relay 2310. The flipping action of the hand in the second step causes the forearm muscles to flex, thereby reducing stiffness and fatigue. Also, the hands, and arms can rest on the run bar until the machine cycle is complete. The second step of the two-step turn-on must occur within some predetermined time (for example 2 seconds) after the release of vertical touch sensor or the first step must be repeated." Col. 23:19-36.

V. CONCLUSION

In view of the above, the Patent Owner submits that the claims are in condition for allowance. The present amendment neither enlarges the scope of the claims of the patent nor introduces new matter. If the Examiner should have any questions, please contact the Patent Owner's Attorney, Brian A. Carlson, at 972-732-1001. The Commissioner is hereby authorized to charge any fees due in connection with this filing, or credit any overpayment, to Deposit Account No. 50-1065.

Respectfully submitted,

December 24, 2013
Date

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US005796183A

United States Patent [19]

Hourmand

[11] **Patent Number: 5,796,183**

[45] **Date of Patent: Aug. 18, 1998**

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[54] **CAPACITIVE RESPONSIVE ELECTRONIC SWITCHING CIRCUIT**

[75] Inventor: **Byron Hourmand**, Hersey, Mich.

[73] Assignee: **Nartron Corporation**, Reed City, Mich.

[21] Appl. No.: **601,268**

[22] Filed: **Jan. 31, 1996**

[51] **Int. Cl.^{6}** **H01H 35/00**

[52] **U.S. Cl.** **307/116**; 361/181; 307/125; 307/139

[58] **Field of Search** 307/112, 113, 307/116, 125, 139, 140, 157; 361/181

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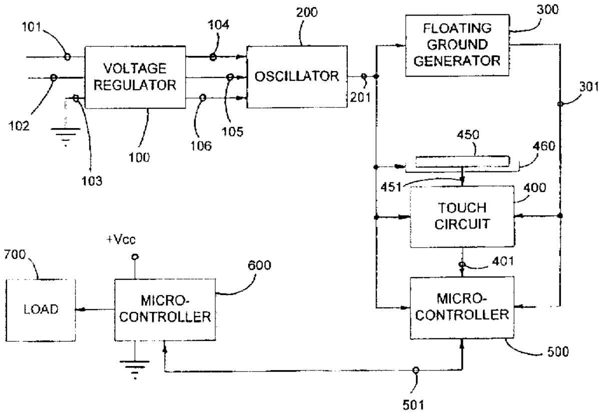
Primary Examiner—William M. Shoop, Jr.
Assistant Examiner—Jonathan Kaplan
Attorney, Agent, or Firm—Price, Heneveld, Cooper, DeWitt & Litton

[57] **ABSTRACT**

A capacitive responsive electronic switching circuit comprises an oscillator providing a periodic output signal having a frequency of 50 kHz or greater, an input touch terminal defining an area for an operator provide an input by proximity and touch, and a detector circuit coupled to the oscillator for receiving the periodic output signal from the oscillator, and coupled to the input touch terminal. The detector circuit being responsive to signals from the oscillator and the presence of an operator's body capacitance to ground coupled to the touch terminal when in proximity or touched by an operator to provide a control output signal. Preferably, the oscillator provides a periodic output signal having a frequency of 800 kHz or greater. An array of touch terminals may be provided in close proximity due to the reduction in crosstalk that may result from contaminants by utilizing an oscillator outputting a signal having a frequency of 50 kHz or greater.

32 Claims, 13 Drawing Sheets



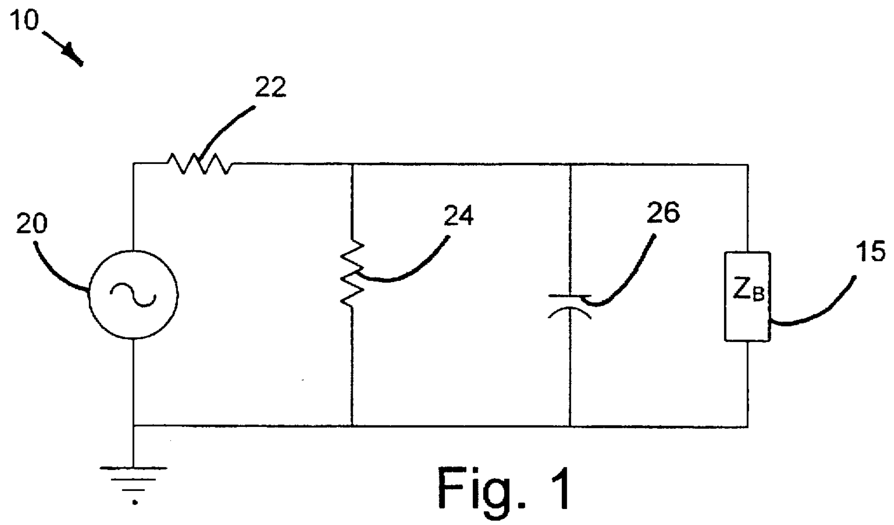


Fig. 1

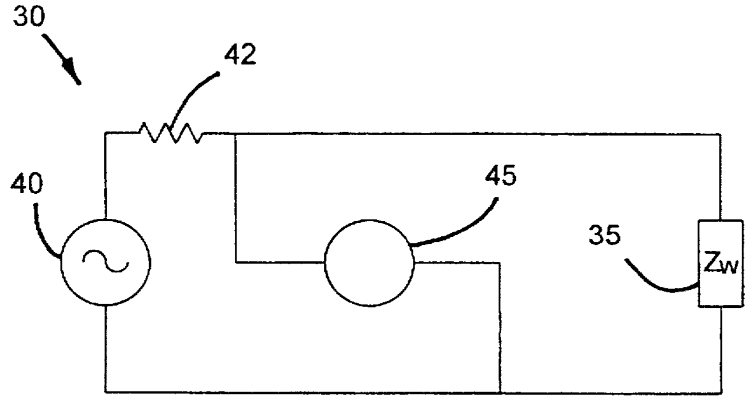
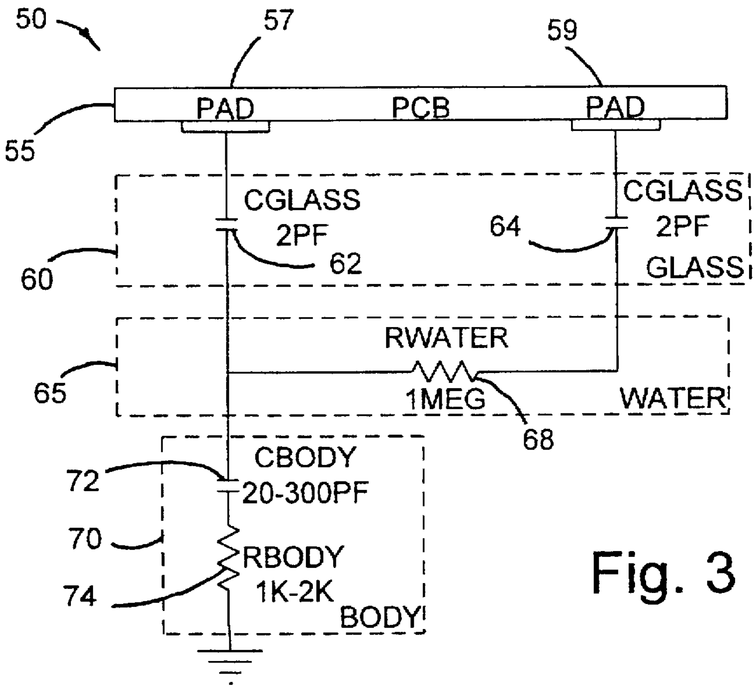


Fig. 2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57
59
PAD
PCB
PAD
55
CGLASS
2PF
62
64
CGLASS
2PF
GLASS
60
RWATER
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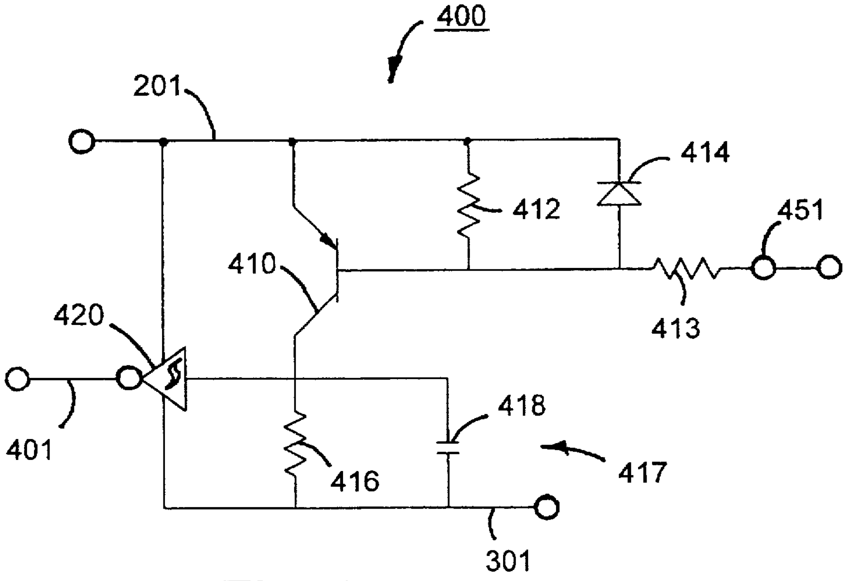
WATER
65
68
CBODY
20-300PF
72
70
RBODY
1K-2K
BODY
74

Fig. 3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414
412
451
410
413
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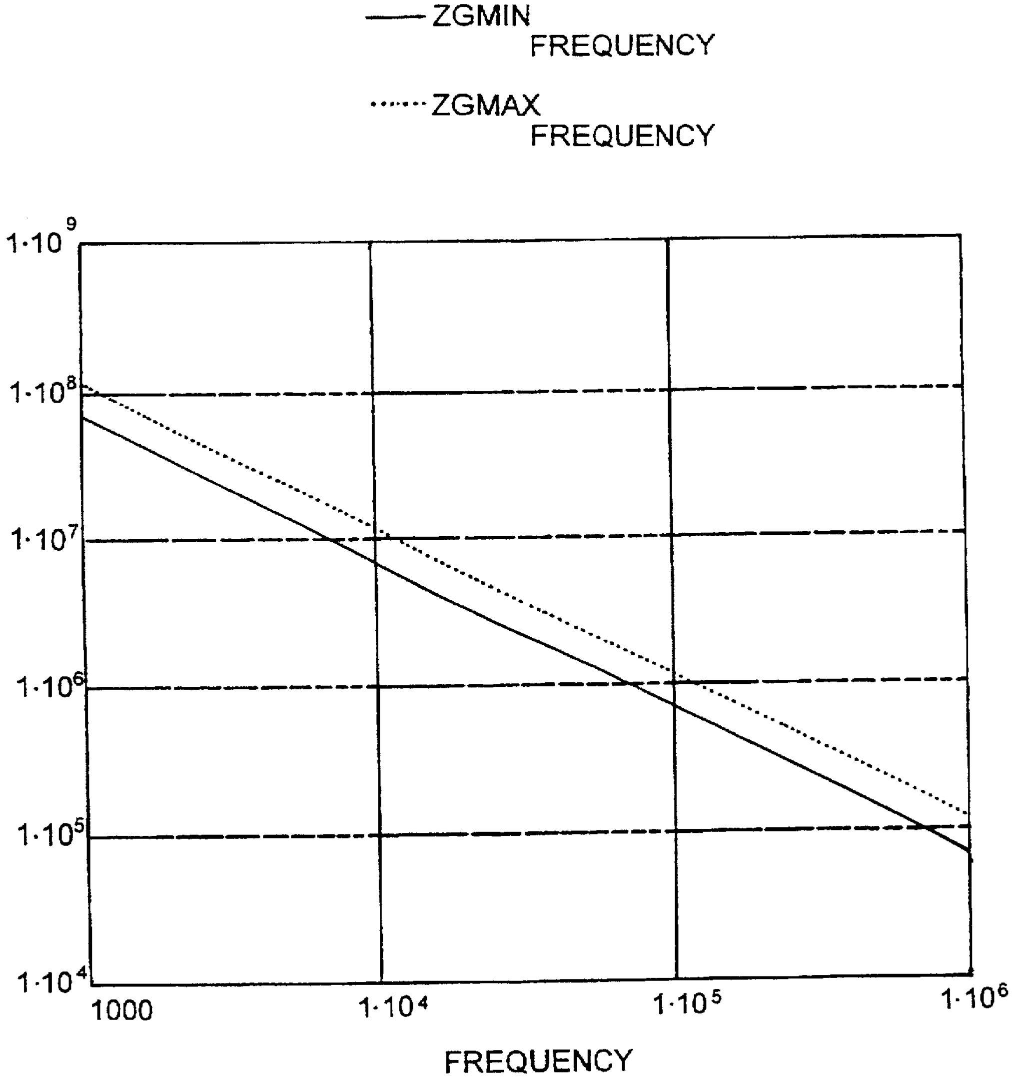
401
418
416
417
301

Fig. 8


ZGMIN
FREQUENCY
ZGMAX
FREQUENCY
1·10^9
1·10^8
1·10^7
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1·10^4
1000
1·10^4
1·10^5
1·10^6
FREQUENCY

Fig. 3A

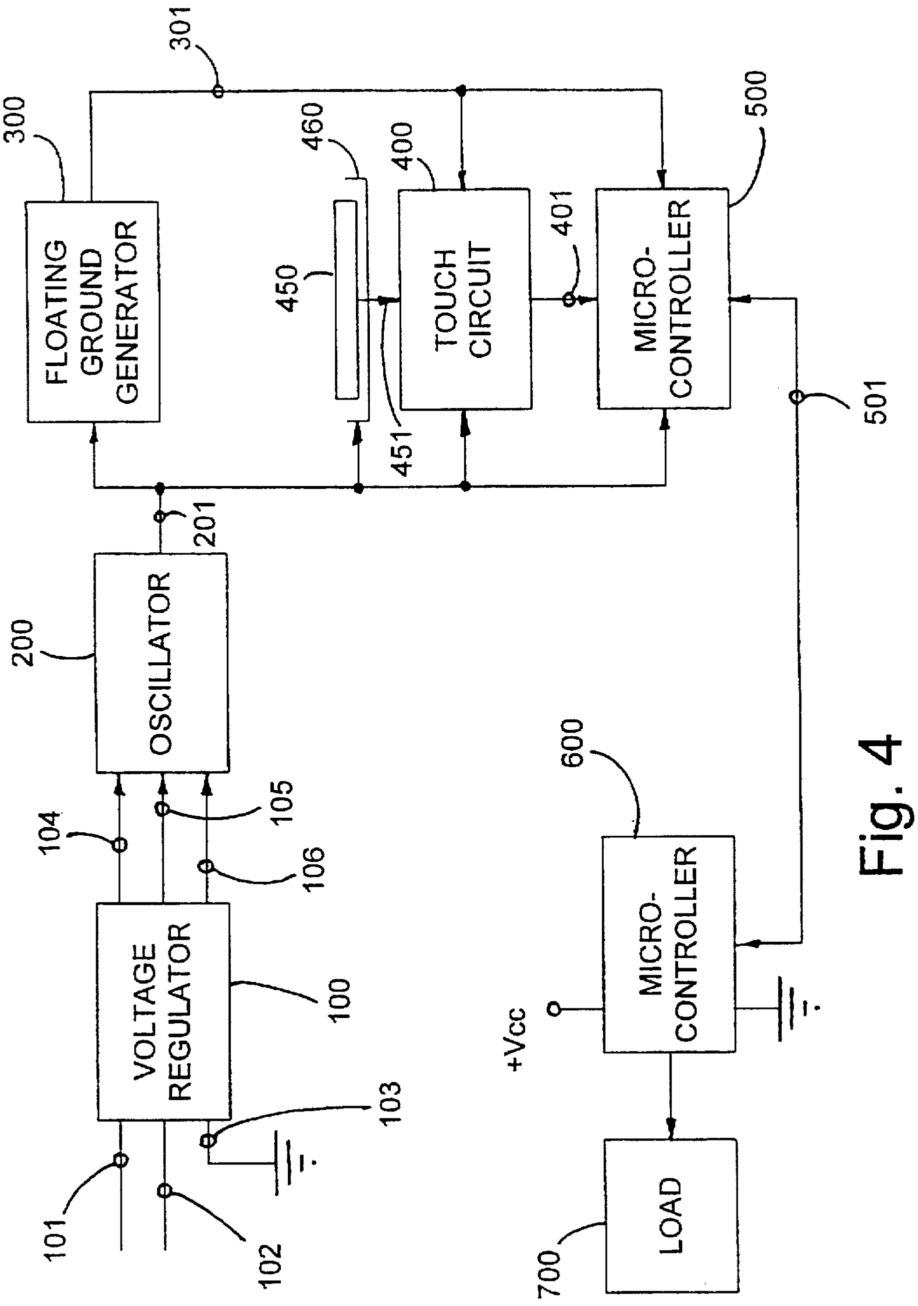

FLOATING GROUND GENERATOR
300
301
460
400
500
450
TOUCH CIRCUIT
401
MICRO-CONTROLLER
451
201
501
200
OSCILLATOR
104
105
106
VOLTAGE REGULATOR
100
103
101
102
600
MICRO-CONTROLLER
+Vcc
LOAD
700

Fig. 4

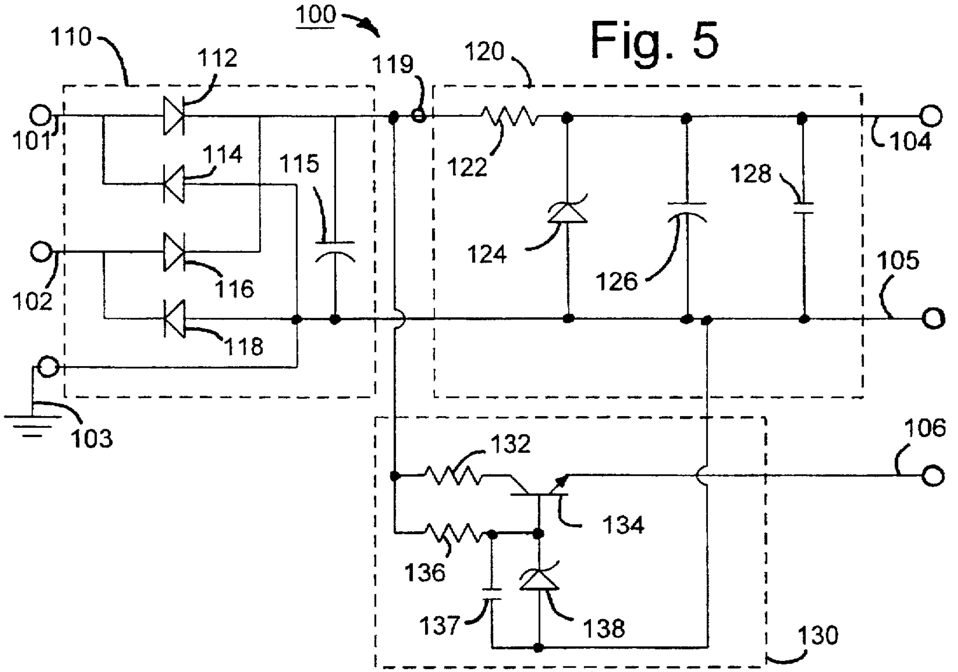


Fig. 5

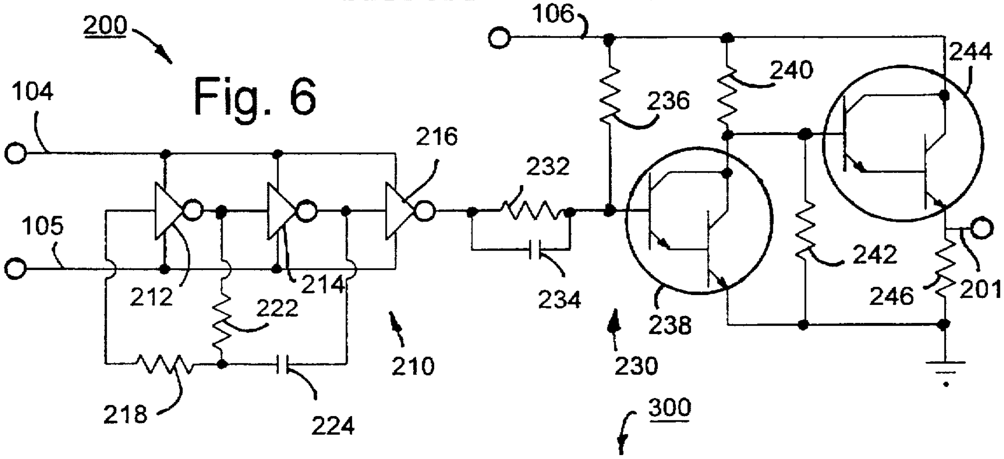


Fig. 6

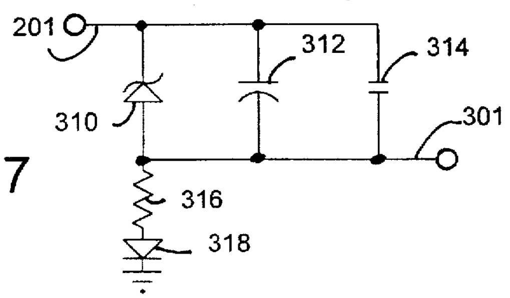


Fig. 7

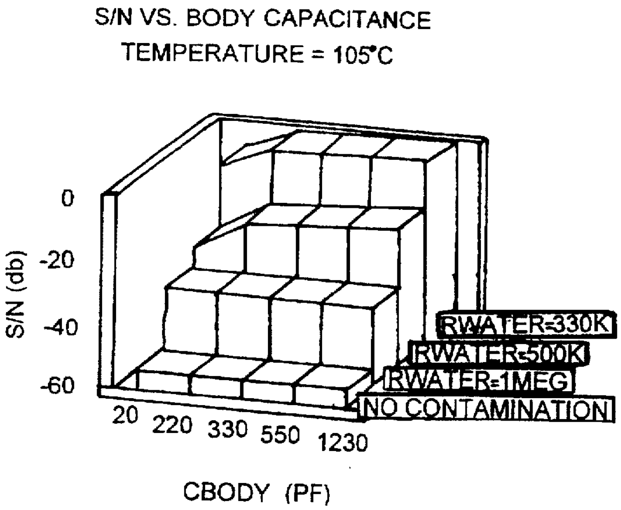
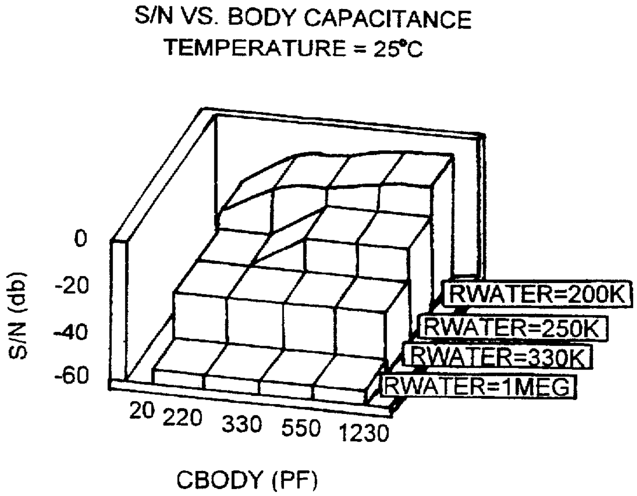

S/N VS. BODY CAPACITANCE
TEMPERATURE = 105°C
S/N (db)
0
-20
-40
-60
20
220
330
550
1230
CBODY (PF)
RWATER=330K
RWATER=500K
RWATER=1MEG
NO CONTAMINATION

Fig. 9


S/N VS. BODY CAPACITANCE
TEMPERATURE = 25°C
S/N (db)
0
-20
-40
-60
20
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1230
CBODY (PF)
RWATER=200K
RWATER=250K
RWATER=330K
RWATER=1MEG

Fig. 10

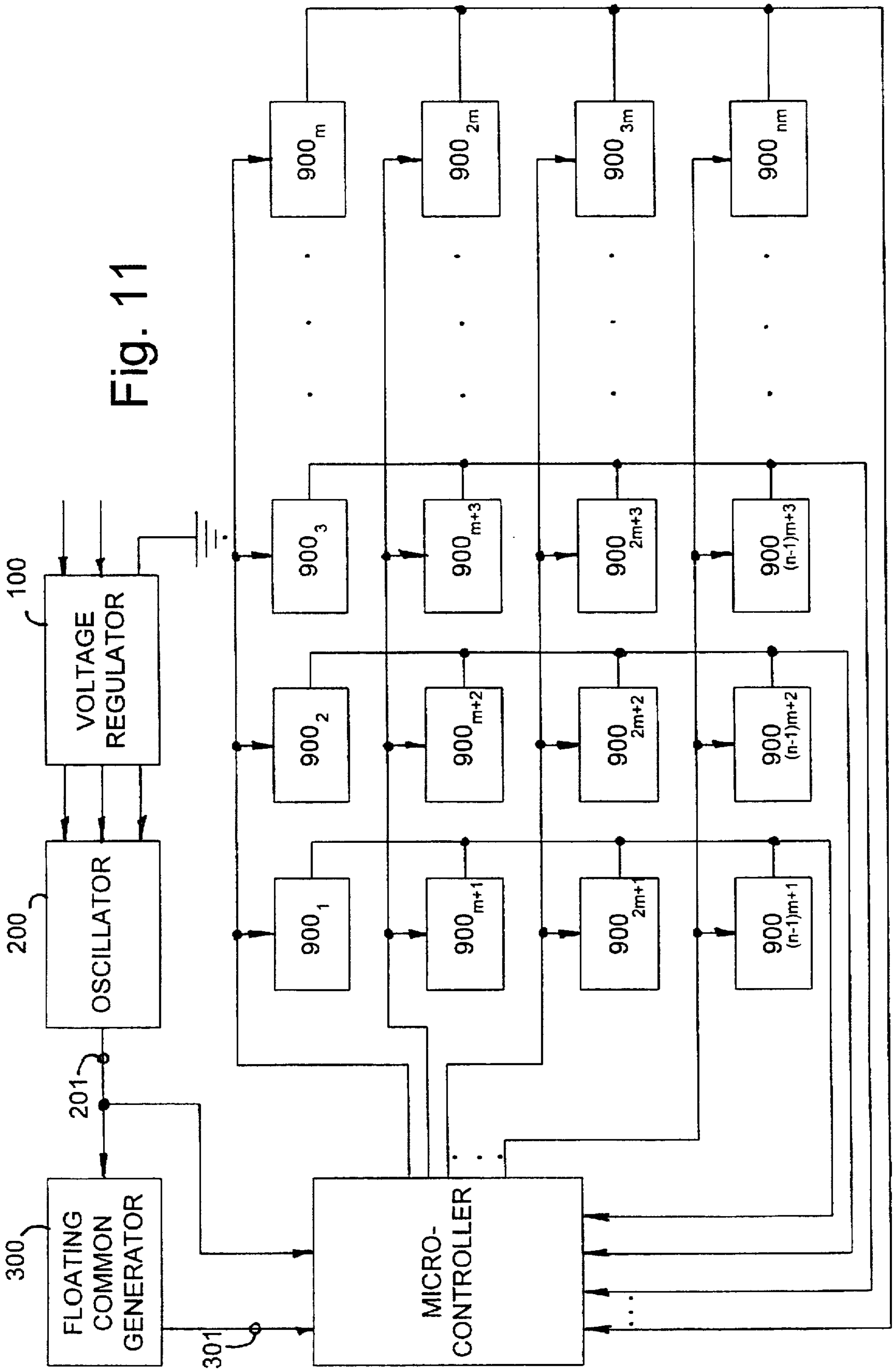

Fig. 11

100
VOLTAGE REGULATOR
200
OSCILLATOR
201
300
FLOATING COMMON GENERATOR
301
MICRO-CONTROLLER
900_1
900_2
900_3
900_m
900_{m+1}
900_{m+2}
900_{m+3}
900_{2m}
900_{2m+1}
900_{2m+2}
900_{2m+3}
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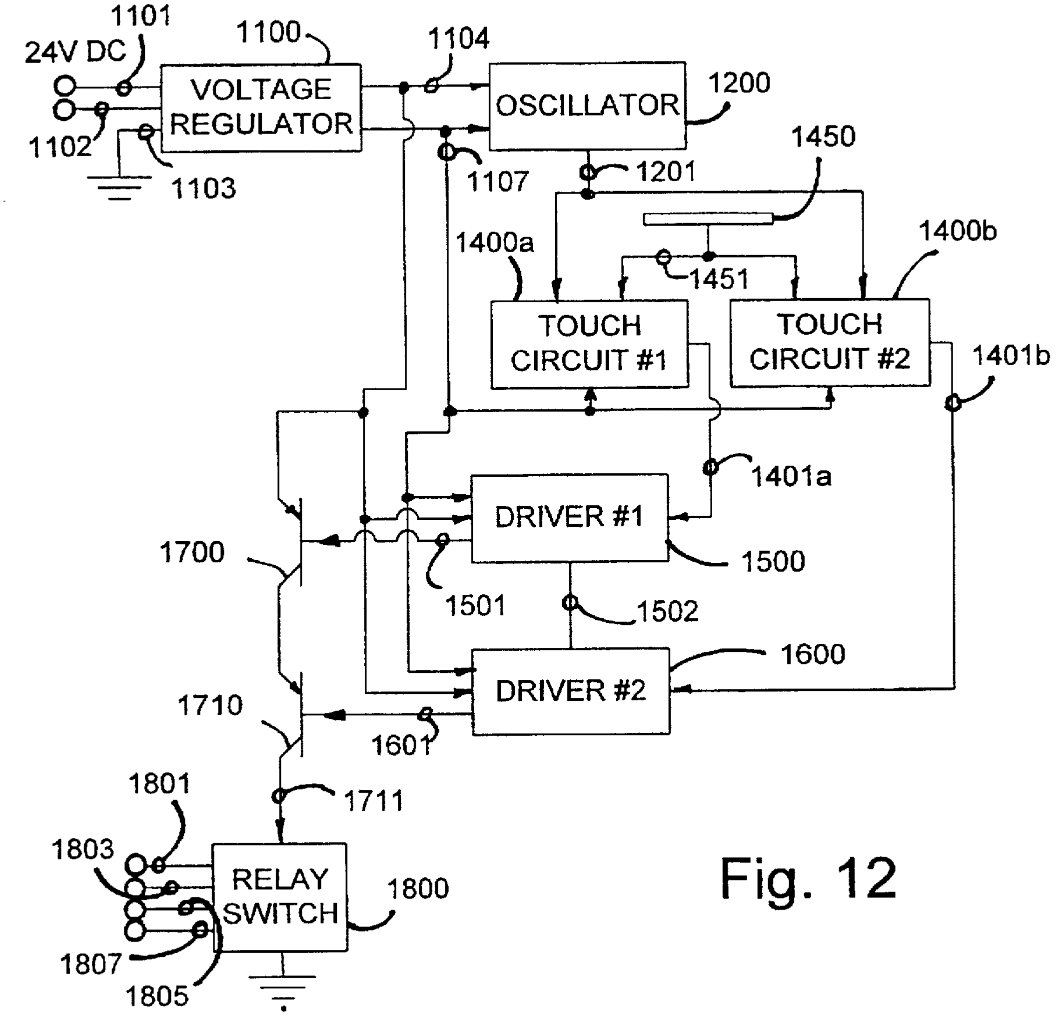
$900_{(n-1)m+3}$
900_{nm}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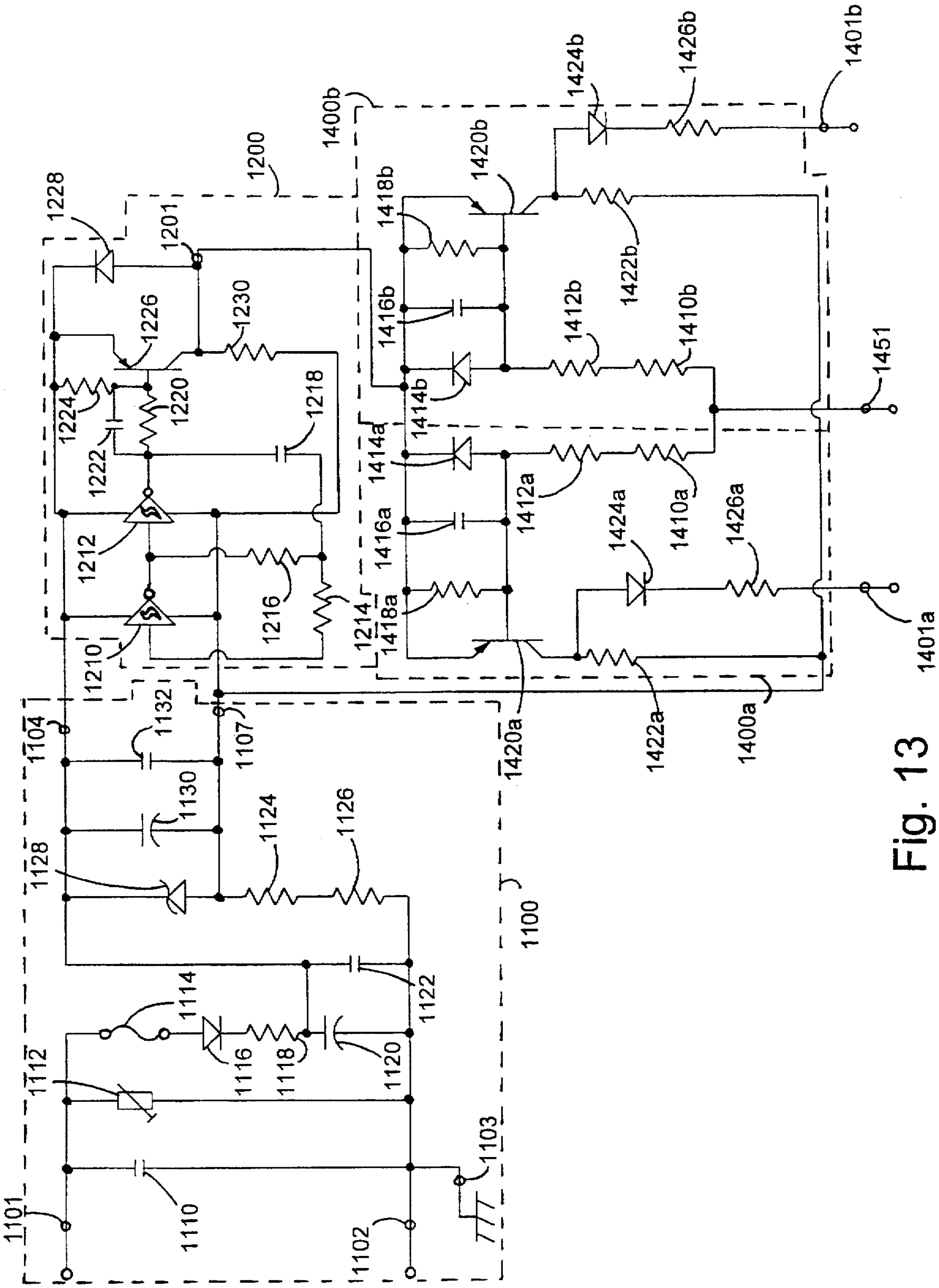
1100
VOLTAGE REGULATOR
1102
1103
1104
OSCILLATOR
1200
1107
1201
1450
1400a
1451
1400b
TOUCH CIRCUIT #1
TOUCH CIRCUIT #2
1401b
1401a
DRIVER #1
1700
1500
1501
1502
1600
DRIVER #2
1710
1601
1801
1711
1803
RELAY SWITCH
1800
1807
1805

Fig. 12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1118
1120
1122
1124
1126
1128
1130
1132
1200
1201
1210
1212
1214
1216
1218
1220
1222
1224
1226
1228
1230
1400a
1400b
1401a
1401b
1410a
1410b
1412a
1412b
1414a
1414b
1416a
1416b
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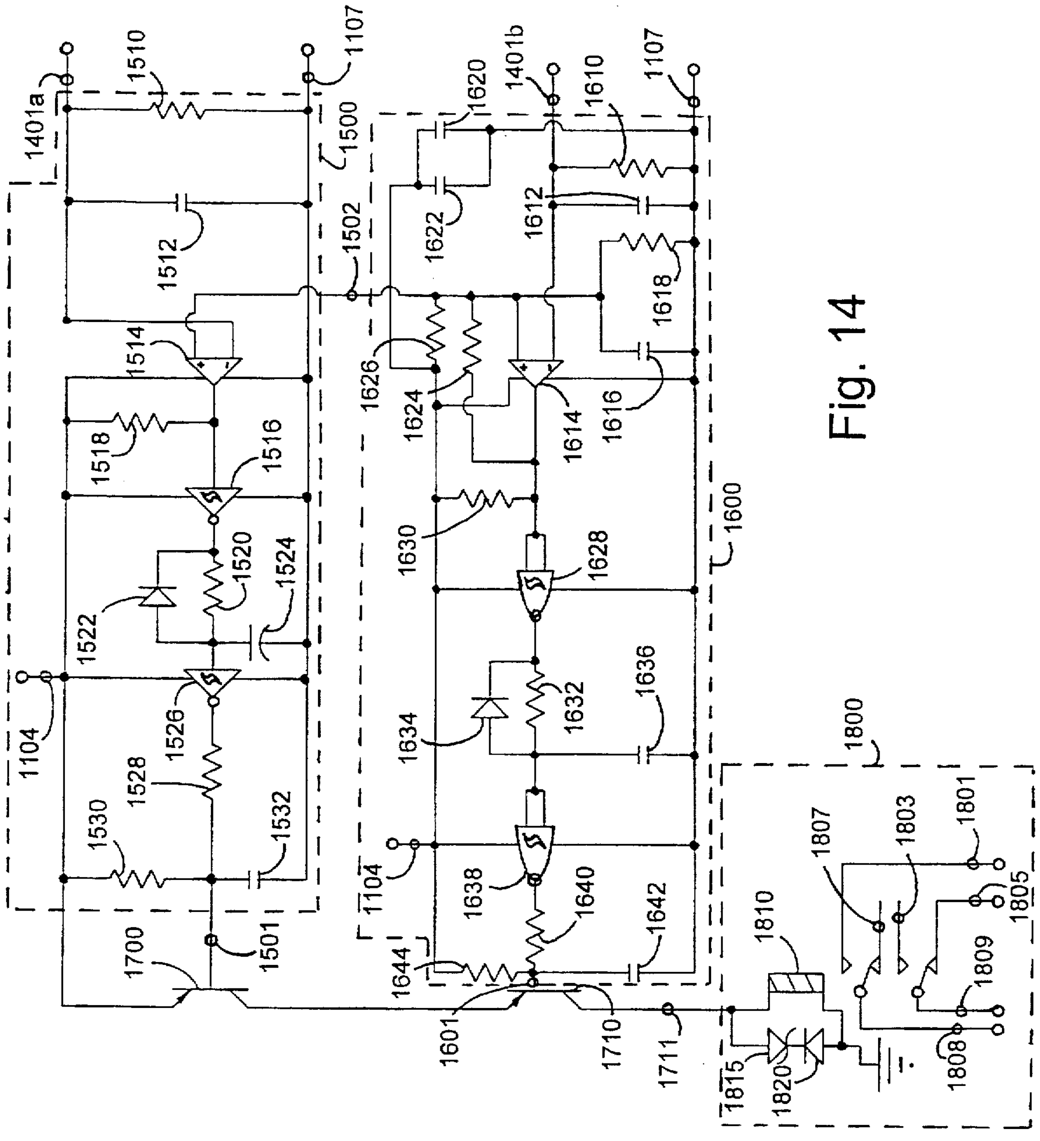
Fig. 13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1624
1614
1616
1630
1628
1600
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1632
1636
1104
1638
1640
1642
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1820

Fig. 14

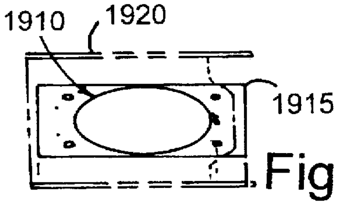


Fig. 15A

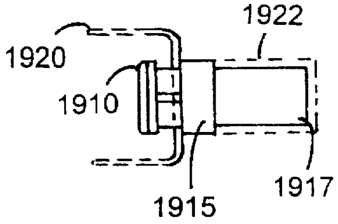


Fig. 15B

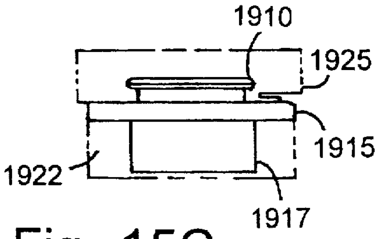


Fig. 15C

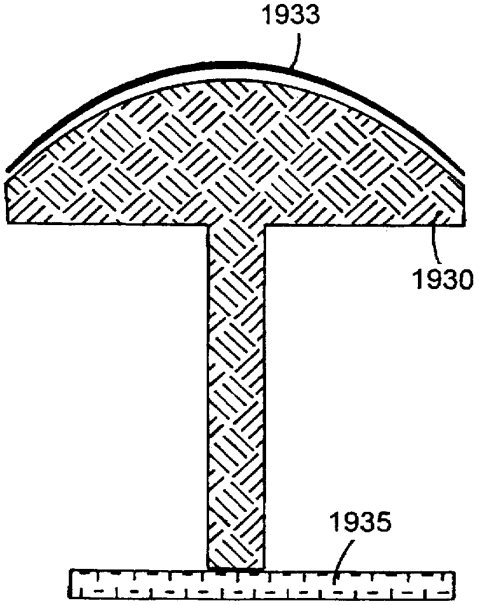


Fig. 16

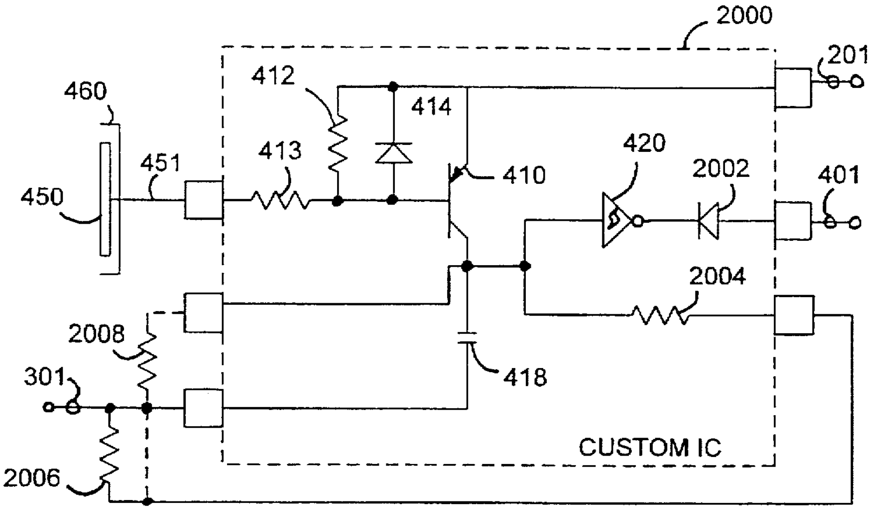

2000
201
412
414
460
413
451
410
420
2002
401
450
2004
2008
301
418
CUSTOM IC
2006

Fig. 17

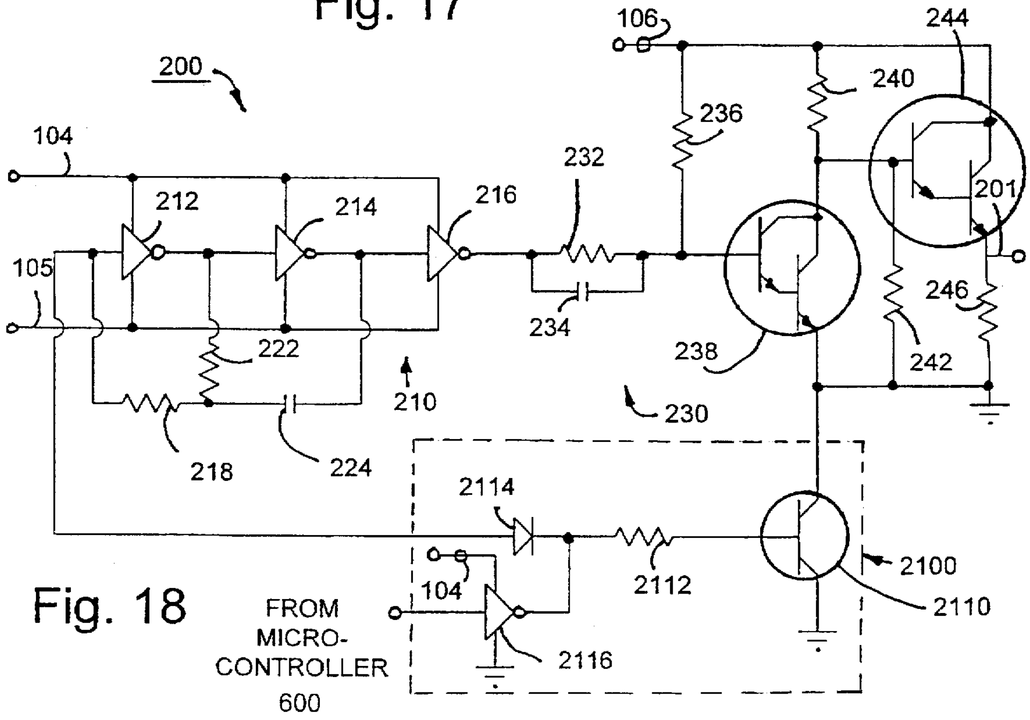

106
244
200
240
236
104
232
216
212
214
201
105
234
246
222
238
242
210
230
218
224
2114
2100
2112
104
2110
FROM MICRO-CONTROLLER 600
2116

Fig. 18

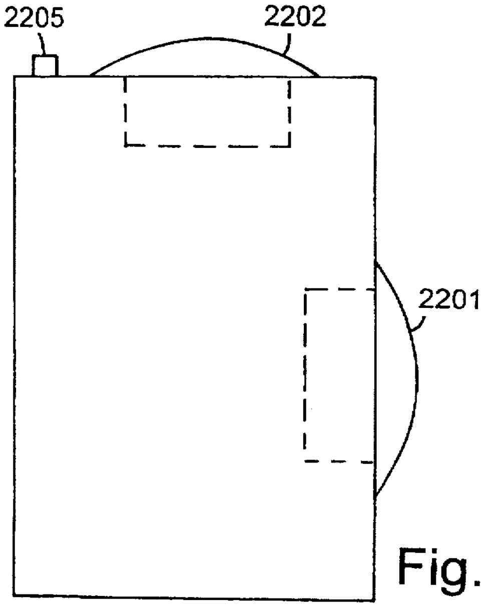


Fig. 19

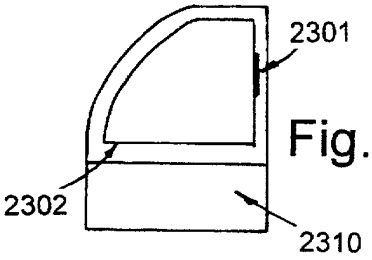


Fig. 20A

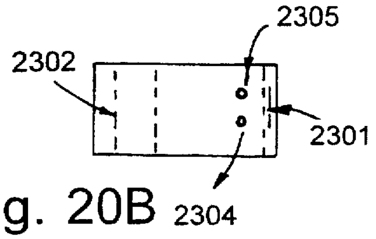


Fig. 20B

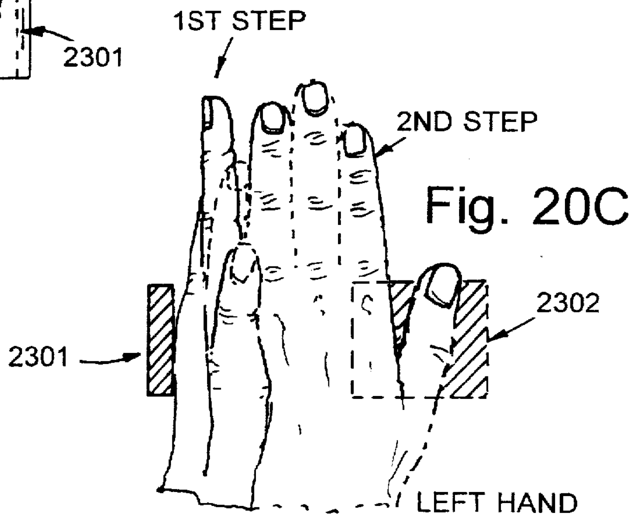


Fig. 20C

CAPACITIVE RESPONSIVE ELECTRONIC SWITCHING CIRCUIT

BACKGROUND OF THE INVENTION

The present invention relates to an electrical circuit and particularly a capacitive responsive electronic switching circuit used to make possible a "zero force" manual electronic switch.

Manual switches are well known in the art existing in the familiar forms of the common toggle light switch, pull cord switches, push button switches, and keyboard switches among others. The majority of such switches employ a mechanical contact that "makes" and "breaks" the circuit to be switched as the switch is moved to a closed or an open condition.

Switches that operate by a mechanical contact have a number of well known problems. First, mechanical movements of components within any mechanism make those components susceptible to wear, fatigue, and loosening. This is a progressive problem that occurs with use and leads to eventual failure when a sufficient amount of movement has occurred.

Second, a sudden "make" or "break" between conductive contacts typically produces an electrical arc as the contacts come into close proximity. This arcing action generates both radio frequency emissions and high frequency noise on the line that is switched.

Third, the separation between contacts that occurs on each break, exposes the contact surfaces to corrosion and contamination. A particular problem occurs when the arc associated with a "make" or "break" occurs in an oxidizing atmosphere. The heat of the arc in the presence of oxygen facilitates the formation of oxides on the contact surfaces. Once exposed, the contact surfaces of mechanical switches are also vulnerable to contaminants. Water borne contaminants such as oils and salts can be a particular problem on the contact surfaces of switches. A related problem occurs in that the repeated arcing of mechanical contact can result in a migration of contact materials away from the area of the mechanical contact. Corrosion, contamination, and migration operating independently or in combination often lead to eventual switch failure where the switch seizes in a closed or opened condition.

An additional problem results from the mechanical force required in operating a mechanical switch. This problem occurs in systems where a human operator is required to repetitively operate a given switch or a number of switches. Such repetitive motions commonly occur in the operation of electronic keyboards such as those used with computers and in industrial switches such as used in forming and assembly equipment among other applications. A common type of industrial switch is the palm button seen in pressing and insertion equipment. For safety purposes, the operator must press the switch before an insertion or pressing can occur. This ensures that the operators hand(s) is(are) on the button (s) and not in the field of motion of the associated machinery. It also ensures that the mechanical motion occurs at a desired and controllable point in time. The difficulty arises from the motion and force required of the operator. In recent years, it has been noted that repeated human motions can result in debilitating and painful wear on joints and soft tissues yielding arthritis like symptoms. Such repetitive motion may result in swelling and cramping in muscle tissues associated with conditions such as Carpal Tunnel Syndrome. Equipment designers combat these Repetitive Motion or Cumulative Trauma Disorders by adopting ergonomic designs that more favorably control the range, angle, number, and force of motions required of an operator as well as the number of the operator's muscle groups involved in the required motions. Prosthetics and tests are used as well to provide strain relief for the operator's muscles, joints, and tendons.

In mechanical switches, the force required to actuate the switch may be minimized by reducing spring forces and frictional forces between moving parts. However, reducing such forces makes such switches more vulnerable to failure. For instance, weaker springs typically lower the pressure between contacts in a "make" condition. This lower contact pressure increases the resistance in the switch which can lead to fatal heating in the switch and/or loss of voltage applied to the switched load. Reducing frictional forces in the switch by increasing the use of lubricants is undesirable because the lubricants can migrate and contaminate the contact surfaces. A switch designer may also reduce friction by providing looser fits between moving parts. However, looser fits tend to increase wear and contribute to earlier switch failure. A designer can also reduce friction by using higher quality, higher cost, surface finishes on the parts. Thus, as apparent from the foregoing description, measures taken to reduce actuator force in mechanical switch parts generally reduce the reliability and performance of the switch and/or increase the cost of the switch.

In applications such as computer keyboards or appliance controls, the electric load switched by a given switch can be quite low in terms of current and/or voltage. In such cases it is possible to use low force membrane switches such as described in U.S. Pat. No. 4,503,294. Such switches can relieve operator strain and are not as susceptible to arcing problems because they switch small loads. However, the flexible membrane remains susceptible to wear, corrosion, and contamination. Although such switches require very low actuation force, they are still mechanically based and thus suffer from the same problems as any other mechanical switch.

A more recent innovation is the development of "zero force" touch switches. These switches have no moving parts and no contact surfaces that directly switch loads. Rather, these switches operate by detecting the operator's touch and then use solid state electronics to switch the loads or activate mechanical relays or triacs to switch even larger loads. Approaches include optical proximity or motion detectors to detect the presence or motion of a body part such as in the automatic controls used in urinals in some public rest rooms or as disclosed in U.S. Pat. No. 4,942,631. Although these non-contact switches are by their very nature truly zero force, they are not practical where a multiplicity of switches are required in a small area such as a keyboard. Among other problems, these non-contact switches suffer from the comparatively high cost of electro-optics and from false detections when the operator's hand or other body part unintentionally comes close to the switch's area of detection. Some optical touch keyboards have been proposed, but none have enjoyed commercial success due to performance and/or cost considerations.

A further solution has been to detect the operator's touch via the electrical conductivity of the operator's skin. Such a system is described in U.S. Pat. No. 3,879,618. Problems with this system result from variations in the electrical conductivity of different operators due to variations in sweat, skin oils, or dryness, and from variable ambient conditions such as humidity. A further problem arises in that the touch surface of the switch that the operator touches must remain clean enough to provide an electrical conductivity path to the operator. Such surfaces can be susceptible to contamination, corrosion, and/or a wearing away of the conductive material. Also, these switches do not work if the operator is wearing a glove. Safety considerations also arise by virtue of the operators placing their body in electrical contact with the switch electronics. A further problem arises in that such systems are vulnerable to contact with materials that are equally or more conductive than human skin. For instance, water condensation can provide a conductive path as good as that of an operator's skin, resulting in a false activation.

A common solution used to achieve a zero force touch switch has been to make use of the capacitance of the human operator. Such switches, which are hereinafter referred to as capacitive touch switches, utilize one of at least three different methodologies. The first method involves detecting RF or other high frequency noise that a human operator can capacitively couple to a touch terminal when the operator makes contact such as is disclosed in U.S. Pat. No. 5,066,898. One common source of noise is 60 Hz noise radiated from commercial power lines. A drawback of this approach is that radiated electrical noise can vary in intensity from locale to locale and thereby cause variations in switch sensitivity. In some cases, devices implemented using this first method, rely on conductive contact between the operator and the touch terminal of the switch. As stated, such surfaces are subject to contamination, corrosion, and wear and will not work with gloved hands. An additional problem can arise in the presence of moisture when multiple switches are employed in a dense array such as a keyboard. In such instances, the operator may touch one touch terminal, but end up inadvertently activating others through the path of conduction caused by the moisture contamination.

A second method for implementing capacitive touch switches is to couple the capacitance of the operator into a variable oscillator circuit that outputs a signal having a frequency that varies with the capacitance seen at a touch terminal. An example of such a system is described in U.S. Pat. No. 5,235,217. Problems with such a system can arise where conductive contact with the operator is required and where the frequency change caused by a touch is close to the frequency changes that would result from unintentionally coming into contact with the touch terminal.

Another method for implementing capacitive touch switches relies on the change in capacitive coupling between a touch terminal and ground. Systems utilizing such a method are described in U.S. Pat. No. 4,758,735 and U.S. Pat. No. 5,087,825. With this methodology the detection circuit consists of an oscillator (or AC line voltage derivative) providing a signal to a touch terminal whose voltage is then monitored by a detector. The touch terminal is driven in electrical series with other components that function in part as a charge pump. The touch of an operator then provides a capacitive short to ground via the operator's own body capacitance that lowers the amplitude of oscillator voltage seen at the touch terminal. A major advantage of this methodology is that the operator need not come in conductive contact with the touch terminal but rather only in close proximity to it. A further advantage arises in that the system does not rely upon radiated emissions picked up by the operator's body which can vary with locale, but relies instead upon the human body's capacitance, which can vary over an acceptable range of 20 pF to 300 pF.

An additional consideration in using zero force switches resides in the difficulties that arise in trying to employ dense arrays of such switches. Touch switches that do not require physical contact with the operator but rather rely on the operator's close proximity can result in unintended actuations as an operator's hand or other body part passes in close proximity to the touch terminals. Above-mentioned U.S. Pat. No. 5,087,825 employs conductive guard rings around the conductive pad of each touch terminal in an effort to decouple adjacent touch pads and prevent multiple actuations where only a single one is desired. In conjunction with the guard rings, it is also possible to adjust the detection sensitivity by adjusting the threshold voltage to which the sensed voltage is compared. The sensitivity may be adjusted in this manner to a point where the operator's body part, for instance, a finger, has to entirely overlap a touch terminal and come into contact with its dielectric facing plate before actuation occurs. Although these methods (guard rings and sensitivity adjustment) have gone a considerable way in allowing touch switches to be spaced in comparatively close proximity, a susceptibility to surface contamination remains as a problem. Skin oils, water, and other contaminants can form conductive films that overlay and capacitively couple adjacent or multiple touch pads. An operator making contact with the film can then couple multiple touch pads to his or her body capacitance and it's capacitive coupling to ground. This can result in multiple actuations where only one is desired. Small touch terminals placed in close proximity by necessity require sensitive detection circuits that in some cases are preferably isolated from interference with the associated load switching circuits that they activate.

As mentioned, in industrial controls, switches can be used to control actuation time and to ensure that the operator's hand(s) or other body part(s) are out of the field of motion of associated machinery. A common type of switch used in this application is the palm button. The button is large enough so that the operator can rapidly bring his or her hand into contact with the button without having to lose the time that would be taken in acquiring and lining up a finger with a smaller switch. Zero force touch switches are also desirable in this application as Repetitive Motion or Cumulative Trauma Disorders have been a problem with operator's utilizing palm buttons—especially those palm buttons that must be actuated against a spring resistance. In this area capacitive touch switches have also been employed. U.S. Pat. No. 5,233,231 is an example of such an implementation. Due to the proximity of machinery with the potential to cause injury, false actuations are a particular liability in such applications. Capacitive touch switches that exhibit vulnerability to radiated electromagnetic noise or that operate off operator proximity have the potential to actuate when the operator's hand(s) is not at the desired location on the palm button(s). In general, this is addressed by the use of redundancies. In U.S. Pat. No. 5,233,231, a separate detector is used to measure RF noise and disable the system to a safe state if excessive RF noise is present. Other systems such as UltraTouch vended by Pinnacle Systems, Inc. use redundant sensing methodologies. In UltraTouch, both optical and capacitive sensors are used and actuation occurs only when both sensor types detect the operator's hand at the desired location. These implementations have a number of disadvantages. In the case of the RF noise detection system, the system is unusable in the presence of RF noise. This forces the user to employ a backup mechanical switch system or accept the loss of function when RF noise is present. The second system is less reliable and more expensive because it requires two sensor systems to accomplish the same task, i.e., detect the operator. Such system may also suffer from problems inherent in any optical system, namely, susceptibility to blockages in the optical path and the need to achieve and maintain specific optical alignments. A further problem is that this system considerably constrains the angle and direction of motion that the operator must use in activating the switch.

Currently, there are several zero force palm buttons in the market. These products utilize optical and/or capacitive coupling to activate a normally closed (NC) or a normally open (NO) relay, and thereby switching 110 V AC, 220 V AC, or 24 V DC to machine controllers. The UltraTouch by Pinnacle Systems Inc. uses two sensors (infrared & capacitive) with isolated circuits to activate a relay when a machine operator inserts his hand into a U-shaped sensor actuation tunnel. The company claims that by permitting the machine operator to activate the machine with no force or pressure and with the operator's hand and wrist in the ergonomic neutral position (i.e. 0° wrist joint angle and 100% hand power positions as shown in FIG. **1.0-1**), hand, wrist, and arm stresses are minimized and contributing elements to Carpal Tunnel Syndrome are negated. After a machine cycle is initiated, the operator must maintain an initial posture until the cycle is completed. A typical cycle time lasts approximately one to two seconds and is repeated about 3000 times daily. This adds up to about one hour to one hour and a half per day while the operator is in the posture. While this module reduces stress on wrist and hand, it strains the muscles in the forearm. Also, because of limited space permitted for the operator to insert his hand, it stresses the operator mentally and reduces productivity by causing fatigue. Furthermore, the infrared emitters and detectors rely on a clean path between the transmitter and receiver and will not operate properly if contaminants block the beam of light.

SUMMARY OF THE INVENTION

The present invention overcomes the above problems by using the method of sensing body capacitance to ground in conjunction with redundant detection circuits. Additional improvements are offered in the construction of the touch terminal (palm button) itself and in the regime of body capacitance to ground detection which minimizes sensitivity to skin oils and other contaminants. The invention also allows the operator to utilize the system with or without gloves which is a particular advantage in the industrial setting.

The specific touch detection method of the present invention has similarities to the devices of U.S. Pat. No. 4,758,735 and U.S. Pat. No. 5,087,825. However, significant improvements are offered in the means of detection and in the development of an overall system to employ the touch switches in a dense array and in an improved zero force palm button. The touch detection circuit of the present invention features operation at frequencies at or above 50 kHz and preferably at or above 800 kHz to minimize the effects of surface contamination from materials such a skin oils and water. It also offers improvements in detection sensitivity that allow close control of the degree of proximity (ideally very close proximity) that is required for actuation and to enable employment of a multiplicity of small sized touch terminals in a physically close array such as a keyboard. The circuitry of the present invention minimizes the force required in human operator motions and eliminates awkward angles and other constraints required in those motions. The outer surface of the touch switch typically consists of a continuous dielectric layer such as glass or polycarbonate with no mechanical or electrical feed-throughs. The surface can be shaped to have no recesses that would trap or hold organic material. As a result it is easily cleaned and kept clean and so is ideal for hygienic applications such as medical or food processing equipment.

In a first preferred embodiment the circuit offers enhanced detection sensitivity to allow reliable operation with small (finger size) touch pads. Susceptibility to variations in supply voltage and noise are minimized by use of a floating common and supply that follow the oscillator signal to power the detection circuit. The enhanced sensitivity allows the use of a 26V or lower amplitude oscillator signal applied to the touch terminal and detection circuit. This lower voltage (as compared to the device of U.S. Pat. No. 4,758,735) obviates the need for expensive UL listed higher voltage construction measures and testing to handle what would otherwise be large enough voltages to cause safety concerns. A further advantage of the present invention is seen in the manner in which the touch terminal detection circuit is interfaced to the touch terminals and to external control systems. A dedicated microprocessor referenced to the floating supply and floating common of the detection circuit maybe used to cost effectively multiplex a number of touch terminal detection circuits and multiplex the associated touch terminal output signals over a two line optical bus to a dedicated microprocessor referenced to a fixed supply and ground. An additional advantage of the microprocessor is an expanded ability to detect faults, i.e. a pad that is touched for an excessive amount of time that is known a priori to be an unlikely mode of operation or two or more pads touched at the same time or in an improper order. Additionally, the microprocessor can be used to distinguish desired multiple pad touches in simultaneous or sequential modes, i.e. two or more switches touched in a given order within a given amount of time. The microprocessor can be used to perform system diagnostics as well. The microprocessor also allows the use of visual indicators such as LEDs or annunciators such as a bell or tone generator to confirm the actuation of a given touch switch or switches. This is particularly useful in cases where a sequence of actuations is required before an action occurs. The feedback to the operator provided by a visual or audio indicator activated by the microprocessor in response to intermediate touches in a required sequence can minimize time lost and/or frustration on the part of the operator due to failed actuations from partial touches or wrong actuations from touching the wrong pad in a given required sequence or combination of touches. The second microprocessor may be used to communicate with the user's control system. Additional features include a "sleep mode" to minimize power consumption during periods of non-use or power brown outs, and redundant control circuits to facilitate "fail to safe" operation. Another improvement is offered in a means to move much of the cost of the system into simplified custom integrated circuits that allow ease of sensitivity adjustment and assembly.

In a second preferred embodiment, an improved palm button is featured. Through the use of a dielectric cover, a large metallic touch terminal can be used that differentiates between the touch of a finger or partial touch and the full touch of a palm. In this way the system avoids false triggers due to inadvertent finger touches or brushing contact with the palm prior or after an intended touch. The second embodiment also features redundant control circuits to facilitate "fail to safe" operation.

To achieve these and other advantages, and in accordance with the purpose of the invention as embodied and described herein, the capacitive responsive electronic switching circuit comprises an oscillator providing a periodic output signal having a frequency of 50 kHz or greater, an input touch terminal defining an area for an operator to provide an input by touch, and a detector circuit coupled to the oscillator for receiving the periodic output signal from the oscillator, and coupled to the input touch terminal. The detector circuit being responsive to signals from the oscillator and the presence of an operator's body capacitance to ground coupled to the touch terminal when touched by an operator to provide a control output signal. Preferably, the oscillator provides a periodic output signal having a frequency of 800 kHz or greater.

These and other features, objects, and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out in the written description and claims hereof, as well as by the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an electrical schematic of a testing circuit used to measure the impedance of the human body;

FIG. **2** is an electrical schematic of a testing circuit used to measure the impedance of water;

FIG. **3** is an electrical schematic of an equivalent circuit model for analyzing a human body in contact with glass covered with water;

FIG. **4** is a block diagram of a capacitive responsive electronic switching circuit constructed in accordance with a first embodiment of the present invention;

FIG. **5** is an electrical schematic of a preferred voltage regulator circuit for use in the capacitive responsive electronic switching circuit shown in FIG. **4**;

FIG. **6** is an electrical schematic of a preferred oscillator circuit for use in the capacitive responsive electronic switching circuit shown in FIG. **4**;

FIG. **7** is an electrical schematic of a preferred floating common generator circuit for use in the capacitive responsive electronic switching circuit shown in FIG. **4**;

FIG. **8** is an electrical schematic of a preferred touch circuit for use in the capacitive responsive electronic switching circuit shown in FIG. **4**;

FIG. **9** is a three dimensional bar graph illustrating signal-to-noise ratio vs. body capacitance at T=105° C.;

FIG. **10** is a three dimensional bar graph illustrating signal-to-noise ratio vs. body capacitance at T=22° C.;

FIG. **11** is a block diagram of a capacitive responsive electronic switching circuit constructed in accordance with a second embodiment of the present invention;

FIG. **12** is a block diagram of a capacitive responsive electronic switching circuit constructed in accordance with a third embodiment of the present invention;

FIG. **13** is an electrical schematic of a preferred voltage regulator, oscillator, and touch circuits for use in the capacitive responsive electronic switching circuit shown in FIG. **12**;

FIG. **14** is an electrical schematic of preferred driver circuits for use in the capacitive responsive electronic switching circuit shown in FIG. **12**;

FIGS. **15**A–C are top, side, and front views, respectively, of an example of a flat palm button constructed in accordance with the present invention;

FIG. **16** is a cross-sectional view of an example of a dome-shaped palm button constructed in accordance with the present invention;

FIG. **17** is an electrical schematic of a touch circuit of the present invention implemented in a custom integrated circuit;

FIG. **18** is an electrical schematic of an oscillator having a sleeper circuit for use in the capacitive responsive electronic switching circuits of the present invention;

FIG. **19** is a pictorial view of a device having two palm buttons and an indicator light operated in accordance with the present invention; and

FIGS. **20**A–C are pictorial views of another embodiment of the device shown in FIG. **19**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As apparent from the above summary, the touch circuit of present invention operates at a higher frequency than prior touch sensing circuits. A move to high frequency operation (>50 to 800 kHz) is not a benign choice relative to the lower frequency (60 to 1000 Hz) operation seen in existing art such as U.S. Pat. No. 4,758,735 and U.S. Pat. No. 5,087,825. Higher frequencies require generally more costly, higher speed parts, and often results in the added cost of special design measures to minimize electronic emissions and the introduction of high frequency noise on power supply lines. The preference for using such higher frequencies is based on a study performed to determine if high frequency operation would allow a touch of an operator and conduction via surface contamination films, such as moisture, providing a conductive path from a non-touched area to the touched area. The study also determined whether a high frequency touch circuit could operate over a sufficiently wide temperature range, an assortment of overlying dielectric layer thicknesses and materials, and in the presence of likely power supply fluctuations. The following calculations and measurements are the results of this study. The results summarize the investigation conducted to reduce crosstalk due to condensation of water on the dielectric member (glass). By increasing the frequency of operation, the impedance of the body-glass combination is reduced as compared to the impedance of water between the touch pads.

The equivalent circuit of body impedance was measured using the testing circuit **10** shown in FIG. **1**. Testing circuit **10** includes an oscillator **20** coupled between ground plate and a 100 kΩ series resistor **22** and in parallel with a 10 MΩ resistor **24**, a 20 pF capacitor **26**, and contacts for connecting to a human body identified in the figure as an impedance load **15** having an impedance Z_B representing the body's impedance.

Two types of measurements were taken: one with the person under test standing on a large ground plane i.e., concrete slab; and another while standing on a subfloor. The subfloor was used to simulate a typical northern home, i.e., wood joists with plywood sheeting. Carpeting was used as an added insulation layer. Table 1 below shows the measured body resistance and capacitance for five individuals.

TABLE 1

CONCRETE SLAB	CONCRETE SLAB	SUBFLOOR	SUBFLOOR
1.4 kΩ	100 pF	1.7 kΩ	73 pF
1.4 kΩ	217 pF	1.9 kΩ	78 pF
1.3 kΩ	174 pF	1.9 kΩ	93 pF
1.2 kΩ	160 pF	1.6 kΩ	85 pF
1.0 kΩ	107 pF	1.4 kΩ	75 pF

As apparent from Table 1 above and the discussion to follow, a human body's impedance may be represented by the series combination of a 20–300 pF capacitor and a 1 k–2 kΩ resistor.

The impedance of water, which is mainly resistive, was measured using the testing circuit **30** shown in FIG. **2**. Testing circuit **30** includes an oscillator **40** coupled in series with a 1 MΩ resistor **42** and contacts across which water is applied to define an impedance load **35** having an impedance Z_w representing the impedance of water. A true RMS voltage meter **45** is connected across the contacts of the impedance load **35**.

The resistance of tap water over a 1×1 inch area and 1/32 inch deep, was measured to be around 160 kΩ.

The following calculation is for resistance of rain water where c is the conductivity for rain:

$$R = \left(\frac{1}{cin}\right) \times \left(\frac{L}{A}\right) \qquad \text{Eq. 1}$$

where,

$$c = 128 \times 10^{-6} (\Omega - \text{cm})^{-1}$$

$$cin = c\left(\frac{100\text{ cm}}{\text{m}}\right)\left(\frac{.0254\text{ m}}{\text{in}}\right)$$

$$L = 1.0\text{ in}$$

$$A = (1.0) \times \left(\frac{1}{32}\right) = \frac{1}{32}\text{ in}^2$$

therefore,

$$R = \left(\frac{1}{325.12 \times 10^{-6}}\right) \times \left(\frac{1.0\text{ in}}{\frac{1}{32}\text{ in}^2}\right) = 98.43\text{ k}\Omega$$

However, the thickness of a layer of water condensed on the surface of glass is much less than 1/32 inch and it's resistance is higher than that of tap water. For design purposes, a resistance value of 1 MΩ was used to simulate water.

The capacitance of a piece of glass measuring ½"×½"×¼", is approximately 2 pF.

where,

$$C = K_{glass} K_a \frac{A(\text{cm}^2)}{L(\text{cm})}\ (\mu F) \qquad \text{Eq. 2}$$

K_a=0.08842×10^{-6} for vacuum

$6.0 < K_{glass} < 10$

A=0.25 in^2

L=0.25 in

therefore,

$C_{max}=10\times0.08842\times10^{-6}\times2.54\times10^{-6}=2.25$ pF

$C_{min}=6\times0.08842\times10^{-6}\times2.54\times10^{-6}=1.35$ pF

Table 2 below shows the dielectric constant for several types of glass:

TABLE 2

TYPE OF GLASS	Dielectric Constant (K)
Corning 0010	6.32
Corning 0080	6.75
Corning 0120	6.65
Corning 8870	9.5

The equivalent circuit **50** of body touching the glass with the presence of water is shown in FIG. **3**. As shown, the equivalent circuit **50** includes a polycarbon (PCB) plate **55** having at least two pads **57** and **59** formed thereon, a glass plate **60** adjacent to PCB plate **55**, water **65** on glass plate **60** spanning at least two touch pad areas, and a body **70** in contact with the water **65** and glass plate **60** at one touch pad area. The impedance of glass plate **60** is approximated by two 2 pF capacitors **62** and **64** connected to pads **57** and **59**, respectively. The water **65** is approximated by a 1 MΩ resistor **68** connected between capacitors **62** and **64**. The body is represented by a 20–300 pF capacitor **72** coupled at one end to water resistor **68** and glass plate capacitor **62**, and by a 1–2 kΩ resistor **74** coupled between the other end of capacitor **72** and ground.

Referring to FIG. **3**, it can be seen that a human touch opposite pad **57** will couple pad **57** to ground through the capacitance of glass **62** and the series contact with the human body impedance provided by the 20–300 pF capacitance and the 1 k–2 kΩ resistance of a typical human body. This will have the effect of pulling any voltage on the pad towards ground. Pad **59** will be similarly effected, however it's coupling to ground will not only be through capacitance **64**, and the series capacitance and resistance of the human body, but will also be through the ohmic resistance of water on the glass cover between the proximate location of pad **59** and the touched pad **57**. Because the human capacitance is considerably greater than the 2 pF capacitance of the glass, the impedance of the path to ground for pads **57** and **59** will be dominated by the glass and water impedances. If the impedance of the water path is significant compared to that of the glass, then the effect of a touch will be more significant at pad **57** than at pad **59**. To overcome the effect of condensation or possible water spills, the impedance of the glass is preferably made as small as is practical compared to the impedance of the water. This allows discrimination between touched and adjacent pads. As the water impedance is primarily resistive and the glass impedance is primarily capacitive, the impedance of the glass will drop with frequency.

FIG. **3**A shows the maximum and minimum glass impedance as a function of frequency. The maximum and minimum glass impedances shown were computed as follows:

$e_o=8.854\times10^{-12}C^2/(\text{nm}^2)$

$K_{gmin}=6$

$K_{gmax}=10$

A=0.25 in^2

L=0.25 in

$C_{max}=K_{gmax}e_0A/L\ C_{max}=2.249$ pF

$C_{min}=K_{gmin}e_0A/L\ C_{min}=1.349$ pF

$Zgmin_{frequency}=1/(2\ \pi C_{max}\text{frequency})$

$Zgmax_{frequency}=1/(2\ \pi C_{min}\text{frequency})$

As can be seen, at 1 kHz, the capacitive impedance of the glass is much greater than the nominal 1 MΩ of the water bridge between the pads. As a result, at 1 kHz, there would be little difference in the impedance paths to ground of the two adjacent pads when either is touched. This would result in the voltage on both pads being pulled towards ground by comparable amounts. Conversely, at 100 kHz, the glass impedance drops to approximately 1 MΩ resulting in the impedance of the path to ground for pad **59** being twice that of the touched pad **57**. For cases where background noise and temperature drifts are comparatively small, a 100 kHz oscillator frequency would allow a sufficiently low detection threshold to be set to differentiate between the signal changes induced at both pads by a human touch opposite a single pad. At 800 kHz, the impedance of the glass drops to 200 kΩ or lower giving a ratio of a greater than 5 to 1 impedance difference between the paths to ground of the touched pad **57** and adjacent pads **59**. In fact, the impedance ratio may exceed 10 to 1, as illustrated in the calculation below. This allows the detection threshold for the touched pad to be set well below that of an adjacent pad resulting in a much lower incidence of inadvertent actuation of adjacent touch pads to that of the touched pad. Ideally, the frequency of operation would be kept at the 800 kHz of the preferred embodiment or even higher. However, as noted earlier, higher frequency operation forces the use of more expensive components and designs. For applications where thermal drift and electronic noise levels are low, operation at or near 100 kHz may be possible. However, at 10 kHz and below, the impedance of the glass becomes much greater than that of likely water bridges between pads resulting in adjacent pads being effected as much by a touch as the touched pad itself. Although the preferred frequency is at or above 100 kHz, and more preferably at or above 800 kHz, it is conceivable that frequencies as low as 50 kHz could be used provided the frequency creates a difference in the impedance paths of adjacent pads that is sufficient enough to accurately distinguish between an intended touch and the touch of an adjacent pad. Use of frequencies as low as 50 kHz may also be possible depending upon the type of glass or covering or the thickness thereof used for the touch pad. However, in cases where there is little or no surface contamination, the frequency of operation can go well below 50 kHz. Ultimately, the frequency chosen will be a tradeoff between the likelihood of surface contamination and the cost of going to higher frequencies to prevent cross talk due to such contamination. The following analysis illustrates one example of how a frequency may be calculated based on the typical parameters used to construct a touch switch and the typical impedance of a contaminant, such as rain water. In the analysis below a 10 to 1 ratio of water to glass impedance is sought.

To eliminate crosstalk due to condensation of water on the glass, the impedance of body (Z_B) and glass (Z_g) combination must be much lower than impedance of water (Z_W). Since the impedance of glass is much higher than body impedance, Z_g will be considered only. Therefore,

$$10|Z_g|<|Z_W| \qquad \text{Eq. 3}$$

where,

$$C_{glass}=2\text{ pF}\ Z_W=1\text{ M}\Omega$$

$$Z_g=\frac{1}{2\pi fC_g}=\frac{7.96\times10^{10}}{f} \qquad \text{Eq. 4}$$

$$10\times\left(\frac{7.96\times10^{10}}{f}\right)<1\text{ M}\Omega$$

Therefore,

$$f>796\text{ kHz}$$

Having provided a basis for the use of higher frequencies, the basic construction of the electronic switching circuit constructed in accordance with a first embodiment of the present invention is now described with reference to FIG. **4**. The electronic switching circuit includes a voltage regulator **100** including input lines **101** and **102** for receiving a 24 V AC line voltage and a line **103** for grounding the circuit. Voltage regulator **100** converts the received AC voltage to a

DC voltage and supplies a regulated 5 V DC power to an oscillator **200** via lines **104** and **105**. Voltage regulator also supplies oscillator **200** with 26 V DC power via line **106**. The details of voltage regulator **100** are discussed below with reference to FIG. **5**.

Upon being powered by voltage regulator **100**, oscillator **200** generates a square wave with a frequency of 50 kHz, and preferably greater than 800 kHz, and having an amplitude of 26 V peak. The square wave generated by oscillator **200** is supplied via line **201** to a floating common generator **300**, a touch pad shield plate **460**, a touch circuit **400**, and a microcontroller **500**. Oscillator **200** is described below with reference to FIG. **6**.

Floating common generator **300** receives the 26 V peak square wave from oscillator **200** and outputs a regulated floating common that is 5 volts below the square wave output from oscillator **200** and has the same phase and frequency as the received square wave. This floating common output is supplied to touch circuit **400** and microcontroller **500** via line **301** such that the output square wave from oscillator **200** and floating common output from floating common generator **300** provide power to touch circuit **400** and microcontroller **500**. Details of floating common generator **300** are discussed below with reference to FIG. **7**.

Touch circuit **400** senses capacitance from a touch pad **450** via line **451** and outputs a signal to microcontroller **500** via line **401** upon detecting a capacitance to ground at touch pad **450** that exceeds a threshold value. The details of touch circuit **400** are described below with reference to FIG. **8**.

Upon receiving an indication from touch circuit **400** that a sufficient capacitance to ground (typically at least 20 pF) is present at touch pad **450**, microcontroller **500** outputs a signal to a load-controlling microcontroller **600** via line **501**, which is preferably a two way optical coupling bus. Microcontroller **600** then responds in a predetermined manner to control a load **700**. Having generally described the basic construction of the first embodiment, the preferred detailed construction of the depicted components will now be described with FIGS. **5–8**. In cases where the number of lines to be switched is low, microcontroller **600** can be replaced by additional optical coupling lines. The number of lines to be switched will dictate whether it is more cost effective to multiplex over a two line optical bus such as line **501** and use a microcontroller to demultiplex, or to use a multiplicity of optical coupling lines. Other considerations such as reliability and power consumption may also affect this choice. In this preferred embodiment, the use of a single pair of optical coupling paths (line **501**) and a microcontroller **600**, is shown to emphasize the capability to switch a large number of lines.

A preferred circuit for implementing a voltage regulator **100** is shown in FIG. **5**. Voltage regulator **100** preferably includes an AC/DC convertor **110** for generating 29 V to 36 V unregulated DC on line **119**. This unregulated DC power is supplied to a 5 V DC regulator **120** and to a 26 V DC regulator **130**. AC/DC convertor **110** includes diodes **112**, **114**, **116**, and **118**, which rectify the supplied 24 V AC power provided on power lines **101** and **102**. The anode of the first diode **112** is coupled to power line **101** and to the cathode of the second diode **114**. The cathode of the first diode **112** is coupled to output line **119**. The anode of the second diode **114** is coupled to ground via line **103** and to the anode of the fourth diode **118**. The anode of the third diode **116** is coupled to the cathode of the fourth diode **118** and to power line **102**. The cathode of the third diode **116** is coupled to line **119** and to the cathode of the first diode **112**. The anode of the fourth diode **118** is coupled to ground via line **103**. Diodes **112**, **114**, **116**, and **118** are preferably diodes having part no. 1N4002 available from LITEON. AC/DC convertor **110** also preferably includes a capacitor **115** for filtering the rectified output of the diodes. Capacitor **115** is preferably a 1000 μF capacitor coupled between output line **119** and ground via line **103**.

The 5 V regulator **120** preferably includes a 500 Ω resistor **122** coupled between line **119** and 5 V output line **104**, and a zener diode **124**, a first capacitor **126**, and second capacitor **128** all connected and parallel between output power lines **104** and **105**. Preferably, zener diode **124** is a 5.1 V zener diode having part no. 1N4733A available from LITEON, first capacitor **126** has a capacitance of 10 μF, and second capacitor **128** has a capacitance of 0.1 μF.

The 26 V regulator **130** preferably includes a transistor **134** having a collector connected to line **119** via a first resistor **132**, a base connected to line **119** via a second resistor **136**, and an emitter coupled to the regulated 26 V output power line **106**. The 26 V regulator **130** also preferably includes a capacitor **137** and zener diode **138** connected in parallel between the base of transistor **134** and ground line **103**. Preferably, first resistor **132** is a 20 Ω, 0.5 W resistor, second resistor **136** is a 1 kΩ, 0.5 W resistor, capacitor **137** is a 0.1 μF capacitor, and zener diode **138** is a 27 V, 0.5 W diode having part no. 1N5254B available from LITEON. It will be apparent to those skilled in the art, that various components of voltage regulator **100** may be added or excluded depending upon the source of power available to power the oscillator **200**. For example, if the available power is a 110 V AC 60 Hz commercial power line, a transformer may be added to convert the 110 V AC power to 24 V AC. Alternatively, if a DC battery is used, the AC/DC convertor among other components may be eliminated.

A preferred example of an 800 kHz oscillator is shown in FIG. **6**. Oscillator **200** preferably includes a square wave generator **210**, which is powered by 5 V regulator **120** via lines **104** and **105**, for generating a 5 V peak square wave having the desired frequency, and a buffer circuit **230** powered by 26 V regulator **130** via line **106** for buffering the output of square wave generator **210** and boosting its peak from 5 V to 26 V while maintaining the preferred frequency. Square wave generator **210** is preferably an astable multivibrator constructed with at least two serially connected invertor gates **212** and **214**, and optionally, a third serially connected invertor gate **216**. Invertor gates **212**, **214** and **216** are preferably provided in a single integrated circuit designated as part 74HC04 available from National Semiconductor. The output of the first invertor gate **212** is coupled to it's input via resistors **218** and **222** and is coupled to the output of the second invertor gate **214** via a capacitor **224**. The input of the second invertor gate **214** is directly connected to the output of the first invertor gate **212** and the output of the second invertor gate **214** is directly connected to the input of the optional third invertor gate **216**. To provide an 800 kHz output, resistor **218** preferably has a 10.0 kΩ value, resistor **222** preferably has a 1.78 kΩ value, and capacitor **224** is preferably a 220 pF capacitor.

The 5 V peak square wave generated by square wave generator **210** is supplied from either the output of invertor gate **214** or the output of optional invertor gate **216** to the base of a first transistor **238** via a first resistor **232** connected and parallel a capacitor **234**. The base of first transistor **238** is connected to the 26 V regulated DC power line **106** via a second resistor **236**. The collector of first transistor **238** is connected to 26 V power line **106** via a third resistor **240** and to the base of a second transistor **244**. The emitter of first transistor **238** is coupled to ground and to it's own collector and the base of second transistor **244** via a fourth resistor **242**. The collector of the second transistor **244** is connected directly to 26 V power line **106** and the emitter of second transistor **244** is connected to ground via a fifth resistor **246**. Second transistor **244** provides the 26 V peak square wave on output line **201**, which is connected to it's emitter. In operation, the square wave signal applied to the base of transistor **238** causes the collector of transistor **238** to swing between near to the DC supply **106** voltage and the collector-emitter saturation voltage. Capacitor **234** is provided to improve the turning off of transistor **238**. Transistor **244** along with resistors **242** and **246** are used to buffer the square wave signal generated by transistor **238**. In a preferred embodiment, the values of the resistors and capacitor are as follows: first resistor **232** is 5.1 kΩ, capacitor **234** is 0.0047 μF, second resistor **236** is 1 MΩ, third resistor **240** is 1.6 kΩ, fourth resistor **242** is 100 kΩ, and fifth resistor **246** is 4.7 kΩ. Preferably, transistors **238** and **244** are those identified as part no. ZTX600 available from ZETEX. In this configuration, the oscillator **200** sources 80 mA to the floating common generator **300** such that together they supply a floating 5 V DC to power touch circuit(s) **400**, microcontroller **500**, and Schmitt triggered gates **420** (FIG. **8**). As will be apparent to those skilled in the art, the values of the resistors and capacitors utilized in oscillator **200** may be varied from those disclosed above to provide for different oscillator output frequencies. As discussed above, however, oscillator **200** is preferably constructed so as to output a square wave having a frequency of 50 kHz or greater, and more preferably, of 800 kHz or greater. In some cases it may be necessary to use lower gain bandwidth product transistors or filtration to achieve a softer roll-off of the square edges to reduce high frequency noise emissions. When this is done the amplitude of the oscillator voltage can be increased to compensate.

The preferred construction of floating ground generator **300** is shown in FIG. **7** includes a zener diode **310** having a cathode connected to the oscillator output on line **201** and an anode connected to floating ground output line **301** and to ground via resistor **316** and diode **318**. Floating ground generator **300** also preferably includes a first capacitor **312** and a second capacitor **314** connected in parallel with zener diode **310**. In the preferred embodiment, zener diode **310** is a 5.1 V zener diode identified by part no. 1N4733A available from LITEON, capacitor **312** is a 47 μF tantalum capacitor, capacitor **314** is a 0.1 μF capacitor, resistor **316** is a 270 Ω resistor, and diode **318** is a diode identified as part no. 1N914B available from LITEON.

Touch circuit **400**, as shown in FIG. **8**, preferably includes a transistor **410** having a base connected to touch pad **450** via resistor **413** and line **451**, an emitter coupled to oscillator output line **201**, and a collector coupled to floating ground line **301** via a pulse stretcher circuit **417**, which includes a resistor **416** and a capacitor **418** connected in parallel. To minimize susceptibility to noise, the physical length of the path between the touch pad **450** and the base of the transistor **410**, must be held to a minimum. Additionally, RC filters can be placed in line **401** between the output of the touch circuit **400** and the input of the microcontroller **500** to give additional EMI/RFI immunity. Additionally, the higher the frequency, the higher the gain bandwidth product that is required in transistor **410**. The gain bandwidth product must be sufficient to guarantee that the oscillator turns on during oscillator High pulses. A further trade-off is to use higher gain bandwidth product to allow lower oscillator voltages or higher oscillator voltages to all allow a lower gain bandwidth product transistor to be used. The combination of oscillator voltage, frequency and transistor gain bandwidth product that is used will necessarily vary with the cost, safety and reliability requirements of a given application. The present combination was chosen to keep the oscillator voltage down and allow operation at 800 kHz to minimize cross talk. At higher frequencies a higher gain bandwidth product transistor would be required in both the oscillator **200** and detection **400** circuits. Touch circuit **400** also preferably includes resistor **412** and a diode **414** having an anode connected to the base of transistor **410** and to resistor **413**, and a cathode connected to the emitter of transistor **410** and to a resistor **412** connected in parallel with diode **414** between the base and emitter of transistor **410**. The pulse stretcher circuit **417** is identified as such because the sensitivity of the touch circuit may be increased or decreased by varying the resistance of resistor **416**. The base of transistor **410** is connected via resistor **413** to line **451** connected to touch pad **450**.

Additionally, touch circuit **400** may include at least one Schmitt triggered gate **420** powered by the voltage difference existing between oscillator line **201** and **301**, and having an input terminal coupled to the collector of transistor **410** and an output coupled to microcontroller **500** via output line **401**. Schmitt triggered invertor gate **420** is optionally provided to improve the rise time of the touch switch output and to buffer the output. Preferably, transistor **410** is part no. BC858CL available from Motorola, resistor **412** is a 12 MΩ resistor, diode **414** is part no. 1N914B available from Diodes, Inc., resistor **416** is a 470 kΩ resistor, capacitor **418** is a 0.001 μF capacitor, and resistor **413** is a 10 kΩ resistor.

As stated above, the operator's body includes a capacitance to ground, which may range in a typical person from between 20 to 300 pF. The base terminal of transistor **410** is coupled to it's emitter by resistor **412** such that unless capacitance is present by the user touching the touch pad **450**, transistor **410** will not be forward biased and will not conduct. Thus, when touch pad **450** is not touched, the output signal at the collector terminal of transistor **410** and across pulse stretcher circuit **417** will be zero volts. When, however, a person touches the touch pad **450**, that person's body capacitance to ground couples the base of transistor **410** to ground **103** through resistor **413**, thereby forward biasing transistor **410** into conduction. This charges capacitor **418** providing a positive DC voltage with respect to the line **301** and causes the output of the Schmitt trigger **420** to go low. Diode **414** is coupled across the base to emitter junction of transistor **410** to clamp the base emitter reverse bias voltage to −0.7 V and also reduce the forward recovery and turn-on time.

Touch pad **450** includes a substrate on which a plurality of electrically conductive plate members are mounted on one surface thereof. The substrate is an insulator and the plates are spaced apart in order to insulate the plates from one another and from ground. Also, positioned on the substrate is a guard band, generally shown as **460**. Guard band **460** is a grid of conductor segments extending between adjacent pairs of plate members. All conductor segments are physically interconnected to define a plurality of spaces with one plate member positioned centrally within each space. Components of the touch circuit may be positioned on the side of substrate opposite plate members and guard band **460**.

A planar dielectric member is spaced from the substrate facing plate members. The dielectric member is made from a non-porous insulating material such as polycarbonate or glass. A plurality of electrically conductive spring contacts are sandwiched between the inner surface of the dielectric member and the substrate. An indicia layer may be adhered to the inner surface of the dielectric member to provide an indication of the function of each input portion.

As mentioned above, interface between the dielectric member and a conductive plate is a metallic spring contact that is attached to the back of the dielectric member. The spring contacts offer advantages at high temperature extremes. However, for sufficiently narrow temperature ranges, conductive polymer foam pads cut to the size of the touch pads are preferably used to fill the gap between conductive pad and dielectric layer. The function of the spring contacts or conductive foam pads is to eliminate that capacitive contribution of the air filled gap between the conductive pads and the overlying dielectric layer.

A problem with capacity responsive keyboards is the tendency of switches that are closely positioned in a keyboard system to inadvertently become actuated even though the user is touching an adjacent switch. Furthermore, this problem is greatly aggravated by the presence of contamination on the outer surface of dielectric member. Contamination such as skin oil or moisture causes erratic keyboard operation and multiple switches will turn on even though one switch is touched. By operating at a high frequency such as 100 kHz or 800 kHz, the impedance of the series combination of body and glass capacitance are lowered as compared to the impedance of contamination present on the glass thereby reducing crosstalk.

If glass thickness is smaller than 3/16 inch, the touch circuit becomes more sensitive to body capacitance. There are two ways to adjust the sensitivity so that crosstalk does not occur: remove diode **414** and/or reduce the resistance of resistor **416**. Increasing the resistance of resistor **416** would allow usage of thicker glass. However, this resistance preferably should not go above 750 kΩ. This is because of the maximum low input voltage of 0.8 V and input leakage current of 1 μA at the Schmitt trigger gate **420**.

The oscillator circuitry shown in FIG. **6** is very stable over the temperature range of −40° C. to 105° C. The output of the touch switch circuitry drops at a rate of approximately 40 mV/°C. when temperature falls below 0° C. If application requires operation at low temperatures (−40° C.), the following three methods may be used to increase the output of the switch: increase the oscillator's regulated supply voltage, increase the resistance of resistor **416**, and use a higher gain transistor **410**. All of these methods would increase sensitivity at high temperatures. Another way to correct this problem is to use a thermistor to vary the regulated supply voltage as a function of temperature.

Since the input power is regulated down to 26 V DC, variation of power (24 V AC±10% or 29 V DC to 36 V DC) does not affect circuit operation. Table 3 below shows the measured output voltage of the switch for various supply voltages.

TABLE 3

SUPPLY VOLTAGE	SWITCH OUTPUT
36 VDC	4.96 V
35 VDC	4.96 V
34 VDC	4.95 V
33 VDC	4.95 V
32 VDC	4.94 V
31 VDC	4.93 V
30 VDC	4.93 V
29 VDC	4.92 V

PSRR=6 mV/V=−45 dB

In order to determine the effect of body capacitance on circuit operation, the circuit of FIG. **3** was used to simulate glass, water resistance, and body capacitance. The following two conditions were simulated and tested:

1—The maximum body capacitance that does not cause crosswalk when:
Temperature=105° C.
Supply Voltage=36VDC
Glass Capacitance=2 pF
Water Resistance=330 k to 1 MΩ

2—The minimum capacitance to turn on a switch when:
Temperature=0° C.
Supply Voltage=29VDC
Glass Capacitance=2 pF

3—Operation at room temperature.

Table 4 below shows the signal and noise voltages at the switch output for different values of body capacitance and contamination resistance.

TABLE 4

CONTAMINATION RESISTANCE	BODY CAPACITANCE				
	20 pF	220 pF	330 pF	550 pF	1230 pF
330 kΩ	S: 5.1 V N: 2.0 V	S: 5.1 V N: 4.0 V	S: 5.1 V N: 4.5 V	S: 5.1 V N: 4.9 V	S: 5.1 V N: 5.0 V
500 kΩ	S: 5.1 V N: 0.2 V	S: 5.1 V N: 0.6 V	S: 5.1 V N: 0.7 V	S: 5.1 V N: 0.8 V	S: 5.1 V N: 0.8 V
1 MΩ (Condensed Water)	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V
NONE	S: 5.1 V N: 10 mV	S: 5.1 V N: 10 mV	S: 5.1 V N: 10 mV	S: 5.1 V N: 10 mV	S: 5.1 V N: 10 mV

S = Signal (TOUCH)
N = Noise (NO TOUCH)
supply voltage = 36 VDC
temperature = 105° C.

With contamination resistance of 1 MΩ or more, the circuit is insensitive to body capacitance variations and has a minimum signal-to-noise ratio of −34 dB. With no contamination, signal-to-noise ratio is approximately −54 dB. The graph in **FIG. 9** shows the signal-to-noise ratio versus body capacitance, for different values of contamination resistance at 105° C. The minimum body capacitance to turn on a switch is 20 pF.

At room temperature, crosstalk decreases because of gain drop of transistor **410**. Table 5 below shows that at room temperature, the circuit rejects 250 kΩ of contamination, independent of body capacitance. Below 250 kΩ, body capacitance will affect crosstalk.

TABLE 5

CONTAMINATION RESISTANCE	BODY CAPACITANCE				
	20 pF	220 pF	330 pF	550 pF	1230 pF
200 kΩ	S: 5.1 V N: 0.2 V	S: 5.1 V N: 1.0 V	S: 5.1 V N: 1.2 V	S: 5.1 V N: 1.8 V	S: 5.1 V N: 2.2 V
250 kΩ	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.5 V	S: 5.1 V N: 0.5 V	S: 5.1 V N: 0.5 V
330 kΩ	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V
1 MΩ (Condensed Water)	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V	S: 5.1 V N: 0.1 V

S = Signal (TOUCH)
N = Noise (NO TOUCH)
supply voltage = 36 VDC
temperature = 25° C.

The graph of **FIG. 10** shows the measured signal-to-noise ratio versus body capacitance, for different contamination resistance values at room temperature.

The particular advantages of the preceding circuit over that of existing touch detection circuits such as that disclosed in U.S. Pat. No. 4,758,735, are the use of diode **414** (selected for high speed) to minimize forward recovery time rather than merely provide reverse polarity protection (as with the slower type of diode used in the existing circuits) and the omission of a capacitor coupled across the base to emitter junction of the detection transistor **410** to make the circuit more sensitive and operable with a lower oscillator amplitude and higher oscillator frequency. These features along with appropriate choices in component values make possible operation at significantly higher frequencies (>50 to 800 kHz) than are seen in existing art (60 to 1000 Hz). At frequencies at or near 800 kHz, the 20–300 pF of capacitance to ground offered by the human body presents a considerably lower impedance than the primarily resistive impedance of skin oil or water films that may appear on the dielectric layer overlying the conductive touch pads. This allows the peak voltage of a pad that is touched to come considerably closer to ground than adjacent pads which will have a voltage drop across any contaminating film layer that is providing a conductive path to the area that is touched. The enhanced sensitivity offered by the omission of any capacitor between the base and emitter of the detection transistor **410**, allows the threshold of detection to be set much closer to ground than would be the case otherwise. This allows discrimination between the pad that is touched and adjacent pads that might be pulled towards ground via the conductive path to the touch formed by a contaminating film. This high frequency regime of operation offers a considerable advantage relative to the existing art in terms of immunity to surface contaminants such as skin oil and moisture.

A multiple touch pad circuit constructed in accordance with the second embodiment is shown in **FIG. 11**. In the second embodiment of **FIG. 11**, components similar to those in the first embodiment in **FIG. 4** are designated with the same references numerals and will not be discussed in detail. The multiple touch pad circuit is a variation of the first embodiment in that it includes an array of touch circuits designated as $\mathbf{900}_1$ through $\mathbf{900}_{nm}$, which, as shown, include both the touch circuit **400** shown in **FIGS. 4** and **8** and the input touch terminal pad **451** (**FIG. 4**). Microcontroller **500** selects each row of the touch circuits $\mathbf{900}_1$ to $\mathbf{900}_{nm}$ by providing the signal from oscillator **200** to selected rows of touch circuits. In this manner, microcontroller **500** can sequentially activate the touch circuit rows and associate the received inputs from the columns of the array with the activated touch circuit(s). To keep the path length **451** between the touch pad **450** and the base to the detection transistor **410** to a minimum, the detection circuits **900** are physically located directly beneath the touch pads. To simplify assembly, a flexible circuit board such as vended by Sheldahl, Inc. or Circuit Etching Technics, Inc. can be used for this purpose. Ideally, the printed circuit will be fixed directly against the surface (typically glass) bearing the conductive touch pads to eliminate air gaps and the need for conductive foam pads and spring contacts which were used to fill air gaps.

For this second embodiment, the oscillator **200** of the first embodiment may be slightly modified from that shown in **FIG. 6** to include a transistor (not shown) coupled between the oscillator output and ground with it's base connected to microcontroller **600** such that microcontroller **600** may selectively disable the output of oscillator **200**.

The use of a high frequency in accordance with the present invention provides distinct advantages for circuits such as the multiple touch pad circuit of the present invention due to the manner in which crosstalk is substantially reduced without requiring any physical structure to isolate the touch terminals. Further, the reduction in crosstalk afforded by the present invention, allows the touch terminals in the array to be more closely spaced together.

A third embodiment of the present invention, which provides touch circuit redundancy, is described below with reference to FIGS. **12–14**. As shown in FIG. **12**, the switching circuit according to the third embodiment includes a voltage regulator **1100** for regulating power supplied by 24 V DC power lines **1101** and **1102** with ground connection **1103**, for supplying the regulated power to an oscillator **1200** via lines **1104** and **1107**.

Oscillator **1200** supplies a continuous and periodic signal to touch circuits **1400***a* and **1400***b* via line **1201**. Preferably, the frequency of the oscillator output signal is at least 100 kHz, and more preferably, at least 800 kHz. The two touch circuits **1400***a* and **1400***b* are identical in construction and both receive the output of touch terminal **1450** via line **1451**. A detailed description of the preferred voltage regulator circuit **1100**, oscillator **1200**, and touch circuits **1400***a* and **1400***b* is provided below with reference to FIG. **13** following the description of the remaining portion of the third embodiment.

The output of the first touch circuit **1400***a* is supplied to a first driver circuit **1500** via line **1401***a* while the output of the second touch circuit **1400***b* is supplied to a second driver circuit **1600** via line **1401***b*. The two driver circuits **1500** and **1600** are provided to drive first and second serially connected switching transistors **1700** and **1710**. The switching transistors **1700** and **1710** must both be conducting to supply power to a relay switch **1800**. Thus, if one of touch circuits **1400***a* and **1400***b* does not detect a touch of touch terminal **1450**, one of switching transistors **1700** and **1710** will not conduct and power will not be supplied to relay switch **1800**. The preferred construction of driver circuits **1500** and **1600** and relay switch **1800** are described below with reference to FIG. **14**.

As shown in FIG. **13**, voltage regulator **1100** may be constructed by providing a first capacitor **1110** and a varistor **1112** connected in parallel across input power terminals **1101** and **1102**. Preferably, return power terminal **1102** is connected via line **1103** to ground. Varistor **1112** is used to protect the circuit for over-voltage conditions. Also connected in parallel with first capacitor **1110** and varistor **1112**, are the serially connected combination of a fuse **1114**, a diode **1116**, a resistor **1118** and two parallel connected capacitors **1120** and **1122**. The voltage regulator **1100** is reverse polarity protected by diode **1116** and current limited by resistor **1118**. Capacitors **1120** and **1122** provide filtering.

Voltage regulator **1100** further includes a zener diode **1128** having it's cathode connected to a node between resistor **1118** and capacitors **1120** and **1122** and to output power line **1104**. The anode of zener diode **1128** is coupled to output power common line **1107** and to ground line **1103** via two serially connected resistors **1124** and **1126**. Zener diode **1128** and resistors **1124** and **1126** generate regulated 15 V DC. Two capacitors **1130** and **1132** are connected in parallel with zener diode **1128** between power lines **1104** and **1107**. Capacitors **1130** and **1132** provide filtering and decoupling, respectively. Preferably, capacitor **1110** has a capacitance of 1000 pF, 1000V, varistor **1112** is part no. S14K25 available from Siemens, fuse **1114** is a ¼A fuse, diode **1116** is part no. 1N4002 available from LITEON, resistor **1118** has a resistance of 10Ω, ½W, capacitor **1120** has a capacitance of 22 μF, 35V, capacitor **1122** has a capacitance of 0.1 μF, zener diode **1128** is part no. 1N4744A available from LITEON, resistor **1124** has a resistance of 220Ω, resistor **1126** has a resistance of 220Ω, capacitor **1130** has a capacitance of 1 μF, 25V, and capacitor **1132** has a capacitance of 0.1 μF.

Oscillator **1200** is preferably comprised of a first invertor gate **1210** having it's input coupled to it's output via resistors **1214** and **1216**, and a second invertor gate **1212** having it's input coupled to the output of first invertor gate **1210** and it's output coupled to it's input via a capacitor **1218** and resistor **1216**. The oscillating output of the second invertor gate **1212** is buffered via transistor **1226**, which has it's base connected to the output of second invertor gate **1212** via resistor **1220** and capacitor **1222**, which are connected in parallel therebetween. The base of transistor **1226** is also coupled to power line **1104** via a resistor **1224**. The emitter of transistor **1226** is connected to power line **1104** and the collector is connected to power line **1107** via a resistor **1230**, to the anode of a diode **1228**, and to the oscillator output line **1201**. Diode **1228** has it's cathode connected to power line **1104** and is used to protect transistor **1226**.

Preferably, invertor gates **1210** and **1212** are provided by part no. CD40106B available from Harris, resistor **1214** has a resistance of 10 kΩ, resistor **1216** has a resistance of 1.18 kΩ, 1%, capacitor **1218** has a capacitance of 220 pF, resistor **1220** has a resistance of 4.7 kΩ, capacitor **1222** has a capacitance of 220 pF, resistor **1224** has a resistance of 100 kΩ, transistor **1226** is part no. MMBTA70L available from Motorola, diode **1228** is part no. RLS4448 available from LITEON, and resistor **1230** has a resistance of 3.3 kΩ.

Two touch circuits **1400***a* and **1400***b* are provided in parallel to provide redundancy so that if one fails, the relay drivers are disabled. Because the touch circuits **1400***a* and **1400***b* are identical, only one of the touch circuits will now be described. Touch circuit **1400***a* preferably includes two resistors **1410***a* and **1412***a* coupled in series between touch terminal output line **1451** and the base of a bipolar PNP transistor **1420***a*. Transistor **1420***a* has it's emitter connected to the oscillator output line **1201** and it's collector connected to power common line **1107** via a resistor **1422***a*. Touch circuit **1400***a* further includes a diode **1414***a*, a capacitor **1416***a*, and a resistor **1418***a* all connected in parallel between the base of transistor **1420***a* and the emitter thereof, which is connected to oscillator output line **1201**. Touch circuit **1400***a* also includes a diode **1424***a* having it's anode connected to the collector of transistor **1420***a* and it's cathode connected to touch circuit output line **1401***a* via a resistor **1426***a*.

Preferably, resistor **1410***a* has a resistance of 5.1 kΩ, resistor **1412***a* has a resistance of 5.1 kΩ, diode **1414***a* is part no. RLS4448 available from LITEON, capacitor **1416***a* has a capacitance of 240 pF, resistor **1418***a* has a resistance of 12 MΩ, transistor **1420***a* is part no. BC857CL available from Motorola, resistor **1422***a* has a resistance of 100 kΩ, diode **1424***a* is part no. RLS4448 available from LITEON, and resistor **1426***a* has a resistance of 100 kΩ.

The preferred detailed construction of the first and second driver circuits **1500** and **1600** will now be described with reference to FIG. **14**. In first driver circuit **1500**, the output line **1401***a* of first touch circuit **1400***a* is connected to power common line **1107** via a resistor **1510** and also via a capacitor **1512** connected in parallel therewith. The output line **1401***a* is also connected to the inverting input terminal of an operational amplifier **1514**. The non-inverting input terminal of operational amplifier **1514** is connected to line **1502**, which runs between first and second driver circuits

1500 and **1600** and is connected to power line **1104** via a resistor **1626**. The output of op amp **1514** is connected to power line **1104** via a resistor **1518** and to the input of a Schmitt trigger invertor gate **1516**. The output of Schmitt trigger invertor gate **1516** is connected to the input of a second Schmitt trigger invertor gate **1526** via a resistor **1520**. A diode **1522** is connected in parallel with resistor **1520** with it's cathode connected to the output of invertor gate **1516** and it's anode connected to the input of invertor gate **1526** and to power common line **1107** via capacitor **1524**. The output of invertor gate **1526** is connected to the base of bipolar PNP switching transistor **1700** via a resistor **1528**. The base of transistor **1700** is also connected to power common line **1107** via a capacitor **1532** and to power line **1104** and it's emitter via a resistor **1530**.

Preferably, resistor **1510** has a resistance of 10 MΩ, capacitor **1512** has a capacitance of 0.01 μF, op amp comparator **1514** is part no. LM393 available from National Semiconductor, invertor gate **1516** is part no. CD40106B available from Harris, resistor **1518** has a resistance of 10 kΩ, resistor **1520** has a resistance of 1 MΩ, diode **1522** is part no. RLS4448 available from LITEON, capacitor **1524** has a capacitance of 0.22 μF, invertor gate **1526** is part no. CD40106 available from Harris, resistor **1528** has a resistance of 12 kΩ, resistor **1530** has a resistance of 100 kΩ, capacitor **1532** has a capacitance of 0.01 μF, and transistor **1700** is part no. MMBTA56L available from Motorola.

In second driver circuit **1600**, the output line **1401*b*** of second touch circuit **1400*b*** is connected to power common line **1107** via a resistor **1610** and also via a capacitor **1612** connected in parallel therewith. The output line **1401*b*** is also connected to the inverting input terminal of an operational amplifier **1614**. The non-inverting input terminal of operational amplifier **1614** is connected to line **1502**, which is connected to power line **1104** via resistor **1626**. The non-inverting input terminal of op amp **1614** is also connected to power common line **1107** via a capacitor **1616** and a resistor **1618**, which are connected in parallel. The output of op amp **1614** is connected to power line **1104** via a resistor **1630** and to the coupled inputs of a Schmitt trigger invertor gate **1628**. The output of op amp **1614** is also connected to it's non-inverting input terminal via a resistor **1624**. The output of Schmitt trigger invertor NAND gate **1628** is connected to the input of a second Schmitt trigger invertor gate **1638** via a resistor **1632**. A diode **1634** is connected in parallel with resistor **1632** with it's cathode connected to the output of invertor NAND gate **1628** and it's anode connected to the input of invertor NAND gate **1638** and to power common line **1107** via a capacitor **1636**. The output of invertor gate **1638** is connected to the base of switching bipolar PNP transistor **1710** via a resistor **1640**. The base of transistor **1710** is also connected to power common line **1107** via a capacitor **1642** and to power line **1104** via a resistor **1644**. Second driver circuit **1600** also preferably includes capacitors **1620** and **1622** connected in parallel between it's connections to power lines **1104** and **1107**.

Preferably, resistor **1610** has a resistance of 10 MΩ, capacitor **1612** has a capacitance of 0.01 μF, op amp comparator **1614** is part no. LM393 available from National Semiconductor, capacitor **1616** has a capacitance of 0.01 μF, the resistor **1618** has a resistance of 20 kΩ, capacitor **1620** has a capacitance of 0.1 μF, capacitor **1622** has a capacitance of 0.1 μF, resistor **1624** has a resistance of 100 kΩ, resistor **1626** has a resistance of 10 kΩ, invertor NAND gate **1628** is part no. CD4093B available from Harris, resistor **1630** has a resistance of 10 kΩ, resistor **1632** has a resistance of 1 MΩ, diode **1634** is part no. RLS4448 available from LITEON, capacitor **1636** has a capacitance of 0.22 μF, invertor NAND gate **1638** is part no. CD4093B available from Harris, resistor **1640** has a resistance of 12 kΩ, capacitor **1642** has a capacitance of 0.01 μF, resistor **1644** has a resistance of 100 kΩ, and transistor **1710** is part no. MMBTA56L available from Motorola.

In operation, the output of transistor **1420*a*** (FIG. **13**) taken at it's collector is rectified by diode **1424*a*** and a DC level is generated by resistors **1426*a*** and **1510** and capacitor **1512** (a DC level of the output of transistor **1420*b*** is generated by resistors **1426*b*** and **1610** and capacitor **1612**). When this DC level exceeds the upper threshold voltage of op amp comparator **1514** (**1614**), the output of schmitt triggered invertor gate **1516** inverter NAND gate **1628** (**1628**) goes high which charges capacitor **1524** (**1636**) through resistor **1520** (**1632**). Gates **1516** and **1526** (**1628** and **1638**), resistor **1520** (**1632**), and capacitor **1524** (**1636**) provide debounce in a conventional manner. Diode **1522** (**1634**) is used to provide fast release when the palm of the hand is removed from the touch terminal **1450**. The output of the debounce circuitry drives transistor **1700** (**1710**). Resistor **1528** (**1640**) and capacitor **1532** (**1642**) are used to filter noise. Both touch circuits must be functional in order to drive the relay switch **1800**. Also, if one of the transistors **1700** or **1710** fails, the relay will not be activated.

Relay switch **1800** may be any conventional relay. An example of such a relay is shown in FIG. **14**. Relay switch **1800** may include a relay coil **1810** coupled between the selective power supply **1711** of transistors **1700** and **1710** and ground, and a pair of magnetically responsive switches that switch from normally closed terminals **1805** and **1807** to normally open terminals **1801** and **1803** when the relay coil is energized. A zener diode **1815** may be placed in series with a diode **1820** to reduce stress on the relay coil **1810** and to protect transistor **1710** when transistors **1700** and **1710** switch off.

Although the touch circuits of the third embodiment are disclosed as operating a relay switch via driver circuits, it will be appreciated by those skilled in the art that the outputs of touch circuits **1400*a*** and **1400*b*** could be supplied to a microcontroller in the manner discussed above with respect to the first embodiment.

The palm button switch of the present invention uses two redundant touch switch circuits, such as shown in FIG. **12**, to disable relay drivers if one of the touch switch circuits fails and redundant relay driver circuitry to turn off a relay switch if one of the driver circuits fails.

Alternatively, the circuitry shown in FIG. **4** could be used. In another embodiment a method to prevent inadvertent actuations is to require a multi-step process. Referring to FIG. **19**, a device is shown having a first palm button **2201**, a second palm button **2202**, and an indicator light **2205**. Palm button **2201** has to be activated first and then button **2202** has to be activated within a 2 second time window before a desired actuation can occur. The 90 degree orientation of the two buttons makes it extremely difficult to accidently touch both with an arm and an elbow or other such physical combination. An added advantage is that the motion required to move the hand from button **2201** to button **2202** can provide some relief from fatigue in the forearm by the resulting muscle flexure that would otherwise not occur if the hand had to be kept near a single button for extended periods of time. A further redundancy can be achieved by requiring simultaneous operation of two such devices, one for each hand. This provides further safeguards against inadvertent actuations and forces the operator to have both hands in a desired safe location once a desired actuation occurs. A further option is to provide one or more LEDs **2205** or audible annunciators for visual or audible feedback to the operator. Specifically, in FIG. **19** the LED **2205** will come on when button **2201** has been successfully activated to cue the operator that it is time to move to button **2202**. Where required a second LED with a different color than the first (yellow for the first LED and red for the second) can be provided to provide visual confirmation that the second button **2202** has been activated or that the required combination of the two buttons has been activated. Two different audible tone or sound generators could also be used in lieu of the LEDs to provide feedback to the operator. In industrial or other challenging settings, the housing is made of high strength polycarbonate (or other high strength non-metallic material) to meet high impact and vibration requirements, preferably NEMA 4. A further option is to provide lighting for the switches to allow operation in the dark.

In a variation of the multi-step process, two touch plates within a housing (one vertical and one horizontal) are used to provide a two-step turn-on. Referring to FIGS. **20**A–C, the first step to actuate the output relay **2310**, is initiated when the operator inserts his hands and touches the vertical touch sensor **2301** with the dorsal side of the hands. A yellow LED **2304** on top of the device show the successful completion of the first step. The second step is to flip the hand over and touch the horizontal touch sensor **2302** with the palmar side of the hand. A red LED **2305** on top of the device shows the completion of the two step turn-on and activation of output relay **2310**. The flipping action of the hand in the second step causes the forearm muscles to flex, thereby reducing stiffness and fatigue. Also, the hands, and arms can rest on the run bar until the machine cycle is complete. The second step of the two-step turn-on must occur within some predetermined time (for example 2 seconds) after the release of vertical touch sensor or the first step must be repeated. In this proposed embodiment, the second step provides an added stimulus and reduces operator errors due to mental and physical fatigue. The top cover prevents actuation of two devices by the use of one hand and elbow of the same arm, as required by ANSI Standard B11.19-1990. The enclosure must be a high strength polycarbonate module to meet the high impact and vibration requirements of the industry, preferably NEMA 4. In both embodiments, high frequency switching is used to desensitize the unit against moisture and contaminants that could generate a path between the button and grounded chassis. The palm button may be formed as the flat palm button shown in FIGS. **15**A–C or as a dome-shaped palm button shown in FIG. **16**. The button is made of a brass plate **1910** (**1930**) and can be covered with a plastic or glass **1925** (**1933**) cover or membrane to desensitize the unit even more against contaminants and other inadvertent actuation. The plastic cover **1925** (**1933**) acts as a dielectric and capacitance is varied as a function of the area of the plastic being touched. Therefore, if button is touched by finger, a much smaller series capacitance is generated as opposed to button being touched by the palm of a hand. This capacitance is placed in series with the capacitance of the body to ground when the button is touched. Since the capacitance of the body to ground is much larger than the capacitance generated by the button, the functionality of the unit is independent of the variations in body capacitance to ground from person to person. The other factor that needs to be considered here is body resistance. If the button is not covered with an insulator such as plastic, the unit would become sensitive to body resistance. Body resistance to ground, changes as a function of moisture in the work area, skin dryness, floor structure, and shoes. By using a plastic cover, the unit is made insensitive to variations of body resistance and capacitance. The shape of the button is also a factor in sensitivity. If the button is flat, less of the button area would be covered by the palm of the hand as opposed to a dome shape button that matches the contour of the palm. Therefore, if the button is dome-shaped, the unit can be even more desensitized against inadvertent operation.

By providing a large space for hand insertion and switch activation and a flat or dome shape button where the palm of the hand rests while machine cycle is in process, stress on the forearms is ergonomically reduced. The palm button of the present invention can be activated with or without gloves. The zero force palm button of the present invention may be used to activate electric, pneumatic, air clutch, and hydraulic equipment such as punch presses, molding machines, etc.

As shown in FIGS. **15**A–C, the flat palm button may include a plastic housing **1917** having an optional metallic enclosure **1922** for surface mounting. The button also may include a flush mount surface **1915** and optional guarding **1920**.

The circuit board **1935** used with the palm button of the present invention may be packaged on two printed circuit boards. One board for power and relay and the other for touch switches and relay drivers. The touch circuit on the touch switch board is interfaced to the button through a screw that also holds the button in place. The power/relay board is interfaced to the touch switch board through a three pin right angle connector. Wiring to the unit is done through a seven position terminal block on the power/relay board. The power/relay board is designed for 24 V DC input power and provides two double-throw relay contacts. However, it can be modified to accommodate different power inputs and switch outputs. For example, a transformer may be added to the power board so that the unit is powered 110VAC/220VAC instead of 24 V DC. Also, the relays may be replaced with other outputs such as digital or 4–20 mA outputs.

The touch circuit components can be integrated in a custom IC 2000, as shown in FIG. **17**, to facilitate manufacturing and to reduce cost. Components **413**, **412**, **414**, **410**, **418**, and **420** are similar to those of circuit **400** shown in FIG. **8**. Preferably, resistor **2004** has a resistance of 470 kΩ and diode **2002** has characteristics similar to part no. 1N4148 available from LITEON. Resistors **2008** and **2006** are used to adjust the sensitivity. Diode **2002** at the output of **420**, allows the IC to be used in applications where several touch circuit IC's are multiplexed.

As shown in FIG. **18**, a sleep circuit **2100** may be added to the oscillator circuit **200** (FIG. **6**) to allow microcontroller **600** to turn off the oscillator circuit **200**. The disabling of oscillator circuit **200** is done to reduce drainage of capacitor **126** in the regulator circuit **120** during brown outs. The circuit diagram shown in FIG. **18** is a modified version of circuit **200** in FIG. **6**. During normal operation microcontroller **600** pulls the input of gate **2116** to ground and causes the output of gate **2116** to go high (power line **104**). Therefore, transistor **2110** is biased on and oscillator **200** is functional. When in a sleep mode, microcontroller **600** sources the input to gate **2116** high and causes the output of gate **2116** to go low which turns off transistor **2110** and pulls the input of gate **212** low. Therefore, the oscillator will stop oscillating and drainage on capacitor **126** decreases considerably.

The above described embodiments were chosen for purposes of describing but one application of the present invention. It will be understood by those who practice the invention and by those skilled in the art, that various modifications and improvements may be made to the invention without departing from the spirit or scope of the invention as defined by the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A capacitive responsive electronic switching circuit comprising:

an oscillator providing a periodic output signal having a frequency of 50 kHz or greater;

an input touch terminal having a dielectric cover defining an area for an operator to provide an input by proximity and touch, an operator's body capacitance to ground as sensed through said input touch terminal varying as a function of the area of said input touch terminal that is proximate the operator's body; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminal, said detector circuit being responsive to signals from said oscillator and the presence of an operator's body capacitance to ground coupled to said touch terminal when proximal or touched by an operator to provide a control output signal, wherein said detector circuit includes means for generating said control signal when the sensed body capacitance to ground exceeds a threshold level in order to prevent unintended activation based upon an operator's inadvertent proximity and touch with said input touch terminal.

2. The switching circuit as defined in claim **1**, wherein said oscillator provides a periodic output signal having a frequency of 800 kHz or greater.

3. The switching circuit as defined in claim **1** and further including a DC power supply for supplying power to said oscillator and a ground.

4. The switching circuit as defined in claim **1**, wherein said periodic output signal provided by said oscillator is a square wave output signal, said oscillator includes a square wave generator for generating a square wave, and a plurality of active elements coupled to an output of said square wave generator to buffer and improve the shape of the square wave output therefrom.

5. The switching circuit as defined in claim **1**, wherein said detector circuit includes a microcontroller and a charge pump circuit coupled between said input touch terminal and said microcontroller.

6. The switching circuit as defined in claim **1**, wherein said detector circuit includes a microcontroller and a touch circuit coupled between said input touch terminal and said microcontroller.

7. The switching circuit as defined in claim **6** and further including a plurality of said input touch terminals and a plurality of said touch circuits respectively associated with said input touch terminals.

8. The switching circuit as defined in claim **7**, wherein said microcontroller selectively applies said periodic output signals received from said oscillator to each of said touch circuits to separately activate each touch circuit.

9. A capacitive responsive electronic switching circuit comprising:

an oscillator providing a periodic output signal having a frequency of 50 kHz or greater;

an input touch terminal defining an area for an operator to provide an input by proximity and touch;

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminal, said detector circuit being responsive to signals from said oscillator and the presence of an operator's body capacitance to ground coupled to said touch terminal when proximal or touched by an operator to provide a control output signal; and

a floating common generator coupled to said oscillator for receiving said square wave output signal, said floating common generator generating a floating common reference for said detector circuit that is set at a fixed voltage below and tracks the square wave output signal.

10. The switching circuit as defined in claim **9**, wherein said detector circuit is powered by said square wave output signal provided by said oscillator and by said floating common reference provided by said floating common generator thereby increasing the sensitivity of said detector circuit to proximity and touching of said touch terminal by an operator's body.

11. The switching circuit as defined in claim **10**, wherein said detector circuit includes a microcontroller and a charge pump circuit coupled between said input touch terminal and said microcontroller, by an operator's body, wherein said charge pump circuit includes at least one high speed diode coupled between said oscillator and said touch terminal, for enhancing a sensitivity at which said charge pump responds to sensed body capacitance at said touch terminal for higher frequencies.

12. A proximity and touch controlled switching circuit comprising:

an oscillator providing a square wave output signal having a frequency of 50 kHz or greater;

a touch terminal having a dielectric cover defining an input terminal for coupling to an operator's body capacitance to ground; and

a charge pump circuit coupled to said oscillator for receiving said square wave output signal, and coupled to said touch terminal, said charge pump circuit having an output terminal that supplies an output signal having a voltage that varies when said touch terminal is proximal or touched by an operator's body, the voltage of said output signal varies as a function of the area of said touch terminal that is proximal or touched by an operator,

wherein said charge pump circuit includes at least one high speed diode coupled between said oscillator and said touch terminal, for enhancing a sensitivity at which said charge pump responds to sensed body capacitance to ground at said touch terminal for higher frequencies.

13. The proximity and touch controlled circuit as defined in claim **12** and further including a DC power supply for supplying power to said oscillator and a ground.

14. The proximity and touch controlled circuit as defined in claim **12**, wherein said oscillator includes a square wave generator for generating a square wave, and a plurality of active elements coupled to an output of said square wave generator to buffer and improve the shape of the square wave output therefrom.

15. The proximity and touch controlled circuit as defined in claim **12**, wherein said oscillator provides a periodic output signal having a frequency of 800 kHz or greater.

16. A proximity and touch controlled switching circuit comprising:

an oscillator providing a square wave output signal having a frequency of 50 kHz or greater;

a touch terminal defining an input terminal for coupling to an operator's body capacitance to ground;

- a charge pump circuit coupled to said oscillator for receiving said square wave output signal, and coupled to said touch terminal, said charge pump circuit having an output terminal that supplies an output signal having a voltage that varies when said touch terminal is proximal or touched by an operator's body; and
- a floating common generator coupled to said oscillator for receiving said square wave output signal, said floating common generator generating a floating common reference for said charge pump circuit that is set at a fixed voltage below and tracks said square wave output signal,
- wherein said charge pump circuit includes at least one high speed diode coupled between said oscillator and said touch terminal, for enhancing a sensitivity at which said charge pump responds to sensed body capacitance to ground at said touch terminal for higher frequencies.

17. The proximity and touch controlled circuit as defined in claim **16**, wherein said charge pump circuit is powered by said square wave output signal provided by said oscillator and by said floating common reference provided by said floating common generator thereby increasing the sensitivity of said charge pump circuit to proximity and touching of said touch terminal by an operator's body.

18. A capacitive responsive electronic switching circuit comprising:

- an oscillator providing a periodic output signal having a predefined frequency;
- a plurality of input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and
- a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator and the presence of an operator's body capacitance to ground coupled said touch terminals when proximal or touched by an operator to provide a control output signal,
- wherein said predefined frequency of said oscillator is selected to decrease the impedance of said dielectric substrate relative to the impedance of any contaminate that may create an electrical on said dielectric substrate path between said adjacent areas, and wherein said detector circuit compares the sensed body capacitance to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.

19. The switching circuit as defined in claim **18**, wherein said oscillator provides a periodic output signal having a frequency of 800 kHz or greater.

20. A capacitive responsive electronic switching circuit comprising:

- an oscillator providing a periodic output signal having a predefined frequency;
- a dome-shaped touch terminal defining an area for an operator to provide an input by proximity and touch, wherein the dome shape of the touch terminal is constructed to ergonomically fit the palm of a human hand; and
- a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said touch terminal, said detector circuit being responsive to signals from said oscillator and the presence of an operator's body capacitance to ground coupled to said touch terminal when proximal or touched by an operator to provide a control output signal, said detector circuit including means for discriminating between a proximity and touch of said dome-shaped touch terminal by the palm of a human hand and a proximity and touch by a human finger.

21. A capacitive responsive electronic switching circuit comprising:

- an oscillator providing a periodic output signal having a predefined frequency;
- a touch terminal defining an area for an operator to provide an input by proximity and touch; and
- a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said touch terminal, said detector circuit being responsive to signals from said oscillator and the presence of an operator's body capacitance to ground coupled to said touch terminal when proximal or touched by an operator to provide a control output signal, said detector circuit including discriminating means for discriminating between a proximity and touch of said touch terminal covering substantially all of said area of said touch terminal and a proximity and touch covering less than substantially all of said area of said touch terminal.

22. The switching circuit as defined in claim **21**, wherein said touch terminal includes a dome-shaped dielectric cover.

23. The switching circuit as defined in claim **21**, wherein said touch terminal includes a palm-sized dielectric cover.

24. The switching circuit as defined in claim **23**, wherein said discriminating means determines that a proximity and touch of said touch terminal covers substantially all of said area of said touch terminal when said dielectric cover is proximal or touched with the palm of an operator's hand and determines that a proximity or touch covers less than substantially all of said area of said touch terminal when said dielectric cover is proximal or touched with one of an operator's fingers.

25. The switching circuit as defined in claim **21**, wherein said discriminating means discriminates between a proximity and touch of said touch terminal covering substantially all of said area of said touch terminal and a proximity and touch covering less than substantially all of said area of said touch terminal based upon a sensed level of body capacitance to ground proximate said touch terminal.

26. The switching circuit as defined in claim **21**, wherein said coupling of capacitance to ground occurs when an operator's body is proximate, but not touching, said touch terminal.

27. A capacitive responsive electronic switching circuit for a controlled device comprising:

- an oscillator providing a periodic output signal having a predefined frequency;
- first and second touch terminals defining areas for an operator to provide an input by proximity and touch; and
- a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator and the presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by an operator to provide a control output signal for actuation of the controlled device, said detector circuit being con-

figured to generate said control output signal when said an operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

28. The capacitive responsive electronic switching circuit as defined in claim **27**, wherein said detector circuit generates said control signal only when an operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.

29. The capacitive responsive electronic switching circuit as defined in claim **27**, wherein said first and second touch terminals are adapted to be mounted on different surfaces of the controlled device.

30. The capacitive responsive electronic switching circuit as defined in claim **27**, wherein said first and second touch terminals are adapted to be mounted on non-parallel planar surfaces of the controlled device.

31. The capacitive responsive electronic switching circuit as defined in claim **27**, wherein said first and second touch terminals are adapted to be mounted on perpendicular planar surfaces of the controlled device.

32. The capacitive responsive electronic switching circuit as defined in claim **27** and further including an indicator for indicating when said detector circuit determines that an operator is proximal or touches said first touch terminal.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,796,183 Page 1 of 3
DATED : August 18, 1998
INVENTOR(S) : Byron Hourmand

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

Column 5, line 52, "such a" should be --such as--.

Column 9, line 31, before "water" insert --condensed--.

Column 14, line 35, "is" should be --as--.

Column 13, line 65, "it's" should be --its--.

Column 18, line 38, "references" should be --reference--.

Column 20, line 7, "it's" should be --its-- (both occurrences).

Column 20, line 9, "it's" should be --its--.

Column 20, line 10, "it's" should be --its-- (both occurrences).

Column 20, line 13, "it's" should be --its--.

Column 20, line 20, "it's" should be --its--.

Column 20, line 39, "it's" should be --its--.

Column 20, line 40, "it's" should be --its--.

Column 20, line 46, "it's" should be --its--.

Column 20, line 47, "it's" should be --its--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,796,183
DATED : August 18, 1998
INVENTOR(S) : Byron Hourmand

Page 2 of 3

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

Column 21, line 8, "it's" should be --its--.

Column 21, line 9, "it's" should be --its--.

Column 21, line 15, "it's" should be --its--.

Column 21, line 42, "it's" should be --its--.

Column 21, line 46, "it's" should be --its--.

Column 21, line 47, "it's" should be --its--.

Column 21, line 56, "it's" should be --its--.

Column 22, line 8, "it's" should be --its--.

Column 22, line 13, "schmitt" should be --Schmitt--.

Column 26, lines 22-27, after "microcontroller." delete "by an operator's body . . . higher frequencies."

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,796,183 Page 3 of 3
DATED : August 18, 1998
INVENTOR(S) : Byron Hourmand

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

Column 27, line 44, after "electrical" insert --path--.

Column 27, line 45, delete "path".

Column 29, line 1, after "when" delete "said".

Signed and Sealed this

Eleventh Day of May, 1999

Attest:

Q. TODD DICKINSON

Attesting Officer

Acting Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,796,183
APPLICATION NO. : 08/601268
DATED : August 18, 1998
INVENTOR(S) : Byron Hourmand et al.

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

Title Page, Item (75) Inventor, should read --(75) Inventors: Byron Hourmand, Hersey, MI (US); John M. Washeleski, Cadillac, MI (US); Stephen R. W. Cooper, Fowlerville, MI (US)--.

Signed and Sealed this
Eleventh Day of October, 2011

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

US005796183C1

(12) EX PARTE REEXAMINATION CERTIFICATE (9614th)

United States Patent
Hourmand et al.

(10) **Number: US 5,796,183 C1**
(45) **Certificate Issued: Apr. 29, 2013**

(54) **CAPACITIVE RESPONSIVE ELECTRONIC SWITCHING CIRCUIT**

(75) Inventors: **Byron Hourmand**, Hersey, MI (US); **John M. Washeleski**, Cadillac, MI (US); **Stephen R. W. Cooper**, Fowlerville, MI (US)

(73) Assignee: **Nartron Corporation**, Reed City, MI (US)

Reexamination Request:
No. 90/012,439, Aug. 17, 2012

Reexamination Certificate for:

Patent No.:	**5,796,183**
Issued:	**Aug. 18, 1998**
Appl. No.:	**08/601,268**
Filed:	**Jan. 31, 1996**

Certificate of Correction issued May 11, 1999

Certificate of Correction issued Oct. 11, 2011

(51) **Int. Cl.**

H03K 17/96	(2006.01)
H03K 17/94	(2006.01)

(52) **U.S. Cl.**
USPC **307/116**; 307/125; 307/139; 361/181

(58) **Field of Classification Search**
None
See application file for complete search history.

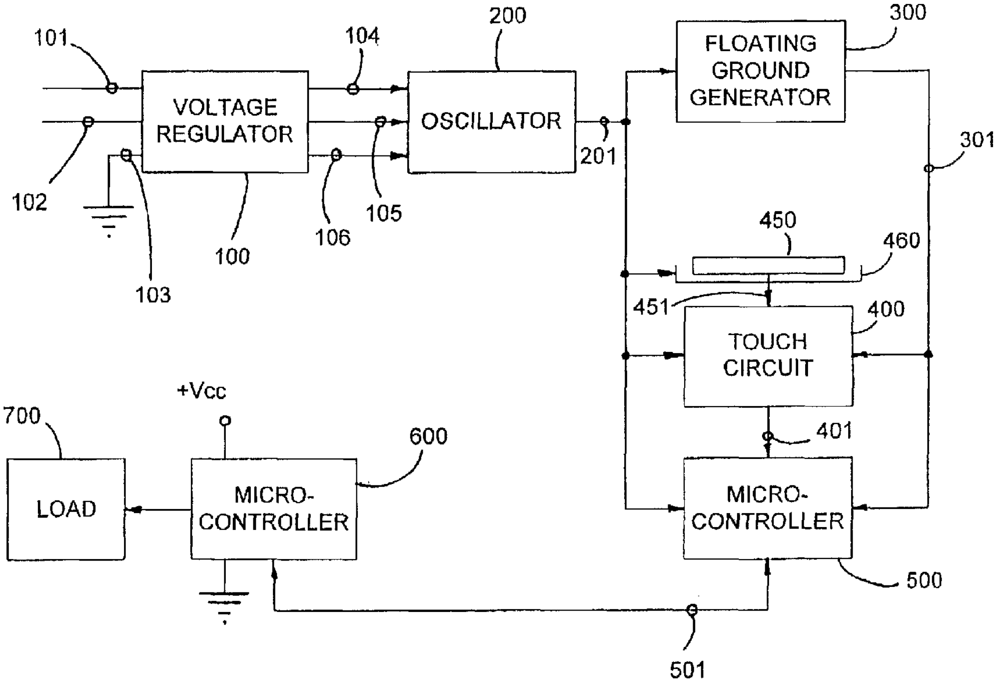
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/012,439, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner — Linh M. Nguyen

(57) **ABSTRACT**

A capacitive responsive electronic switching circuit comprises an oscillator providing a periodic output signal having a frequency of 50 kHz or greater, an input touch terminal defining an area for an operator provide an input by proximity and touch, and a detector circuit coupled to the oscillator for receiving the periodic output signal from the oscillator, and coupled to the input touch terminal. The detector circuit being responsive to signals from the oscillator and the presence of an operator's body capacitance to ground coupled to the touch terminal when in proximity or touched by an operator to provide a control output signal. Preferably, the oscillator provides a periodic output signal having a frequency of 800 kHz or greater. An array of touch terminals may be provided in close proximity due to the reduction in crosstalk that may result from contaminants by utilizing an oscillator outputting a signal having a frequency of 50 kHz or greater.



EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **18**, **27**, **28** and **32** are determined to be patentable as amended.

New claims **33-39** are added and determined to be patentable.

Claims **1-17**, **19-26** and **29-31** were not reexamined.

18. A capacitive responsive electronic switching circuit comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a plurality of small sized input touch terminals of a keypad;

[a] *the* plurality of *small sized* input touch terminals defining adjacent areas on a dielectric substrate for an operator to provide inputs by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said input touch terminals, said detector circuit being responsive to signals from said oscillator *via said microcontroller* and [the] *a* presence of an operator's body capacitance to ground coupled *to* said touch terminals when proximal or touched by [an] *the* operator to provide a control output signal,

wherein said predefined frequency of said oscillator [is] *and said signal output frequencies are* selected to decrease [the] *a first* impedance of said dielectric substrate relative to [the] *a second* impedance of any contaminate that may create an electrical path on said dielectric substrate between said adjacent areas *defined by the plurality of small sized input touch terminals*, and wherein said detector circuit compares [the] *a* sensed body capacitance *change* to ground proximate an input touch terminal to a threshold level to prevent inadvertent generation of the control output signal.

27. A capacitive responsive electronic switching circuit for a controlled *keypad* device comprising:

an oscillator providing a periodic output signal having a predefined frequency;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;

the first and second *input* touch terminals defining areas for an operator to provide an input by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator *via said microcontroller* and [the] *a* presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by [an] *the* operator to provide a control output signal for actuation of the controlled *keypad* device, said detector circuit being configured to generate said control output signal when [an] *the* operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

28. The capacitive responsive electronic switching circuit as defined in claim **27**, wherein said detector circuit generates said control signal only when [an] *the* operator is proximal or touches said second touch terminal within a predetermined time period after the operator is proximal or touches said first touch terminal.

32. The capacitive responsive electronic switching circuit as defined in claim **27** and further including an indicator for indicating when said detector circuit determines that [an] *the* operator is proximal or touches said first touch terminal.

33. The capacitive responsive electronic switching circuit as defined in claim 18, further comprising wherein said detector circuit compares the sensed body capacitance change caused by the body capacitance decreasing an input touch terminal signal on the detector to ground when proximate to the input touch terminal to a second threshold level to generate the control output signal.

34. The capacitive responsive electronic switching circuit as defined in claim 18, further comprising wherein said detector circuit compares the sensed body capacitance change caused by the body capacitance decreasing an input touch terminal signal amplitude on the detector to ground when proximate to the input touch terminal to a second threshold level to generate the control output signal.

35. The capacitive responsive electronic switching circuit as defined in claim 27, wherein when the second touch terminal is not touched on its defining area by the operator to provide input, the control output signal is prevented.

36. The capacitive responsive electronic switching circuit as defined in claim 27 and further including an indicator for indicating when said detector circuit determines that the operator is proximal or touches said second touch terminal.

37. A capacitive responsive electronic switching circuit for a controlled device comprising:

an oscillator providing a periodic output signal having a predefined frequency, wherein an oscillator voltage is greater than a supply voltage;

a microcontroller using the periodic output signal from the oscillator, the microcontroller selectively providing signal output frequencies to a closely spaced array of input touch terminals of a keypad, the input touch terminals comprising first and second input touch terminals;

the first and second touch terminals defining areas for an operator to provide an input by proximity and touch; and

a detector circuit coupled to said oscillator for receiving said periodic output signal from said oscillator, and coupled to said first and second touch terminals, said detector circuit being responsive to signals from said oscillator via said microcontroller and a presence of an operator's body capacitance to ground coupled to said first and second touch terminals when proximal or touched by the operator to provide a control output signal for actuation of the controlled device, said detector circuit being configured to generate said control output signal when the operator is proximal or touches said second touch terminal after the operator is proximal or touches said first touch terminal.

38. The capacitive responsive electronic switching circuit as defined in claim 37, wherein feedback to the operator is provided by an indicator activated by the microcontroller after the operator touches the second touch terminal.

39. The capacitive responsive electronic switching circuit as defined in claim 37,

wherein said detector circuit compares a sensed body capacitance change caused by the body capacitance decreasing a second touch terminal signal on the detector to ground when proximate to the second touch terminal to a threshold level to generate the control output signal, and

wherein feedback to the operator is provided by an indicator activated by the microcontroller after the operator touches the second touch terminal.

* * * * *

STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: Byron Hourmand

Application No./Patent No.: 5,796,183 B1 Filed/Issue Date: August 18, 1998

Titled: Capacitive Responsive Electronic Switching Circuit

UUSI, LLC, a Corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

   ☐ The extent (by percentage) of its ownership interest is ____________%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

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The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel ____________, Frame ____________, or for which a copy thereof is attached.

B. ☑ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: Byron Hourmand To: Nartron Corporation

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[Page 1 of 2]

STATEMENT UNDER 37 CFR 3.73(c)

3. From: John M. Washeleski To: Nartron Corporation

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[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Brian A. Carlson/	December 24, 2013
Signature	Date
Brian A. Carlson	37,793
Printed or Typed Name	Title or Registration Number

[Page 2 of 2]

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☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

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The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	9-26-12
Name	Norman A. Rautiola	Telephone	231-832-5525
Title	Manager		

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

U.S. Patent No.:	5,796,183 B1	§	Docket No.:	5796183RX2
Issued:	August 18, 1998	§	Inventors:	Hourmand et al.
Filed:	January 31, 1996	§	Patent Owner:	UUSI, LLC
Control No.	TBD	§	Examiner:	TBD

For: Capacitive Responsive Electronic Switching Circuit

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

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Dear Sir:

Patent Owner wishes to bring to the attention of the U.S. Patent and Trademark Office the information noted on the enclosed form, which may be considered material to the reexamination of the above-identified patent. Patent Owner makes no assertion that a prior art search has been made or that any of the cited references are prior art under 35 U.S.C. § 102. In some instances, publications that are not prior art under 35 U.S.C. § 102 have been cited as they may discuss prior art systems and may provide insight into the state of the art at the time of the invention.

Respectfully submitted,

December 24, 2013
Date

/Brian A. Carlson/
Brian A. Carlson
Reg. No. 37,793

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number	
	Filing Date	
	First Named Inventor	Byron Hourmand
	Art Unit	
	Examiner Name	
	Attorney Docket Number	5796183RX

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Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	4766368		1988-08-23	Cox	
	2	4825385		1989-04-25	Dolph, et al.	
	3	5305017		1994-04-19	Gerpheide	
	4	5337353		1994-08-09	Boie, et al.	
	5	5463388		1995-10-31	Boie, et al.	
	6	5565658		1996-10-15	Gerpheide, et al.	

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	Application Number	
	Filing Date	
	First Named Inventor	Byron Hourmand
	Art Unit	
	Examiner Name	
	Attorney Docket Number	5796183RX

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	1	BUXTON, B., "31.1: Invited Paper: A Touching Story: A Personal Perspective on the History of Touch Interfaces Past and Future," Society for Information Display (SID) Symposium Digest of Technical Papers, Vol. 41, No. 1, Session 31, May 2010, pp. 444-448.	☐
	2	HINCKLEY, K., et al., "38.2: Direct Display Interaction via Simultaneous Pen + Multi-touch Input," Society for Information Display (SID) Symposium Digest of Technical Papers, Vol. 41, No. 1, Session 38, May 2010, pp. 537-540.	☐
	3	LEE, S., "A Fast Multiple-Touch-Sensitive Input Device," University of Toronto, Department of Electrical Engineering, Master Thesis, October 1984, 118 pages.	☐
	4	HILLIS, W.D., "A High-Resolution Imaging Touch Sensor," The International Journal of Robotics Research, Vol. 1, No. 2, Summer (June - Aug.) 1982, pp. 33-44.	☐
	5	LEE, S.K., et al., "A Multi-Touch Three Dimensional Touch-Sensitive Tablet," Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, April 1985, pp. 21-25.	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT **(Not for submission under 37 CFR 1.99)**	Application Number		
	Filing Date		
	First Named Inventor	Byron Hourmand	
	Art Unit		
	Examiner Name		
	Attorney Docket Number	5796183RX	

	6	HLADY, A.M., "A touch sensitive X-Y position encoder for computer input," Proceedings of the Fall Joint Computer Conference, November 18-20, 1969, pp. 545-551.	☐
	7	SASAKI, L., et al., "A Touch-Sensitive Input Device," International Computer Music Conference Proceedings, November 1981, pp. 293-296.	☐
	8	CALLAHAN, J., et al., "An Empirical Comparison of Pie vs. Linear Menus," Human Factors in Computing Systems: Chicago '88 Conference Proceedings: May 15-19, 1988, Washington DC: Special Issue of the SIGCHI Bulletin, New York, Association for Computing Machinery, pp. 95-100.	☐
	9	CASIO, AT-550 Advertisement, published in Popular Science by On The Run, February 1984, p.-129.	☐
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Signature	/Brian A. Carlson/	Date (YYYY-MM-DD)	2013-12-24
Name/Print	Brian A. Carlson	Registration Number	37,793

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31.1: *Invited Paper:* A Touching Story: A Personal Perspective on the History of Touch Interfaces Past and Future

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Abstract

Touch screens have a 40+ year history. Multi-touch and some of the gestures associated with it, are over 25 years old. This paper aspires to provide some perspective on the roots of these technologies, and share some future-relevant insights from those experiences. Since the scope of the article does not permit a comprehensive survey, emphasis has been given to projects and insights that are relevant, but less-well known.

1. Introduction

The announcement of two new products in 2007, the Apple *iPhone* and Microsoft *Surface*, gave a serious boost to interest in touch interfaces – especially those that incorporate multi-touch. Since then, touch, multi-touch, and the gesture-based interfaces that they frequently employ, have become close to "must-have" features in several market segments, including mobile devices, desktop computers, laptops, and large format displays.

What is typically missed amongst this newfound interest – but also typical of virtually all "new" technologies - is how far back these techniques and technologies go [1][2]. For example, the use of touch input as a means to interact with computers began, at least, in the mid-1960s, with early work being done by IBM [3] in Ottawa Canada[4], and the University of Illinois [5]. By the early 1970s, a number of different technologies had been disclosed.

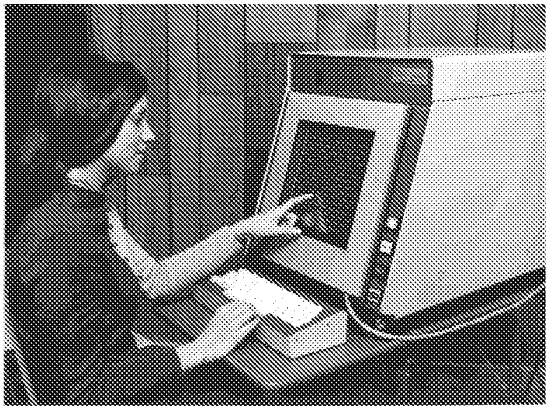

Figure 1: PLATO IV Terminal with touch screen and plasma panel display. (Courtesy of Archives of the University of Illinois, Urban Champaign. Found in RS: 39/2/20, Box COL 13, Folder COL 13-13 Computer Ed. Research Lab / PLATO 1952-74)

By 1972, touch screens had left the labs and computer centers and entered selected grade-school classrooms as part ofthe PLATO IV system, illustrated in Figure 1. This was all the more remarkable when one considers that PLATO IV not only preceded the appearance of the personal computer and local area networks, its relatively wide deployment happened when Xerox PARC was just starting work on the Alto computer!

Through the 1970s-80s a number of different technologies were developed to support touch (such as capacitive, resistive, light interruption, and surface acoustic wave), and a number of different companies were founded to commercialize these technologies. Examples include, Elographics, Carroll Touch, and MicroTouch Systems.

As the options for the interface designer grew, so did the granularity of our understanding of the affordances of the available technologies and techniques. Nakatani and Rohrlich [6], for example, gave voice to the notion of "soft machines", what they defined as:

> .... *using the synergistic combination of real-time computer graphics to display "soft controls," and a touch screen to make soft controls operable like conventional hard controls.*

However, as Gustave Flaubert said, "God is in the details," and getting the details wrong could make a good technology look really bad – as was the case with how cursor control was implemented on the early Apollo workstations, using an Elographics touchpad.

2. Lost Along the Way

From the time of PLATO IV to close to 2000, the use of touch-sensing screens and tablets settled into a number or more-or-less niche markets. Touchpads/tablets (touch sensors not mounted directly over a display) became most visible on laptops, where they were (and are) the dominant technology used for cursor control. Touch screens were largely split into three main segments, kiosks (including ATM machines), point-of-sale devices (restaurants and retail, for example), and mobile devices (starting with PDAs, but as early as 1993 – as we shall discuss – mobile phones).

Many of these markets were not very demanding in terms of the richness of the interaction techniques employed. Kiosks, for example, adopted mainly simple touch-to-select operations. At the same time, however, there was remarkable work which is not well-known, and hence worth highlighting.

Figure 2: The PF-8000 Data Bank (1984). Characters can be entered by printing them on the touchpad with a finger.

Take, for example, the Casio PF-8000, shown in Figure 2. This was a PDA that incorporated an address book and a calculator. It was released in 1984, which is when I got mine. As can be seen in the photo, the right side of the unit consists of a touchpad.

One of the ways that you could enter numbers was to tap them out on a virtual keyboard - defined by the white grid on the touchpad. More interesting, however, was the ability to enter alphanumeric information by tracing it out on the touchpad with your finger. You wrote each character on top of the previous one (segmentation was determined by the time interval between characters), so the whole touchpad surface was used for each character.

Lest one discount the relevance of this device because it used a touchpad, rather than touchscreen, in the same year, Casio released a calculator watch, the AT-550. The watch's crystal was a touch screen. Numbers and operators are "written" on the crystal, in the same manner as the PF-8000.

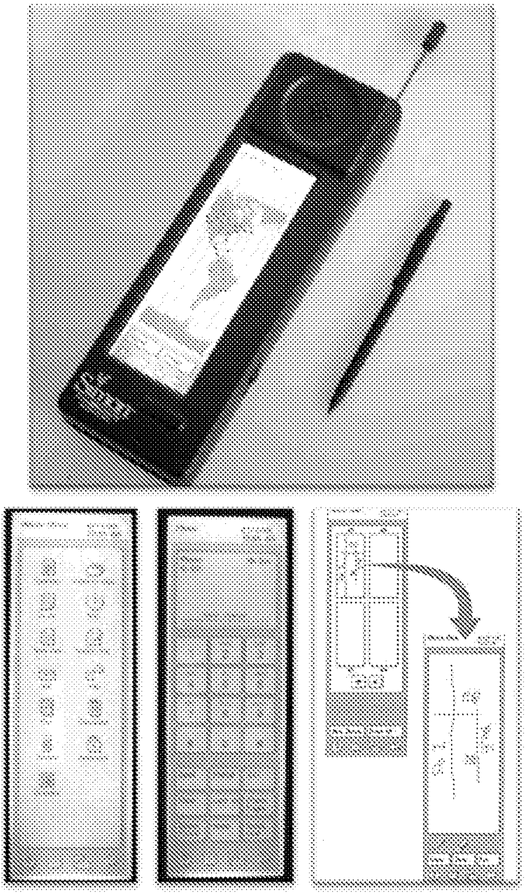

Figure 3: The Simon (1993). The phone's screen shows the display for setting the clock to world time. Interaction was via the touch screen, using either finger or stylus. L-R, the lower 3 images show (a) the desktop icons for accessing applications; (b) the phone dial pad; (c) the manual section for handling sketches and faxes. To place in context, there was no web browser: the World Wide Web had not yet happened yet!

Now flash forward and consider these devices in light of today's world of texting and TWITTER. A few minutes of experience with the PF-8000 or the AT-550 make it clear that one can easily enter alphanumeric text without looking at the device. That is, the character recognition offers essentially the same eyes-free attribute that one has with touch typing on a QWERTY keyboard – something that I call "touch writing". Despite its relevance, this is something that is pretty much unavailable on any of today's mobile touch-entry devices. It is somewhat sobering to realize that Casio was able to do this in products commercially available 25 years ago – the same year that the very first Apple Macintosh computer was released!

Another important example is what I believe to be the world's first smartphone: the Simon [7], shown in Figure 3. This was developed jointly by IBM and Bell South, and first shown in 1993. How much this first smartphone anticipated the phones of today is only matched by how little it is known.

The Simon had only two physical controls: the on/off switch and the volume control. Everything else was controlled by the full-screen touch display – which like the Palm Pilot (which appeared in 1996) – supported both finger and stylus control.

In addition to products, early innovative work was being undertaken in various research labs. Some of the most creative work is, likewise, little known. It was done by Chris Herot and Guy Weinzapfel at the Architecture Machine Group at MIT- the predecessor to MIT's Media Lab [8].

Their work is one of the first attempts to extend the range of touch sensing beyond just horizontal and vertical position. By mounting the touch-screen overlay on strain gauges, they were also able to sense vector information in six different dimensions, as illustrated in Figure 4: force in x, y, and z, as well as torque about the x, y, and z axes.

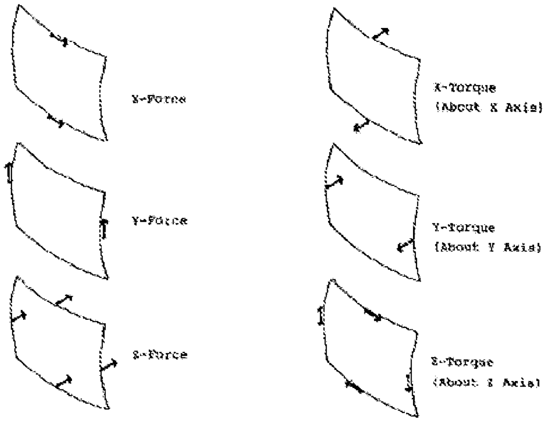

Figure 4: Multidimensional Touchscreen (1978): In addition to sensing position, this touchscreen [8] was capable of sensing 6 degrees of force vector information, including x, y, z, x-torque, y-torque, and z-torque.

Of these additional dimensions, sensing force in z (pressure) is the only one that has gained any prominence, and even that is rare. But that speaks to the nature of the beast: the challenge is,the harder one pushes, the more friction there is in sliding the finger along the surface. Hence, there is an inherent conflict between force*vs.* gesture articulation with touch interfaces.

This is one area where sensing technology can make a difference. Capacitive sensing has a useful attribute in this regard, as was demonstrated by Buxton, Hill and Rowley [9], among others. It goes like this: if you push hard against a surface with your finger, the force tends to cause the fingertip to spread across the surface. Hence, there is a strong correlation between pressure and surface area. Furthermore, while capacitive technologies cannot sense pressure, *per* se, capacitance does vary with the area of contact. Hence, the technology can sense an approximation of pressure – what I call "degree of touch". Knowing this means that the user can control the degree of touch by pressing lightly and varying the contact area. Thus, the user can assert degree of touch while avoiding the friction normally associated with pressure. Yet, just like pressure, this attribute is seldom exploited by interaction designers.

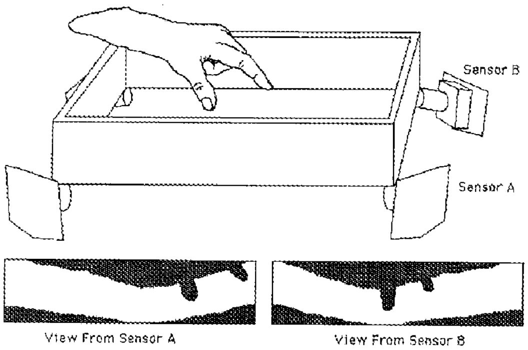

Figure 5: Sensor Frame: A prototype optical touch sensor that detects not only location, but also angle of approach[11].

In terms of exploring less commonly considered dimensions of touch sensing, I want to mention a novel approach to optical sensing of touch begun at Carnegie Mellon University by McAvinney [10], and developed further by Sensor Frame [11]. What they developed by 1988 was a device that used imaging across the display surface to sense touch location. However, unlike the light interruption techniques used with PLATO IV, this system – the Sensor Cube – used what were essentially cameras to detect the finger(s) in the volume above the display, rather than just at the display surface. Hence, as is illustrated in Figure 5, the angle of approach as well of the location of the finger could be determined.

3. Multi-Touch

The Sensor Cube had one other attribute that is sufficiently important to be worth a section on its own: the ability to sense simultaneously the location of multiple points of contact – multi-touch. This also has a history.

In 1984 our group at the University of Toronto developed a capacitive multi-touch tablet capable of sensing degree of touch independently for multiple points of contact [12]. Our initial goal in this work was to make a digital hand drum – a musical percussion instrument. Since this was, I believe, the first multi-touch device reported in the peer-reviewed literature, it is often given credit for being the first multi-touch device. Such is not the case.

The roots of multi-touch lie partially in attempts to construct tactile sensors in robotics. Examples include Wolfeld [13] and Boie [14]. However, to the best of my research, the first use of multi-touch technology for manual control of a digital system was performed by Nimish Metha as part of his MSc thesis at the University of Toronto [15]. This system has additional interest since it is the first use that I have found of capturing touch by using a video camera to optically capture shadows from the underside of a translucent surface – anticipating many current multi-touch systems, including Microsoft Surface. Just to emphasize this point, Metha's system was not only used to capture the shadows of fingers, but to capture and recognize shapes of objects as well!

However, to the best of my research, the first multi-touch display - the first sensor capable of simultaneously capturing multiple touch-points on a display – grew out of the aforementioned work on tactile sensors for robotics by Bob Boie.

After presenting our multi-touch tablet at SIGCHI in 1985, I was approached by Lloyd Nakatani of Bell Labs, Murray Hill, N.J. He invited me to visit the lab to see what they were doing. What I saw when I did so was a capacitive multi-touch screen that Boie had developed. Besides being transparent (ours was an opaque tablet), the performance of this device – in terms of response time – was far beyond what we had accomplished. Seeing the superiority of their system prompted me to stop working on the hardware part of the problem, and focus on the software. My assumption, hope, and expectation was that we would soon be able to get access to the Bell Labs technology. This turned out not to be the case, which was too bad, and the Bell Labs contribution went largely unknown in the larger community – although it was openly shown to me, as well as others [16].

4. A Sponge Without Water …

Thus far, the common factor in virtually all of the work discussed is a desire to extend the range of human capability that can be captured by touch technologies. The reality is that the simple poke-to-select techniques and soft keypads seen in early systems - while useful - only scratched the surface of both the possible and the desirable.

One of the pioneers at really pushing the boundaries of capturing human gesture, and thereby laying the foundation for a great deal of current work, is Myron Krueger [17][18].

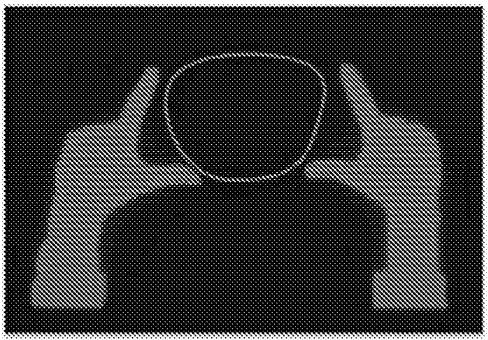

Figure 6: Myron Krueger's Pioneering VIDEODESK, early work using rich gestures. A two-handed pinch gesture is used to govern the shape of the closed object.

Myron's work was all about capturing human gesture, and demonstrating how it can be effectively used. He used a video camera to sense the current pose/action of the user, and then employed digital processing to isolate the human silhouette from the background. The silhouette was then analyzed and gestures extracted. These were then interpreted appropriately to bring about the intended response in the system. One such silhouette is illustrated in Figure 6. Here, two hands are used to control the shape of a closed object. The tips of all four extended fingers affect the shape – two from each hand in this case.

What is important to recognize in approaching Krueger's work is that the technology he used was secondary. It was a means to an end, not the end itself. The underlying point was all about the gesture, not the specifics of how it was captured. Hence, while his work did not sense touch, *per se,* it is relevant nevertheless.

The primary thing that does differentiate Krueger's work from touch systems is that contact with the physical device was not sensed. Hence, proximity, gesture, and/or dwell time – rather than physical contact – was required to initiate or terminate events. However major or minor one views the consequences of such differences, the fact remains that anyone practiced in the art of touch systems, and familiar with Krueger's work, was able to immediately adapt his work to this technology – and he explicitly wrote about its applicability to touch systems [18].

There is yet another class of gesture that has early roots, and which is also having significant impact on touch-based systems. It is that class of gestures where the resulting action is a function of both where one touches, and what direction(s) one strokes/moves, once having made contact. A common example of this found in many of today's mobile phones is the ability to move forward or backward from one image to another by touching the image and quickly sliding the finger left or right on the screen.

An early (1999) example of this technique was in a product called PortfolioWall [19], shown in Figure 7. What is important is that this gesture is a specific instance of a broader class of interaction techniques known generically as *radial menus*. Simply stated, radial menus characterize a class of interaction where the response to an action is a function of both where you touched, and the direction that you move in the gesture after that touch. The options used in viewing images using the PortfolioWall are shown in Figure 8.

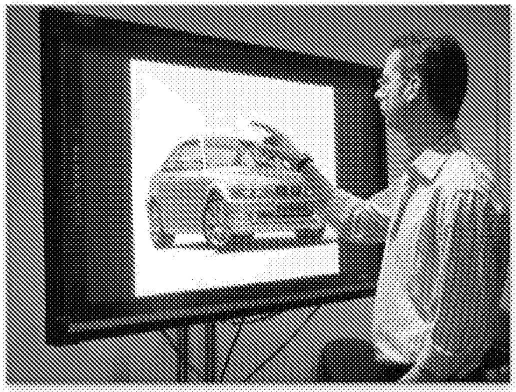

Figure 7: The PortfolioWall (1999). A sliding gesture to the left or right on top of the image moved to the next or previous image, respectively.

In addition to the left and right strokes, the radial menu shown supported the following gestures. A stroke up to the right enabled annotation, while a stroke down to the right enabled one to scale or crop the image. A stroke down closed the image and brought one back to the thumbnail view, while down to the left toggled between *Play* and *Pause* as a slideshow viewer. The menu was only displayed if one touched and held, without moving. Since the actions were easily learned, they were normally articulated without any graphical feedback – thereby illustrating the tight relationship between radial menus and their (in this case), associated eyes-free gestures.

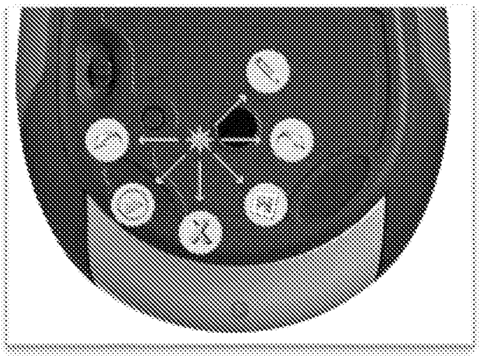

Figure 8: Radial Menu in PortfolioWall. The options when viewing a full sized image are shown by the menu.

Radial menus have a long history, beginning with the PIXIE system of Wiseman, Lemke and Hiles [20]. After a period of neglect, they were brought back into practice by Callahan, Hopkins, Weiser and Shneiderman [21], Hopkins [22], and Kurtenbach [23], for example. The key attribute that distinguishes them from conventional linear menus is that selection of action is determined by direction not distance. As human beings, we are not "wired" to make fine judgments of linear distance without looking. Yet, we *are* wired to be able to easily articulate gestures, eyes free, in any one of the eight primary and secondary directions of the compass. Therein lays the key to understanding that one should not think about radial menus as "just" menus. They also define a class of direction-based gestural interaction. And to emphasize this point, the work of Hopkins and Kurtenbach, cited above, and the PortfolioWall, makes clear that they work even if there is no menu displayed during their use.

The use of stroke direction to control the direction and type of scrolling on some current mobile devices (such as scrolling vertically, horizontally, or bi-dimensional dragging, depending on the direction of the stroke), is a good example of this, and demonstrates the relevance of radial menus to systems today.

5. Moving Forward: Touch is a Means, Not an End

Touch technologies are going to continue to evolve in terms of what they can sense and how they are used. Among other things, we are going to see ever more integration of the sensing technology with the display [24]. But while the technologies will continue to evolve, what must not get lost along the way is that it is just that, a technology, a means to an end. As I have discussed elsewhere [25], the conceptual model of the user interface is more important than the technology, and by that measure, two interfaces using different technologies (only one of which is touch) may have more in common than two where both *do* use touch.

Furthermore, while touch sensing can bring great value to an interface, even greater value can often be gained when it is used in combination, even simultaneously, with other technologies such as a stylus [26]. Again: everything is best for something and worst for something else.

6. Conclusions

From beginnings such as these have emerged the touch technologies which are having such strong impact today – these and a lot of outstanding work from a number of other researchers, designers and engineers whose work I had to neglect in this brief summary. Within this history lie important lessons and contributions that have the potential to inform our current decisions and thinking about these technologies, and their effective use going forward.

Finally, there is something in this history that can help shed light in our understanding of the nature of innovation. The length of time that it has taken for these technologies to reach "prime time" is the norm, not the exception. Innovation in our industry is almost always characterized by such a "long nose" – with 20+ years being the norm [1][2]. Hence, this paper serves a second function as a reminder that the foundation of the next ten years of innovation were almost certainly planted over the past ten years, and are just waiting there to be cultivated.

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38.2: Direct Display Interaction via Simultaneous Pen + Multi-touch Input

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Abstract

Current developments hint at a rapidly approaching future where simultaneous pen + multi-touch input becomes the gold standard for direct interaction on displays. We are motivated by a desire to extend pen and multi-touch input modalities, including their use in concert, to enable users to take better advantage of each.

1. Introduction

We are witnessing a shift towards displays that unify *input* and *output* on surfaces that sense as well as emit. In such systems the user interacts through *direct manual input*, that is, directly on the display with his hands. By contrast, traditional graphical interfaces employ *indirect manual input* [5] using a relative pointing device (mouse) and a cursor. This shift has led to renewed interest in both touch and pen input. When integrated with a display, both pen and touch are *direct input modalities*, albeit through a physical intermediary in the case of the pen. In what shall become a theme here, this is both a strength and a weakness for the pen— as is the lack of an intermediary for touch. Having two opposing sides makes a coin no less valuable.

Despite rapture with the iPhone (and now iPad), multi-touch is not the whole story. Every modality, including touch, is best for something and worst for something else. The tasks demanded of knowledge workers are rich and highly varied [1,13]. As such one device cannot suit all tasks equally well. Your finger is no more suited for signing a contract, or drawing a sketch on a napkin, than is a pen for turning the page in a book, or holding your place in a manuscript. With the impetus to do *everything* with touch, we must underscore this point. The pen has a role to play as well.

But why the pen? Can't one type faster than one can handwrite? Yes, but only if our metric for creative output is in the cold calculus of words-per-minute. What is it that you wish to write? Are you making high-level comments on a manuscript? If so, composing your thoughts is likely to devolve into minutiae with a keyboard, whereas with a pen, brief annotations in context implicitly emphasize the important points. Likewise, if a pen is a poor choice to compose a business memo, then a keyboard is an equally poor choice to generate a breadth of design sketches [4,16]. That one form of work output is often valued more than the other in professional life is a deeper reflection on our society than it is on the effectiveness of the pen as an input device.

The transition to direct input is manifest in form factors ranging from hand-helds, slates, desktops, table-tops, and wall-mounted devices. The iPhone, Tablet PC, Wacom Cintiq, Microsoft Surface, and Smartboard are, respectively, examples of each. These examples include both pen and touch devices, but seldom does the same system support both. Even more seldom can one use both together [2,18,19], as with a stylus in the preferred hand and touch with the nonpreferred hand *(Fig. 1)*. Here, we pursue pen and touch as complementary rather than competitive inputs.

Our research is based on the premise that pen+touch systems present new challenges and opportunities for the designer. Our hypothesis is that the combination of pen and touch yields a richer design space of natural gestures than multi-touch input alone. When a system does not have to provide coverage of all possible functions with a single input modality, implicitly this leads one to ask where each modality should be used to best advantage, where a particular modality should not be used, and in what cases modalities should perhaps be treated interchangeably. To explore these issues, we prototyped a digital drafting table on the Microsoft Surface, using multi-touch and an IR-emitting pen. We developed an application for note-taking and mark-up that supports the key functions of writing, annotation, selection, copying, arrangement, and aggregation of objects [9,12,18].

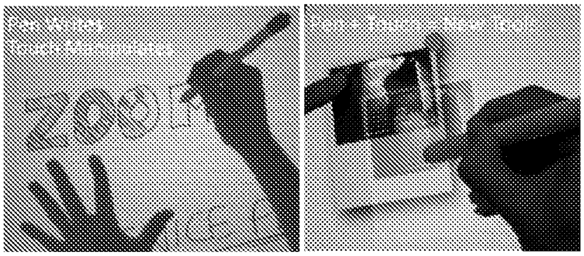

Figure 1. The roles of pen, touch, and multimodal pen+touch.

An earlier generation of devices, such as the Palm Pilot (1996), supported both pen and touch. Users could punch the on-screen calculator with their fingers, or enter Graffiti script with the stylus. Clear lessons were that the best input modality depended on the task, and that this made a significant difference to the user. However, these devices were not pen AND touch, but rather pen exclusive-or (XOR) touch. They sensed only a single point of contact, and could not distinguish touch from pen inputs. Hence we lost an opportunity for meaningful exploration of multimodal interface approaches that combine pen and touch. But a new generation of digitizers is now emerging [7] that can sense multi-touch inputs while simultaneously distinguishing pen from touch.

Why is any of this important and not just a technological quibble? The answer lies not in technology, but in the human mechanism itself, how we are wired, and how our motor, sensory, and cognitive skills have evolved. These are the underpinnings of a natural user experience, not any particular technology or device.

We have multiple fingers for a reason. We do not just point, but we also grasp and manipulate. Furthermore, our nonpreferred hand is not a poor approximation of our preferred hand; rather, it is as skilled at the specialized role that it performs as the preferred hand is at its own role [8]. For a wide class of everyday actions, our hands have evolved to complement one another. People are also predisposed to manipulate physical objects and employ manual tools. Once again, handedness plays an important role. As a simple example, when writing, we hold the pencil in our preferred hand and manipulate the paper with our nonpreferred hand. If we translate this example to a computer screen, we might write on a tablet, electronic whiteboard, or desk with a stylus, and directly manipulate the underlying virtual document, map, or photo with our nonpreferred hand using touch input.

The leap of faith we ask, and believe is justified, is to assume that the richness of such examples that exist in the physical world is matched by analogous transactions in the digital domain. By building on human behaviors and perceptual mechanisms, a

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foundation of physically-grounded interactions enables natural, engaging, and novel non-physical interactions to be designed. It is the implications of this leap that motivate our research, and the purpose of this paper is to share the insights that we have gained.

2. Asymmetric Division of Labor

Let's proceed by pushing a bit harder on our pencil and paper example, by asking you to consider the following question: *Which hand do you write with, your right or your left?* Now, whether you answer "right" or "left," you are wrong. The answer is "Yes!" This is not a trick question. Rather the question is ill-posed. People write with both hands, as demonstrated by Guiard:

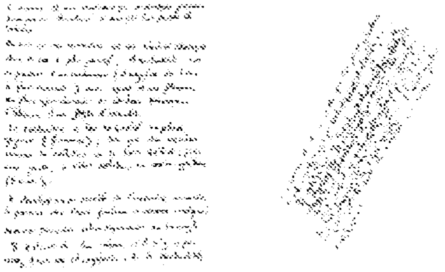

Figure 2. Guiard – transfer paper experiment [8]

What the above figure shows is the result of taking dictation on a sheet of paper. But on the right, we see the impressions left by the pen on a sheet of transfer paper surreptitiously left underneath. That is, it records the movements of the pen relative to the desk. This reveals that the nonpreferred hand sets the *frame of reference* for the action of the preferred hand; the nonpreferred hand repeatedly repositions and reorients the page so as to optimize the working space of the preferred hand [8]. This further implies that the *nonpreferred hand precedes the preferred hand* in its action.

Guiard's key insight was to turn the classic question asked in the study of handedness upside-down. Rather than asking which hand was best for a task– right or left– Guiard observed that most, if not all, manual interactions fundamentally involve both hands, with a differentiation of the roles between the hands. The correct question to ask then becomes: "What is the logic of the division of labor between the preferred and nonpreferred hands?"

Likewise, if in interface design we find ourselves asking which is best– touch or pen– then once again we must recognize an ill-posed question. The question is not which is best, but rather, *What should be the division of labor between pen and touch in interface design?* To begin to answer this question, we must consider the design properties of pen and touch as input modalities.

3. Properties Shared by Pen and Touch

We stated above that every input modality is best for something and worst for something else. Ultimately it is the designer's job to know what to use when, for whom, for what, and why. From a technology standpoint much of this turns on a nuanced understanding of the properties of an input modality. To offer insight into the main issues, the following tableau summarizes interaction properties shared by pen and touch. We do not characterize these properties as "pros" and "cons," as has been attempted elsewhere [2], to accentuate our belief that almost any property of a device can be advantageous in interaction design.

This limited survey shows that pen and touch, while sharing common ground as direct input modalities, also exhibit many important differences, and these again differ substantially from the properties of indirect pointing devices such as the mouse. Indeed, this calls into serious question the commonplace strategy of operating systems to treat all pointing devices as "mice"– that is, interchangeable "virtual devices" [5]. Consider yourself, armed with this tableau, as licensed to fire on the spot anyone in your organization who refers to pen and touch inputs as "the mouse"– or at least to deliver a well-deserved tongue-lashing.

PROPERTY	**PEN**	**TOUCH**
Contacts	**1 point** *A single well-defined point.*	**1-10+ contact regions** *with shape information [6].*
Occlusion	**Small (pen tip)** *But hand still occludes screen.*	**Moderate** *("fat finger" [17]) -* **Large** *(pinch, palm, whole hand)*
Precision	**High** *Tripod grip / lever arm affords precision, writing, sketching.*	**Moderate** *Nominal target width for rapid pointing is ~ 15 mm [17]).*
Hand	**Preferred hand**	**Either hand / Both hands**
Elementary Inputs	**Tap, Drag, Draw Path**	**Tap, Hold, Drag Finger, Pinch**
Inter-mediary	**Mechanical Intermediary** *Takes time to unsheathe the pen. Pen can be forgotten.*	**None: Bare-Handed Input** *Nothing to unsheathe, nothing to lose. No lever arm.*
Acquisition Time	**High** *(first use: unsheathe pen)* **Moderate** *on subsequent uses: pen tucked between fingers.*	**Low** *No mechanical intermediary to acquire.*
Buttons	**Barrel Button** *(some pens)*	**None**
Activation Force	**Non-Zero** *Tip switch/ minimum pressure.*	**Zero (capacitive touch)** *Resistive touch requires force.*
False Positive Inputs	**Palm Rejection** (while writing) *Palm triggers accidental inputs, fingers drag on screen, etc.*	**"Midas Touch Problem"** *Fingers brush screen, finger on screen while holding device, etc.*

Figure 3. Tableau of design properties for pen and touch.

4. Graceful Degradation

We now consider *stationary* versus *mobile* usage contexts. Desktop, table, and wall displays are necessarily stationary, but form-factors such as slates transition between mobile and stationary use. To design a consistent user experience spanning all of these form factors, we seek a conceptual model that supports *graceful degradation* between stationary and mobile usage. For the latter the nonpreferred hand is largely occupied by holding the device itself, whereas for the former we wish to support efficient bimanual interactions that leverage the full potential of human hands, as well as simultaneous pen + touch input.

For example, with physical notebooks we have observed that people deftly *tuck the pen between the fingers of the preferred hand* while flipping pages or grasping scraps of paper [11]. Hence, users can effectively perform multi-touch gestures, such as pinching, while holding the pen tucked between the fingers, and thereby derive significant value even from unimanual interactions that interleave pen and touch inputs as needed. It is important to observe here that a mobile usage model, which *assigns core operations to unimanual touch with the preferred hand*, also serves a stationary usage model that instead assigns these tasks to *touch with the nonpreferred hand.* Bimanual pen + touch gestures can then be articulated in cooperation with the preferred hand to support more efficient interaction as well as advanced gestures.

5. Recognition and Modes

The next distinction we draw is that of *ink* vs. *command* input. The specter of recognition arises as soon as one contemplates marking a virtual sheet of paper. Does drawing a mark leave an ink stroke, is it immediately converted to text, or is it perhaps recognized as a command, such as a gesture to make copies, move objects, or turn the page? Ascribing intent to the motions of an input device is a fundamental problem. People often seem to assume that recognition can overcome this problem. In our view, it does not and will not. But let's back up a moment. Who is it that must do the recognition, and why? Rarely does a user say *"I wish this sheet of paper could understand what is written on it."* Notes in a notebook are for oneself. Annotations on a document are offered as feedback to another person. Significant value arises from experiences where it is a human who recognizes the marks.

Let's say that we do wish to recognize some strokes as gestures. Implicit in this statement is the need to distinguish a *command mode* for gestures as distinct from *ink mode* for leaving marks on the digital paper. Holding a button on the pen, or tapping on a lasso-selection icon, for example, are classic ways of *mode switching* between ink and commands in pen interfaces [15]. One often hears that "modes are bad," but modes are necessary to provide rich interfaces [10] that don't depend on the success of brittle recognition techniques. The key is to rapidly switch modes in a manner that is minimally demanding of the user's cognitive resources. Here, pen+touch has much to offer.

If we assign pen to *ink mode* and touch to *command mode*, the design then *puts the mode switch in the user's hands*. For example, in our prototype the user can jot notes with the pen, but then pinch with two fingers to zoom, swipe across the margin to flip pages, or use a single finger to drag objects such as photos. That is, when considered as unimodal inputs, the logic of the division of labor between pen and touch is that *the pen writes, and touch manipulates*. The mode switch occurs implicitly depending on whether the user interacts with pen or touch. As a desirable side-benefit, this strategy also can dispense with many ancillary interface widgets, such as toolbars stuffed with icons. This leaves more display space for the user's work, while reducing the distraction of secondary controls.

Drawing on all that has preceded, we now see how our approach falls into place along the dimensions that we have identified:

- Pen vs. touch modalities have differentiated effects in the interface. Ink mode is assigned to the pen, while multi-touch articulates commands: the pen writes, and touch manipulates.
- The user can efficiently interleave pen and touch inputs with the preferred hand for mobile, unimanual usage scenarios;
- Designing core tasks for unimanual touch serves mobility while also enabling stationary bimanual interaction that instead assigns these tasks to the nonpreferred hand;
- These benefits are derived while leaving open the possibility of bimanual manipulations with simultaneous pen and touch.

It is in the consideration of this final point, where some of the most novel possibilities may lie, that we now turn our discussion.

6. From Elementary Inputs to Phrases

The preceding interactions that interleave pen and touch may suffice to justify further investment in pen+touch displays. However, we now consider creative ways for interaction designs to leverage *simultaneous pen and multi-touch* interactions to support new capabilities for multimodal bimanual interaction. Let's consider a typical direct-manipulation pen interface for copying an object such as a photo on a digital notebook page [12]. To copy the photo and place it at a desired position, the user must:

1. *Switch the pen from ink mode to command mode;*
2. *Select a photo by tapping or lassoing it with the pen;*
3. *Invoke* Copy *by selecting a command from a context menu associated with the selected photo;*
4. *Invoke the* Paste *command to place the copy onto the page;*
5. *Drag the copy to the desired location on the page;*
6. *Return the pen to ink mode.*

Now, let's contrast this with how our system implements a simultaneous pen+touch gesture for copying a photo. All the steps required by the canonical direct-manipulation approach can be phrased into a single pen+touch bimanual gesture as follows:

1. *Hold photo and drag off a copy with the pen (Fig. 1, right).*

Is this really just one step? Our observations of users suggest that this dedicated pen+touch gesture corresponds closely to the user's mental model of the common use case where one wants to create and place a copy of an object [14]. Hence, the gesture feels like a unitary action to the user, despite invocation of multiple input events on the devices. Consistent with Guiard [8], holding touch precedes the action of the pen, and frames the context of subsequent actions of the pen held in the preferred hand.

Not only does this approach have fewer steps, but by its very nature it encapsulates all the steps into a single gestural phrase. It is syntactically simpler and precludes many types of errors, including mode errors, that can occur with a traditional approach.

Where does the syntactical simplification come from? First, note that holding a finger on the photo *integrates object selection with the transition to gesture mode*. This combines two steps. Once the photo is held with a finger, dragging off a copy with the pen embeds three different pieces of information: the Copy command (verb), what is to be copied (direct object), and where it is to be copied to (indirect object) [14]. Finally, closure is inherent in the means used to introduce the phrase: simply releasing the nonpreferred hand from the screen returns the system to its default state (ink mode), where the pen once again writes. The muscular tension from maintaining touch on the photo is the glue that holds all of these steps together. The muscular tension also has the virtue that it provides continuous proprioceptive feedback to the user that the system is in a temporary state, or mode, where the action of the pen will be interpreted differently.

We focus on the *copy* gesture above, but our system implements many pen+touch gestures. For example, users can employ the pen to *slice* photos by holding a photo with a finger, and then crossing the photo with the pen to define a freeform cut path. Or one may draw a *straightedge* by holding a photo and stroking the pen along its edge. One may even combine these actions into compound phrases, such as by holding an object and then *slicing* along the *straightedge* thus defined (Fig. 4). This illustrates the richness of the vocabulary that users may articulate with our approach.

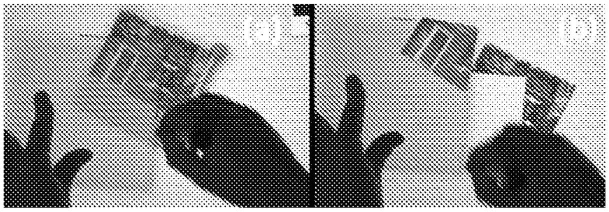

Figure 4. A pen+touch phrase: slice photo along a straightedge.

Earlier in the discussion above we stated a principle: the division of labor between pen and touch for unimodal inputs is that *the pen writes, and touch manipulates*. Now, we can articulate how our system interprets *multimodal* pen + touch inputs: *the combination of pen + touch yields new tools*, such as the aforementioned copy, slice, and straightedge tools. If pen+touch yields new tools, implicitly this means that in some contexts we must violate the original principle: the pen does not always write, nor does touch always manipulate. Our explorations convince us that if a system strictly limits itself so that the pen ONLY writes, and touch ONLY manipulates, this leads to a simple and consistent but artificially crippled system.

By treating multimodal pen + touch inputs differently, our system opens up a design space of new gestures that also have the virtue of leveraging how people naturally use their preferred and nonpreferred hands together. We emphasize the strengths of pen and touch as input modalities, while their use in conjunction allows us to simultaneously sidestep many of their weaknesses.

7. Incidental Contact (Palm Rejection)

Despite the advantages enumerated above, simultaneous pen and touch suffers a serious limitation in that if one rests the palm of the hand on the screen while writing, this represents a "touch" to the computer. The result may be false inputs such as accidentally panning or zooming the page. Our work partially addresses this problem, but to be clear, we do not claim to have solved it.

A simple form of palm rejection goes a long way: one just discards touches with a large contact area. However, large touches start small as the hand moves into contact with the display. Furthermore, the knuckles or side of the hand may precede the pen as it comes into contact with the display. Hence, deciding whether a touch is a true intentional manipulation is not an instantaneous binary decision, but rather is a real-time assessment that varies as the articulation of a combined pen and touch movement plays out over time.

Likewise, in reference to the tableau of Fig. 3, we must recognize that since many touch technologies require zero contact force to trigger an input, false positive inputs will remain an inherent property of multi-touch interaction, including its combination with pen input. As such, clever interaction technique designs that take advantage of this fact [3], as well as more sophisticated "accidental touch" filtering algorithms, will be integral to a rewarding pen+touch user experience. These are fundamental issues that urgently need further research.

8. Conclusion

People have multiple fingers, two hands, and highly developed skills for handling physical objects: we have shown how all of these are defining characteristics of natural pen and touch interaction. Likewise we have shown how our design carefully considers mobile vs. stationary use, ink vs. command input, and the phrasing of elementary actions into higher-level constructs that suit the user's mental model. The map of issues that we have laid out in this manuscript should help the reader to navigate through this thicket of interrelated issues and considerations.

We have advocated a division of labor between pen and touch where the pen writes, touch manipulates, and the combination of pen+touch yields new tools. This articulates how our system interprets unimodal pen, unimodal touch, and multimodal pen + touch inputs, respectively. We have contributed novel pen + touch gestures, while also raising, by way of examples, design issues and questions for the reader to ponder. How should the roles of pen and touch be differentiated (or not) in your own user interface designs? The answers may differ for users of your system, but the design issues we have identified here will arise again and again.

Widespread enthusiasm for multi-touch interfaces belies an oft-overlooked truth: without careful design and a deep understanding of the strengths and weaknesses of touch as an interaction modality, a natural interface a touch-screen does not make. It has to be kept in mind that there is a difference between an *input technology* and either an *interaction technique* or a *conceptual model*-- much less a natural *user experience*. Hence, touch and pen input technologies only lead to a natural experience when lots of hard work meets a thorough and nuanced understanding of these modalities, their strengths and weaknesses, when to use them, and when not to use them. Our goal here has been to impart a sense of these issues, as well as to provide example techniques that illuminate the design space. Our hope is that this can help to spur the further excitement and investment necessary for the emerging area of pen + touch input to flourish as the future of displays.

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