EXHIBIT 3.09

Form PTO-1449 (modified)	Atty. Docket No. 119-0093US	Serial No. 10/840,862
List of Patents and Publications for Applicant's **INFORMATION DISCLOSURE STATEMENT**	Applicant(s): **Steven P. Hotelling; Joshua A. Strickon; Brian Q. Huppi** Title: **MULTIPOINT TOUCHSCREEN**	
(Use several sheets if necessary)	Filing Date: **May 6, 2004**	Group: **2673**

U.S. Patent Documents	Foreign Patent Documents	Other Art
Beginning on Page 1	*See Page 8*	*Beginning on Page 8*

Other Art (Including Author, Title, Date Pertinent Pages, Etc.)

Exam. Init.	Ref. Des.	Citation
	C68	Zimmerman et al., "Applying Electric Field Sensing to Human-Computer Interfaces," In CHI '85 Proceedings, Pages 280-287, 1995
	C69	Application Serial No. 10/774,053 Filed on February 5, 2004
	C70	US Patent Application No. 11/140,529 filed on 5/27/2005 which is a Reissue of 6,570,557 listed above (*see A152*).
	C71	US Patent Application No. 11/381,313 filed on 5/2/2006 entitled "Multipoint Touch Surface Controller".
	C72	US Patent Application No. 11/332,861 filed on 1/13/2006 which is a Reissue of 6,677,932 listed above (*see A160*).
	C73	US Patent Application No. 11/380,109 filed on 4/25/2006 entitled "Keystroke Tactility Arrangement On Smooth Touch Surface."
	C74	US Patent Application No. 11/428,501 filed on 7/3/2006 entitled "Capacitive Sensing Arrangement," which is a Continuation of US 2005/0104867 listed above (*see A177*).
	C75	US Patent Application No. 11/428,503 filed on 07/03/2006 entitled "Touch Surface" which is a Continuation of US 2005/0104867 listed above (*see A177*).
	C76	US Patent Application No. 11/428,506 filed on 07/03/2006 entitled "User Interface Gestures" which is a Continuation of US 2005/0104867 listed above (*see A177*).
	C77	US Patent Application No. 11/428,515 filed on 07/03/2006 entitled "User Interface Gestures" which is a Continuation of US 2005/0104867 listed above (*see A177*).
	C78	US Patent Application No. 11/428,522 filed on 07/03/2006 entitled "Identifying Contacts on a Touch Surface" which is a Continuation of US 2005/0104867 listed above (*see A177*).

EXAMINER:	DATE CONSIDERED:

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Form PTO-1449 (modified)	Atty. Docket No. 119-0093US	Serial No. 10/840,862
List of Patents and Publications for Applicant's **INFORMATION DISCLOSURE STATEMENT**	Applicant(s): **Steven P. Hotelling; Joshua A. Strickon; Brian Q. Huppi** Title: **MULTIPOINT TOUCHSCREEN**	
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U.S. Patent Documents	Foreign Patent Documents	Other Art
Beginning on Page 1	*See Page 8*	*Beginning on Page 8*

Other Art (Including Author, Title, Date Pertinent Pages, Etc.)

Exam. Init.	Ref. Des.	Citation
	C79	US Patent Application No. 11/428,521 filed on 07/03/2006 entitled "Identifying Contacts on a Touch Surface" which is a Continuation of US 2005/0104867 listed above (*see A177*).
	C80	US Patent Application No. 11/426,078 filed on 06/23/2006 entitled "Electronic Device Having Display and Surrounding Touch Sensitive Bezel For User Interface and Control" which is a Continuation-In-Part of 2006/0197753 listed above (*see A181*).
	C81	US Patent Application No. 11/278,080 filed on 03/30/2006 entitled "Force Imaging Input Device and System"
	C82	US Patent Application No. 11/382,402 filed on 05/09/2006 entitled "Force and Location Sensitive Display" which is a Continuation of 11/278,080 listed above (*see C81*).
	C83	International Search Report received in corresponding PCT application number PCT/US2006/008349 dated October ~~20~~ 6, 2006
	C84	
	C85	
	C86	
	C87	
	C88	

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(74) Agent: **MILES, Coe., F.**; Wong, Cabello, Lutsch, Rutherford & Brucculeri LLP, Suite 600, 20333 SH 249, Houston, TX 77070 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

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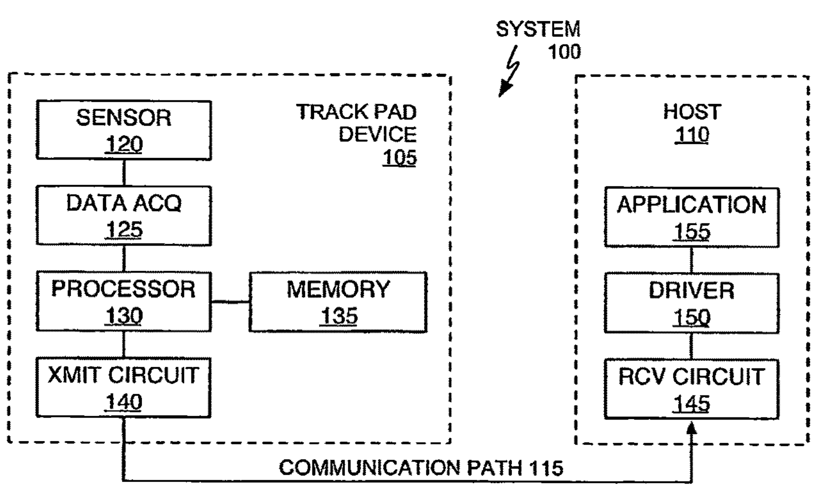
Published:
— *with international search report*

[Continued on next page]

(54) Title: RAW DATA TRACK PAD DEVICE AND SYSTEM



(Prior Art)

(57) Abstract: An input device and system are described that acquires (measures) raw track pad sensor data and transmits this data to a host computer where it is analyzed by an application executing on one or more host computer central processing units. The resulting input processing architecture provides a track pad input device that is both lower in cost to manufacture and more flexible than prior art track pad input devices. Lower costs may be realized by eliminating the prior art's dedicated track pad hardware for processing sensor data (e.g., a processor and associated firmware memory). Increased flexibility may be realized by providing feature set functionality via software that executes on the host computer. In this architecture, track pad functionality may be modified, updated and enhanced through software upgrade procedures.

WO 2006/036607 A1

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2005/033255

A. CLASSIFICATION OF SUBJECT MATTER
G06F3/038 G06F3/044

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97/18547 A (URE, MICHAEL, J) 22 May 1997 (1997-05-22) page 6, line 15 - page 7, line 15; figure 3 page 9, line 18 - page 10, line 23; figure 4 page 11, line 8 - page 12, line 2; figure 6	1-46
A	US 5 825 352 A (BISSET ET AL) 20 October 1998 (1998-10-20) column 5, line 6 - column 8, line 45; figures 1-5 column 11, line 56 - column 15, line 11; figures 7,8	3,7,8, 13,18, 19,21, 27,30-45

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Legrand, J-C

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2005/033255

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/098858 A1 (PERSKI HAIM ET AL) 29 May 2003 (2003-05-29) paragraph '0105! - paragraph '0106!; figure 1 paragraph '0121! - paragraph '0131!; figures 7-11	3,6,8, 12,26,30
A	DE 102 51 296 A1 (TRACHTE, RALF) 19 May 2004 (2004-05-19) paragraph '0002! - paragraph '0004! paragraphs '0009!, '0015!	3,8,30, 35,39, 43,46

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2005/033255

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9718547 A	22-05-1997	EP 0861485 A1	02-09-1998
		JP 2000501526 T	08-02-2000
US 5825352 A	20-10-1998	NONE	
US 2003098858 A1	29-05-2003	AU 2002356407 A1	10-06-2003
		WO 03046882 A1	05-06-2003
		JP 2005510814 T	21-04-2005
DE 10251296 A1	19-05-2004	NONE	

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(74) Agent: URE, Michael, J.; 3000 Sand Hill Road 4-160, Menlo Park, CA 94025 (US).

(81) Designated States: JP, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

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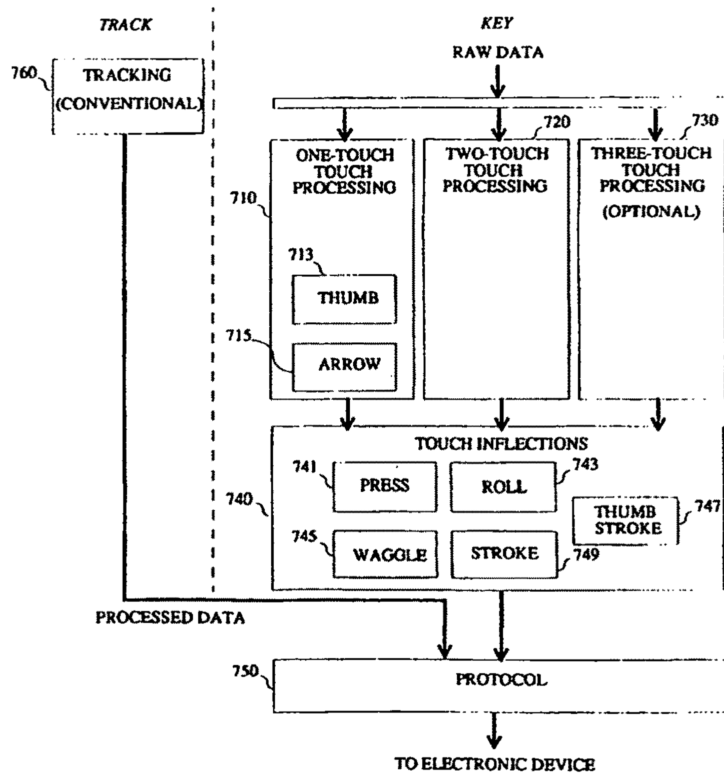
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: MULTI-TOUCH INPUT DEVICE, METHOD AND SYSTEM THAT MINIMIZE THE NEED FOR MEMORIZATION

(57) Abstract

A multi-touch input device, method and system are provided that minimize the need for memorization on the part of the user. Information is input to an electronic device (520, 620) using a pad (510, 610) having a pad surface (300), which pad distinguishes multiple simultaneous touches. Input steps includes: forming marking in relation to the pad suface, the markings including textual elements; a user, with the user's hand, touching one digit of the hand to a first area of the pad surface bearing a marking corresponding to desired textual element that the user desires to input and, at substantially the same time, touching another digit of the hand to a second area of the pad surface identified by the user by its occupying a predetermined position relative to the first area; detecting the first and second areas touched by the user; and inputting the desired textual element.



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MULTI-TOUCH INPUT DEVICE, METHOD AND SYSTEM THAT MINIMIZE THE NEED FOR MEMORIZATION

The present invention relates to input devices for electronic devices such as computers, and more especially to multi-touch input devices.

With the rapid advance of computer and electronic technologies in recent years, the limitations of the computer keyboard as the principal input device for computers and electronic devices have become increasingly apparent. As a result, increasing attention has and will be turned to alternative input devices.

A promising technology for realizing multi-touch input devices is that of capacitive touchpads. Touchpads have been popularized by such companies as Cirque Inc., Apple Computer Inc., Alps Electronics USA Inc., Synaptics Inc., and, most recently, Logitech Inc. Approximately 80% of newly manufactured laptop computers now include a touchpad.

Within the touchpad industry, there exists a trend toward having touchpads do more than just point. Concurrently, others in the computer industry have recognized the need for a new input device, and have further recognized the potential of gesture (hand motions richer in information than the simple finger strokes used in keying) to fill that need. An example of the need for a new input device is provided by the recent emergence of text entry systems using the telephone keypad in which a key bearing multiple letters is pressed, after which 1, 2 or 3 is pressed to specify the first second or third letter on the key. A variant is to press the same key once, twice or three times to designate the first, second or third letter on that key.

Of particular interest in relation to possible new input devices is the second-generation TP2™ touchpad sold by Logitech. With relatively minor firmware modifications, the touchpad may be made to provide raw capacitance measurement data to the outside world. This raw data may be manipulated in various ways to realize enhanced functionality. Also of interest are various display-based touch sensor devices such as that described in U.S. Patent 5,194,862, incorporated herein by reference.

One existing alternative is a prior-art multi-touch input system known as the DatO™ input system. The prior-art input system has the objective of realizing a very compact, touch-sensitive input device for inputting to digital electronic devices command/control information and/or text. Compactness is a key consideration for small portable electronic devices. A DatOPad™ input device (described more fully at www.dato.com) is a touchpad or other device that uses the prior-art DatO input system. The prior-art input system is described in U.S. Patent 5,203,704, incorporated herein by reference. One embodiment of a prior-art input device has a layout 100 as shown in Figure 1. The index finger ("primary indicator") touches within a region 101, pressing one of areas 1-9. The thumb ("first ancillary indicator") touches within a region 103 if applicable. The middle finger ("second ancillary indicator") touches within a region 105 if applicable. For each position 1-9 of the index finger, there are four possible combinations of the "ancillary indicators"--thumb only, middle finger only, both, or neither--for a total of 36 distinct gestures.

Further in accordance with the prior-art input system, a DatOSet™ gesture set is a set of eight groups of 36 gestures, different groups being selected by tapping once or twice with different combinations of the ancillary indicators only, for a total of 288 mode-distinguishable gestures. A gesture set may be thought of as a set of "fonts," for example. Each font may in turn be thought of as four "tic-tac-toe" grids overlaid on top of one another. For purposes of illustration, the tic-tac-toe grids may be drawn side-by-side, whereby an "alpha" font, for example, might be represented as shown in Figure 2. Within each tic-tac-toe grid, each box corresponds to one ofthe primary indicator positions numbered 1-9.

During entry of a word, the index finger remains in contact with the pad, sliding from numbered position to numbered position. A space is indicated by lifting. No details concerning concerning whether or how case or punctuation might be provided for are currently available. In accordance with the prior-art input system, neglecting case and punctuation, the sentence "Gee, this is a great new input device!" would therefore be input as follows, where Xs are used to indicate the required action for each character and MF indicates the middle finger:

TABLE 1.

	Slide to	Press Area	Land thumb	Land MF	Lift thumb	Lift MF	Lift all
g		7					
e	X	5					
e		5					
							X
t		2		X			
h	X	8				X	
i	X	9					
s	X	1		X			
							X
i		9					
s	X	1		X			
							X
a		1					
							X
g		7					
r	X	9	X				
e	X	5			X		
a	X	1					
t	X	2		X			
							X
n		5	X				
e		5			X		
w		5		X			
							X

i		9					
n	X	5	X				
p	X	7					
u	X	3		X	X		
t	X	2					
							X
d		4					
e	X	5					
v	X	4		X			
i	X	9				X	
c	X	3					
e	X	5					

In the prior-art input system, as has been explained, the position of the index finger is important, but only the presence or absence (not position) of the thumb and index finger is important. In one respect, this allows the prior-art input system to be used with a very small device. This assumes, however, that the user has memorized the mapping between gestures and characters/commands, or if not, that the user refers to some external reference such as a display or reference card. To display the mapping would require additional display area. Referencing a reference card is an inconvenience to the user.

Hence, despite the potential of the prior-art input system, there remains a need for an improved input system, particularly an input system that minimizes the need for memorization on the part of the user.

The present invention, generally speaking, provides such a multi-touch input device that minimizes the need for memorization on the part of the user. In accordance with one aspect of the invention, a series of steps are followed to input information to an electronic device using a pad having a pad surface, which pad distinguishes multiple simultaneous touches. The steps include: forming markings in relation to the pad surface, the markings including textual elements; a user, with the user's hand, touching one digit of the hand to a first area of the pad surface bearing a marking corresponding to desired textual element that the user desires to input and, at substantially the same time, touching another digit of the hand to a second area of the pad surface identified by the user by its occupying a predetermined position relative to the first area; detecting the first and second areas touched by the user; and inputting the desired textual element. In accordance with another aspect of the invention, an input device for inputting information to an electronic device includes the following combination of inter-related elements: a touchpad surface formed in relation to a touch sensor array; markings formed in relation to the pad surface, the markings including textual elements; an integrated circuit controller coupled to the touch sensor array for receiving capacitance measurement data from the touch sensor array; and processing means for detecting a particular touch pattern in which a plurality of the areas on the touchpad surface are touched simultaneously and for, in response to the particular touch pattern, signalling for input to the electronic device a textual element corresponding to the particular touch pattern. The markings used in the present input system, preferably and advantageously, are a superset of those of the common telephone keypad, enhancing familiarity and learnability. Other aspects of the invention are set forth in the appended claims.

Figure 1 is a diagram of an exemplary prior art input device;

Figure 2 is a diagram of a gesture group within a potentially larger gesture set of the input device of Figure 1;

Figure 3 is a diagram of the layout of an exemplary input device in accordance with the present invention;

Figure 4 is a simplified schematic representation of a second-generation touchpad that may be used in the present invention;

Figure 5 is a block diagram of a first embodiment of an input device in accordance with the present invention;

Figure 6 is a block diagram of a second embodiment of an input device in accordance with the present invention;

Figure 7 is a more detailed block diagram of the processing means of Figure 5 and Figure 6;

Figure 8 is flow diagram of one-touch processing performed by the processing means of Figure 7;

Figure 9 is flow diagram of two-touch processing performed by the processing means of Figure 7;

Figure 10 is a flow diagram of one-touch touch-inflection processing that follows the processing of Figure 8; and

Figure 11 is a flow diagram of two-touch touch-inflection processing that follows the processing of Figure 9.

The present input device, method, and system is marketed under the tradename TracKey™, referring to the dual capabilities of tracking a pointer finger as in conventional touchpads, and also of keying in information. As distinguished from the prior-art input device, in the present input device, two "indicators," thumb and middle finger (or index finger), are used to form two-touch patterns, or "chords." The position of both indicators is important. Furthermore, characters/commands are screened or displayed on the touch surface, eliminating the need for memorization or an external reference. Preferably, all of the characters/commands are displayed at one time such that there are no separate modes or character groupings.

An exemplary layout of the present input device is shown in Figure 3. As compared to the minimum layout area (primary indicator region only) of about 2.6cm by 2.6cm for the prior art input device, the layout of the present input device occupies about 5.2cm by 3.9cm. However, most or all of the indicia found on a typical computer keyboard are clearly visible.

In the present input system, two-touch chords are formed according to simple conventions. For letters, the middle finger touches the key on which the letter appears. The thumb touches the first, second or third key on the row below, depending on whether the letter is the first, second or third on its key. The bottom row of keys has no letters.

For punctuation and commands, the thumb, instead of touching a key in the row immediately below, touches the first, second or third key in a row once (or twice) removed. The first row is paired with the third row, the second row is paired with the fourth row, and the fourth row is paired with the first row. Hence, in the example of Figure 3, to enter "!," the finger presses 1 and the thumb presses 7; to enter "%," the finger presses 5 and the thumb presses 0; in the case of the bottom row, to enter ")," the *thumb* presses # and the *finger* presses 1.

Numbers are entered using a single touch in the same manner as a touchtone keypad.

Much of the effectiveness of the present input system derives from its use of "touch inflections"--slight touch variations made with minimal additional effort so as to convey additional information. Among the myriad possible touch inflections, the following touch inflections have been found to be particularly useful: "press, pick, roll" and "waggle." These touch inflections are used as follows:

- *"Press a Cap:"* Designate an upper case letter by applying greater-than-normal pressure. Current touchpads are able to sense degrees of pressure. In a similar manner, a punctuation symbol in the second tier on a key is designated by applying an increment of pressure.

- *"Pick a Space:"* When releasing a chord, indicate a subsequent space by causing the finger to stroke the pad slightly in a downward direction. Other similar inflections may be used to indicate common punctuation. These inflection may include, upon release of a chord, stroking the finger slightly upward, stroking the thumb slightly rightward, or stroking the thumb slightly leftward.

- *"Roll a Digraph" (or a Function Key):* Before fully releasing a chord, indicate one of two digraphs beginning with the chorded letter by rolling the finger slightly rightward or leftward. A digraph is a common two-letter combination such as "th." Alternatively, while applying a single touch to a number 0-9, indicate a corresponding function key by rolling the finger slightly rightward. Indicate a function key corresponding to the number plus ten by rolling the finger slightly leftward.

- *"Waggle a Trigraph:"* Before fully releasing a chord, indicate one of two trigraphs beginning with the chorded letter by rolling the finger rightward and back or leftward and back.

Other touch patterns are used to provide for returns and tabs. In one embodiment, a return is entered by landing the thumb only. Because of the different size and shape of a "thumbprint" as compared to a "fingerprint", this gesture may be distinguished from a single finger touch used to enter a number. In a further exemplary embodiment, a tab is indicated similarly, for example by landing the thumb but in addition stroking the thumb slightly to the right.

Where a space commonly follows a particular punctuation mark, the space is preferably input automatically. For convenience, two distinct "." characters are provided for, the traditional period and the now-popular "dot" found in e-mail and Web-page addresses. Preferably, the two are distinguished visually by color, e.g., black for period and red for dot. In the embodiment of Figure 3, the red dot is located central to the pad on the 5 key. The red dot may be slightly raised, if desired, to provide tactile locality information to the user.

Cursor keys may also be provided for. Referring still to Figure 3, note that small arrows appear along each edge of the device, two arrows along each edge. The arrows coincide with the boundary between adjacent keys. When a single finger is touched on one of the arrows, the device recognizes the touch as a cursor key input. Depending on the direction of the arrow, the cursor is spaced upward, downward, rightward or leftward. Alternatively, depending on the current context of a program being run on an electronic device (for example if no text cursor is currently displayed), the cursor key inputs may be interpreted instead as scroll button inputs, causing the display view to scroll upward, downward, rightward or leftward.

The cursor key input are distinguished within the device from two similar types of inputs. The cursor key inputs are like number inputs in that a single touch is used. In the case of number inputs, however, the centroid of the single touch is required to fall squarely within a key corresponding to a number 0-9. Provision is also made for entering "border" textual elements--elements that will often be input by touch inflection--by independent touch gestures. In Figure 3, these border textual elements include space, period, comma and semicolon. Input of border textual elements directly rather than by touch inflection is accomplished by applying a single touch to the border region of the desired textual element--but not to an arrow. In the example of Figure 3 therefore, a space is entered by touching in the bottom-center border region of one of the star key, the 0 key or the pound key. A period is entered by touching in the top-center border region of one of the keys 1, 2 and 3. A comma is entered by touching in the right-center border region; and a semicolon is entered by touching in the left-center border region.

In a preferred embodiment, an input device in accordance with the present invention is realized through a combination of a standard second-generation (G2) touchpad or touchscreen device and custom driver software. An example of a suitable G2 touchpad is the TP2 touchpad of Logitech.

The basic principles of operation of the TP2 touchpad remain the same as its first-generation predecessors and are described in detail in the patent literature, for example U.S. Patent 5,543,588, incorporated herein by reference. However, whereas first-generation touchpads used extensive analog preprocessing, the TP2 touchpad takes a digital approach. Capacitive measurement data from conductors in an orthogonal array are therefore digitized and input directly to a microprocessor or the equivalent. In the case of a particular touchpad having dimensions of approximately 2 in. by 2 in., a total of 42 separate capacitance measurements are taken, digitized and input to a microprocessor. The microprocessor uses firmware to perform various smoothing algorithms, tracking algorithms, etc.

Unlike other G2 touch devices such as the touchscreen described in U.S. Patent 5,194,862, for example, the TP2 touchpad does not form a bit-mapped touch image. Although both X and Y touch coordinate data are provided, these data are not correlated in X and Y. Some touch patterns may therefore potentially be confused. Referring to Figure 4, there is shown a simplified schematic representation of a touch sensor array having a multiplicity of conductors extending in each of the X and Y directions. Superimposed on the touch sensor array are two different two-touch touch patterns, one indicated in solid lines and one indicated in dashed lines. At the edges of the touchpad are shown two waveforms, one representative of capacitance variation across the conductors in the X direction and another representative of capacitance variation across the conductors in the Y direction. Note that the two different touch patterns potentially give identical waveforms.

In the case of the present input system, two-touch chords are formed using a finger and the thumb. The amount and spatial distribution of capacitance presented to the touch sensor array by the thumb is appreciably different than the amount and spatial distribution of capacitance presented to the touch sensor array by the finger. A touch by the thumb is characterized by a pulse waveform having an appreciably larger peak and an appreciably wider base. Hence the two different touch patterns may be distinguished in software/firmware, or in hardware if desired.

Referring now to Figure 5, a block diagram of an input device 500 in accordance with a first embodiment of the invention is shown. A touch sensor array 501 is coupled to a microprocessor 503 or equivalent. Together, the touch sensor array and the microprocessor represent a G2 touchpad or touchscreen 510, i.e., a touchpad or touchscreen in which raw sensor data is digitized and input to a microprocessor where it may be processed or communicated to an external device. In accordance with the present disclosure, the microprocessor 503 is provided with processing means 505, e.g., firmware, for recognizing various touch gestures in accordance with the present input system. The microprocessor 503 is coupled in turn to an electronic device 520 to input information to the electronic device, including positional information, commands and textual information. In the embodiment of Figure 5, the processing means 505 is located accessible to and runs on the microprocessor 503 of the touchpad or touchscreen 510. Results of the processing are then sent to the electronic device 520.

Referring to Figure 6, processing means 625 may instead be accessible to and run on a microprocessor of the electronic device 620. The processing means 625 may, for example, take the form of a custom software driver for the touchpad or touchscreen 610. In this embodiment, the microprocessor 603 sends raw measurement data to the electronic device 620 for processing by the processing means 625. The processing means 625 then signals the results of the processing to other elements within the electronic device 620.

The logical structure of the processing means 505 is shown in greater detail in Figure 7. Touch sensor data is input to various program segments. One segment 710 performs one-touch processing and another segment 720 performs two-touch processing. A third segment 730 may be provided to perform three-touch processing if desired. Results of one-touch and two-touch (and, if desired, three-touch) processing are provided to a touch-inflections segment 740 for further processing. If the outcome of touch-inflection processing is that a valid touch gesture has been recognized, then the touch gesture is communicated to a protocol segment 750 for communication to the electronic device. Processed track data, or pointing data, is also input to the protocol segment 750. The processed track data may be produced by conventional means 760 in accordance with current practice.

In the case of the processing means 625, a protocol layer between the touchpad or touchscreen 610 and the electronic device 620 provides for raw capacitance data and processed tracking data to be input tothe electronic device 630. The raw capacitance data and the tracking data are processed within the electronic device 520, and results of such processing are communicated to further elements within the electronic device 620, e.g., the device operating system.

Referring still to Figure 7, within the one-touch processing and touch-inflection processing segments, various subprocesses have been called out. More particularly, within the one-touch processing segment 710, there is shown a subprocess 713 that detects a thumb touch and a further subprocess 715 that detects a touch on an arrow. Within the touch-inflections processing segment 740, there is shown a subprocess 741 that detects added pressure, subprocesses that detect a roll gesture (743) and a waggle gesture (745), respectively, a subprocess 747 that detects a thumb stroke in particular, and a subprocess 749 that detects other stroke inflections.

Referring to Figure 8, a flow diagram is shown of one-touch touch processing. As described previously, single-touch processing may involve the thumb only or the finger only. If the touch is a thumb touch (801), then the routine checks to see whether the thumb is moved right some minimum amount (803). This checking continues for so long as the thumb touch continues (805). If the thumb was moved right, then a tab is input (807) and the routine returns. If not, then a carriage return is input (809) and the routine returns.

If instead the touch is a finger touch, then the routine checks to see if the centroid of the touch is within a central area of a single key (811). If so, then one of a number 0-9, an asterisk or a pound sign is input per the touched key, except as modified subsequently by the touch inflection routine (813). Processing of the touch inflection routine then follows, beginning at point A.

If the touch is over one of the arrows (815), then a cursor key command is input per the touched arrow (817). The routine then returns.

As seen in block 819, if the touch is in the border region of the touchpad (but not over an arrow), then a border textual element (e.g., space, period, comma, semicolon) is input depending on which border region is touched (821). The routine then returns.

Two-touch touch processing is simple and predictable. As shown in Figure 9, a textual element/command is input per the touched key combination except as modified subsequently by the touch inflection routine. Processing of the touch inflection routine then follows, beginning at point B.

Referring now to Figure 10, the processing of single-touch touch inflections begins at point A. First, the routine checks to see if there is a continuing touch of one of keys 0-9 (1001). If not, the routine returns. If so, the routine checks for a roll. If a roll is detected (1003), then a function key command is input per the touched key and the direction (right or left) of the roll (1005). The routine then returns. Finally, if no roll is detected, then the routine checks for a stroke inflection in which the travel is faster and/or farther than in the case of a roll. If a stroke inflection is detected (1007), then a border textual element (e.g., space, period, comma, semicolon) is input depending on which border region is touched (1009). The routine then returns. If no stroke inflection is detected, then the routine checks again to see if there is a continuing touch, and the routine is repeated as described previously until such time as there is no continuing touch.

Referring now to Figure 11, the processing of double-touch touch inflections begins at point B. First, the routine checks to see if there is a continuing touch (1101). If not, the routine returns. If so, the routine checks for a press, i.e., a touch in which an added increment of pressure is applied. If a press is detected (1103), then an upper case letter or upper tier punctuation mark/command is input per the touched combination (1105), and the routine returns. If no press is detected, next, the routine checks for a roll. If a roll is detected (1107), then the routine checks further whether there is a continuing touch (1109). If not, then a digraph is input per the touched key and the direction (right or left) of the roll (1111). The routine then returns. If there is a continuing touch, then the routine checks for a waggle. If a waggle is detected (1113), then a trigraph is input per the touched key and the initial direction (right or left) of the waggle (1115) and the routine returns. Otherwise, the routine loops back until the touch has been discontinued (1109) or a waggle (1113) has been detected. Finally, if no roll was detected (1107), then the routine checks for a stroke inflection in which the travel is faster and/or farther than in the case of a roll. If a stroke inflection is detected (1117), then a border textual element (e.g., space, period, comma, semicolon) is input depending on which border region is touched (1119). The routine then returns. If no stroke inflection is detected, then the routine checks again to see if there is a continuing touch, and the routine is repeated as described previously until such time as there is no continuing touch.

Insofar as the input of textual information is concerned, the invention has been described principally in terms of inputting textual information based on the English alphabet. The invention is equally applicable to inputting textual information based on "strokes" used in ideographic languages such as Chinese, Japanese, Korean, etc. A second finger (instead of pressure) may be used to advantage to distinguish between different tiers of radicals on a single key. A character would be input by inputting the individual strokes of the character in their usual stroke order.

It will be appreciated by those of ordinary skill in the art that the present invention may be embodiment in other specific forms without departing from the spirit or essential character thereof. The present description is therefore considered in all respects to be illustrative and not restrictive. The scope of the invention is indicated by the appended claims, and all changes which come within the meaning and range of equivalents therefore are intended to be embraced therein.

What is Claimed is:

1. A method of inputting information to an electronic device using a pad having a pad surface, which pad distinguishes multiple simultaneous touches, the method comprising the steps of:

forming markings in relation to the pad surface, the markings including textual elements;

a user, with the user's hand, touching one digit of the hand to a first area of the pad surface bearing a marking corresponding to desired textual element that the user desires to input and, at substantially the same time, touching another digit of the hand to a second area of the pad surface identified by the user by its occupying a predetermined position relative to the first area;

detecting the first and second areas touched by the user; and

inputting the desired textual element.

2. The method of Claim 1, wherein the one digit is one of the index finger and the middle finger, and the other digit is the thumb.

3. The method of Claim 2, wherein the markings delineate a matrix of keys.

4. The method of Claim 3, wherein the pad is a touchpad, the pad surface is a touchpad surface, and the keys are virtual keys.

5. The method of Claim 4, comprising the further steps of:

displaying a cursor on a display of the electronic device;

the user moving one digit of the hand across the touchpad surface;

tracking motion of the one digit across the touchpad surface; and

moving the cursor across the display in accordance with motion of the one digit across the touchpad surface.

6. The method of Claim 3, wherein the matrix comprises a twelve key matrix array in four rows and three columns.

7. The method of Claim 6, wherein respective ones of ten of the keys each bear a marking corresponding to a respective one of the numbers 0 through 9.

8. The method of Claim 7, comprising the further steps of:

the user touching a single one of said ten keys, producing a single touch;

detecting the single touch; and

in response to the single touch, inputting a number.

9. The method of Claim 8, comprising the further steps of:

the user touching with a single digit multiple ones of the virtual keys near a periphery of the touchpad surface, producing a single-digit multiple touch;

detecting the single-digit multiple touch; and

in response to the single-digit multiple touch, inputting one of a cursor-key command and a scroll-bar command.

10. The method of Claim 9, wherein the markings include an up arrow, a down arrow, a right arrow and a left arrow.

11. The method of Claim 7, wherein a plurality of keys each bear markings corresponding to a plural number of distinct textual elements.

12. The method of Claim 11, wherein the plural number of distinct textual elements are letters of an alphabet.

13. The method of Claim 11, wherein the plural number of distinct textual elements are punctuation marks.

14. The method of Claim 11, wherein the plural number of distinct textual elements is greater than two.

15. The method of Claim 1, wherein the textual elements include a period and, distinct from the period, a dot for use in computer addresses.

16. The method of Claim 15, wherein a marking corresponding to the period and a marking corresponding to the dot are distinguished by color.

17. The method of Claim 1, comprising the further steps of:

the user touching only a thumb to the pad such that a thumb touch is applied to the pad surface;

detecting the thumb touch; and

in response to the thumb touch, inputting a desired textual element.

18. The method of Claim 17, wherein the desired textual element is a return.

19. The method of Claim 1, comprising the further steps of:

the user touching only a thumb to the pad;

the user moving the thumb across the pad surface in a direction toward the hand, producing a thumb-stroke gesture;

detecting the thumb-stroke gesture; and

in response to the thumb-stroke gesture, inputting a desired textual element.

20. The method of Claim 19, wherein the desire textual element is a tab.

21. The method of Claim 1, wherein the desired textual element is a letter of an alphabet, comprising the further step of applying an added increment of pressure to the pad in order to designate an upper-case letter.

22. The method of Claim 1, comprising the further steps of:

the user, while withdrawing one digit of the hand from the pad surface, stroking that digit across the pad surface, producing a stroked touch inflection;

detecting the stroked touch inflection; and

in response to the stroked touch inflection, inputting a further desired textual element.

23. The method of Claim 1, comprising the further steps of:

the user touch at least one digit to the pad surface and, prior to removing the digit from the pad surface, rolling the digit in a first direction.

24. The method of Claim 23, wherein rolling the digit in a first direction produces a roll gesture, the method comprising the further steps of:

detecting the roll gesture; and

in response to the roll gesture, inputting a plurality of textual elements.

25. The method of Claim 23, wherein rolling the digit in a first direction produces a roll gesture, the method comprising the further steps of:

detecting the roll gesture; and

in response to the roll gesture, inputting a function key command.

26. The method of Claim 25, wherein respective ones of ten of the keys each bear a marking corresponding to a respective one of the numbers 0 through 9.

27. The method of Claim 26, wherein the user touches a single one of said tens keys, and wherein the function key command is identified with a number to which a marking on the single one of the ten keys corresponds.

28. The method of Claim 23, comprising the further steps of:

prior to removing the digit from the pad surface, rolling the digit again in a second direction to produce a waggle gesture.

29. The method of Claim 28, comprising the further steps of:

detecting the waggle gesture; and

in response to the waggle gesture, inputting at least three textual elements.

30. An input device for inputting information to an electronic device, the input device comprising:

a touchpad surface formed in relation to a touch sensor array;

markings formed in relation to the pad surface, the markings including textual elements;

an integrated circuit controller coupled to the touch sensor array for receiving capacitance measurement data from the touch sensor array; and processing means for detecting a particular touch pattern in which a plurality of the areas on the touchpad surface are touched simultaneously and for, in response to the particular touch pattern, signalling for input to the electronic device a textual element corresponding to the particular touch pattern.

31. The apparatus of Claim 30, wherein said means for processing further comprises means for tracking motion of a touch across the touchpad surface and for signalling for input to the electronic device positional information.

32. The apparatus of Claim 30, wherein the markings delineate a matrix of virtual keys.

33. The apparatus of Claim 32, wherein the matrix comprises a twelve key matrix array in four rows and three columns.

34. The apparatus of Claim 33, wherein respective ones of ten of the keys each bear a marking corresponding to a respective one of the numbers 0 through 9.

35. The apparatus of Claim 34, wherein said means for processing further comprises means for detecting a single touch of one of said ten keys and, in response to the single touch, signalling a number for input to the electronic device.

36. The apparatus of Claim 35, wherein said means for processing further comprises means for detecting a single-digit multiple-key touch and for signalling for input to the electronic device one of a cursor-key command and a scroll-bar command.

37. The apparatus of Claim 36, wherein the markings include an up arrow, a down arrow, a right arrow and a left arrow.

38. The apparatus of Claim 33, wherein a plurality of virtual keys each bear markings corresponding to a plural number of distinct textual elements.

39. The apparatus of Claim 38, wherein the plural number of distinct textual elements are letters of an alphabet.

40. The apparatus of Claim 38, wherein the plural number of distinct textual elements are punctuation marks.

41. The apparatus of Claim 38, wherein the plural number of distinct textual elements is greater than two.

42. The apparatus of Claim 30, wherein the textual elements include a period and, distinct from the period, a dot for use in computer addresses.

43. The apparatus of Claim 42, wherein a marking corresponding to the period and a marking corresponding to the dot are distinguished by color.

44. The apparatus of Claim 30, wherein said means for processing further comprises means for detecting a thumb touch and for, in response to the thumb touch, signalling a first textual element for input to the electronic device.

45. The apparatus of Claim 44, wherein the first textual element is a return.

46. The apparatus of Claim 30, wherein said means for processing further comprises means for detecting a thumb-stroke gesture and for, in response to the thumb-stroke gesture, signalling a second textual element.

47. The apparatus of Claim 46, wherein the second textual element is a tab.

48. The apparatus of Claim 30, wherein said processing means further comprises means for detecting an added increment of pressure applied to the pad and for signalling an upper-case letter for input to the electronic device.

49. The apparatus of Claim 30, wherein said processing means further comprises means for detecting a stroked touch inflection and for, in response to the stroked touch inflection, signalling a textual element for input to the electronic device.

50. The apparatus of Claim 30, wherein said processing means further comprises means for detecting a roll gesture and for, in response to the roll gesture, signalling a plurality of textual elements for input to the electronic device.

51. The apparatus of Claim 30, wherein said processing means further comprises means for detecting a roll gesture and for, in response to the

roll gesture, signalling a function key command for input to the electronic device.

52. The apparatus of Claim 51, wherein respective ones of ten of the keys each bear a marking corresponding to a respective one of the numbers 0 through 9.

53. The method of Claim 52, wherein the roll gesture is characterized by a single touch of one of said tens keys, and wherein the function key command is identified with a number to which a marking on the single one of the ten keys corresponds.

54. The apparatus of Claim 30, wherein said processing means further comprises means for detecting a waggle gesture and for, in response to the waggle gesture, signalling a plurality of at least three textual elements for input to the electronic device.

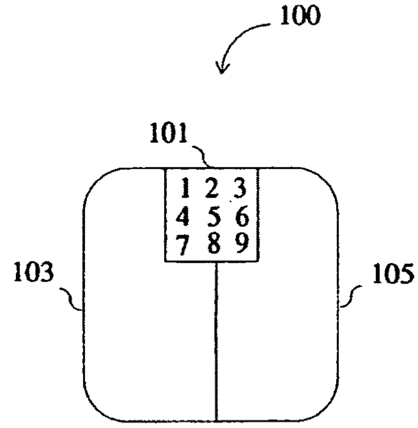

FIGURE 1

(PRIOR ART)

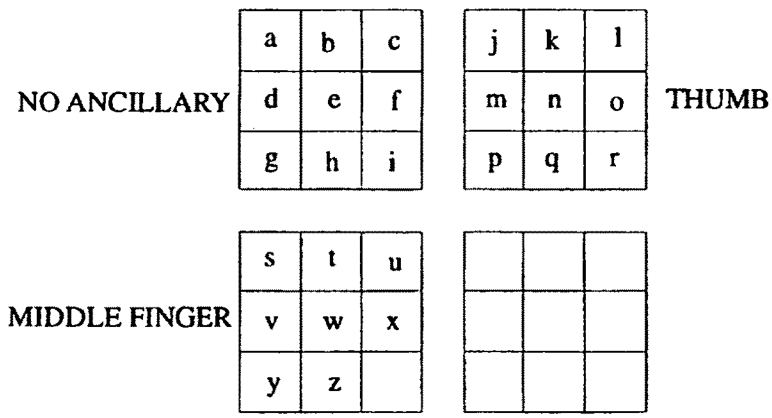

FIGURE 2

(PRIOR ART)

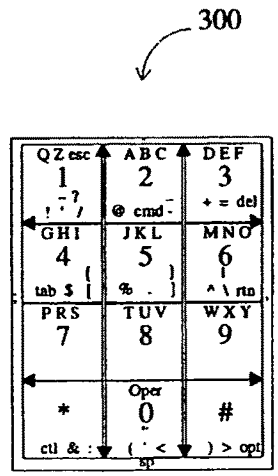

FIGURE 3

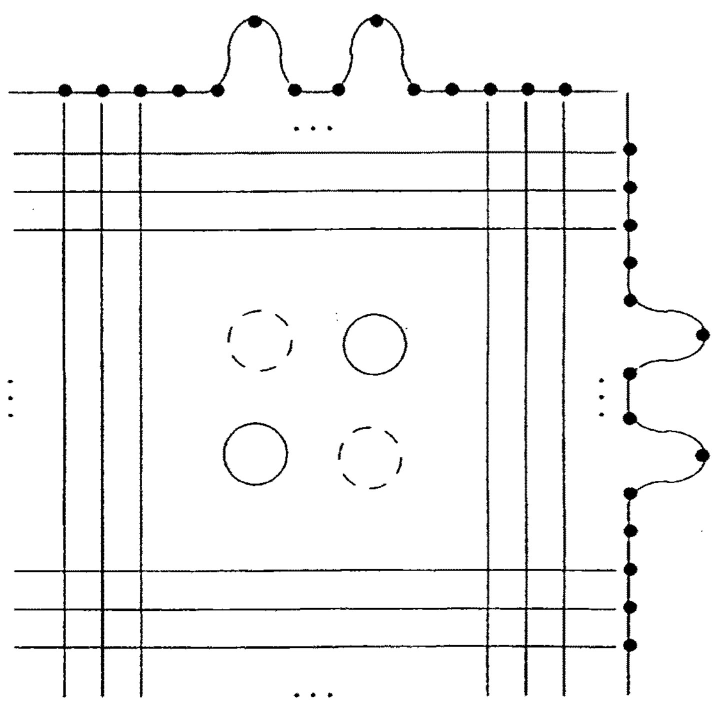

FIGURE 4

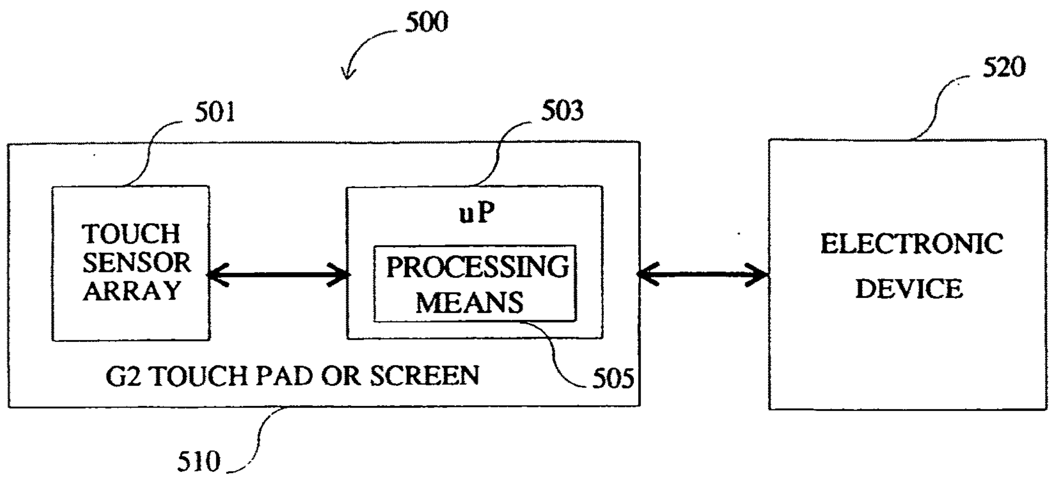

FIGURE 5

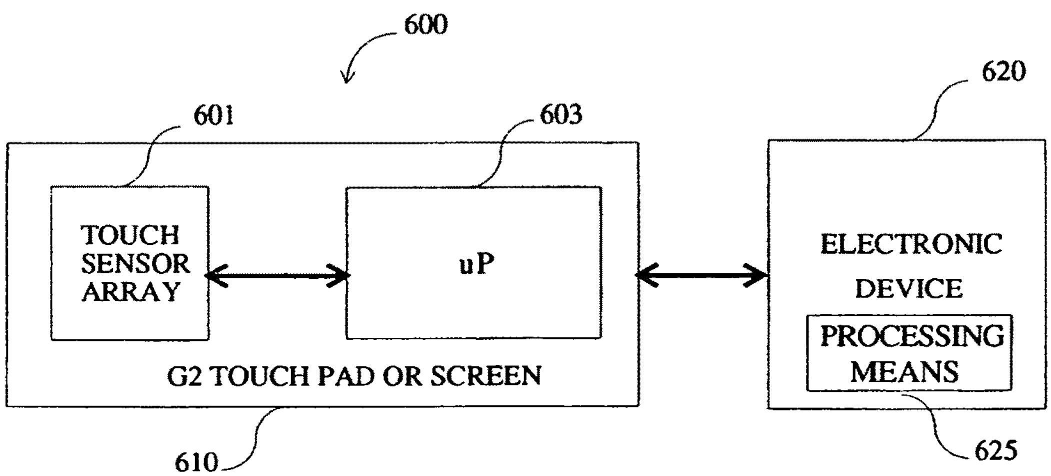

FIGURE 6

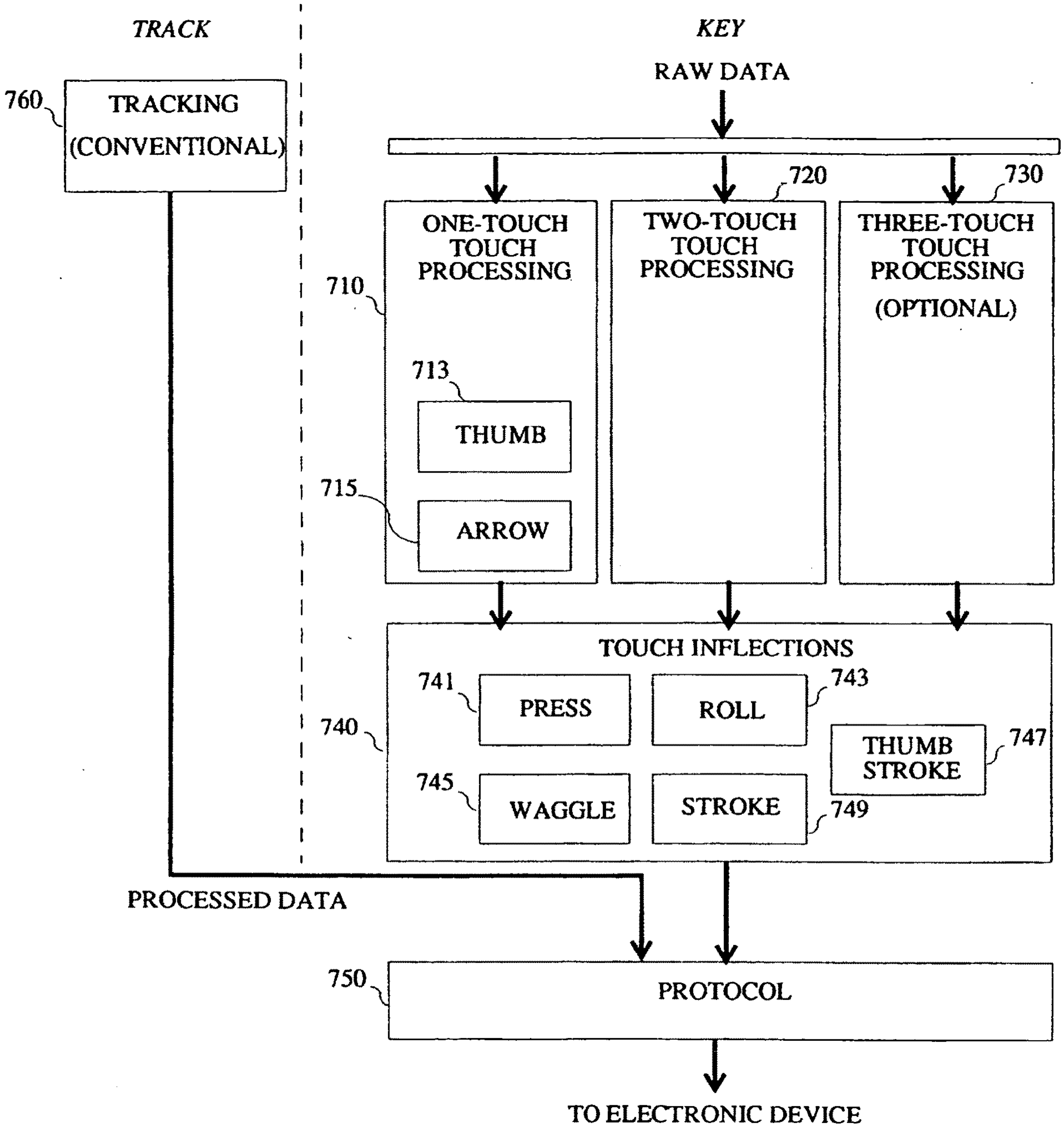
TRACK
KEY
RAW DATA
760
TRACKING
(CONVENTIONAL)
710
ONE-TOUCH
TOUCH
PROCESSING
720
TWO-TOUCH
TOUCH
PROCESSING
730
THREE-TOUCH
TOUCH
PROCESSING
(OPTIONAL)
713
THUMB
715
ARROW
TOUCH INFLECTIONS
740
741
PRESS
743
ROLL
747
THUMB
STROKE
745
WAGGLE
STROKE
749
PROCESSED DATA
750
PROTOCOL
TO ELECTRONIC DEVICE

FIGURE 7

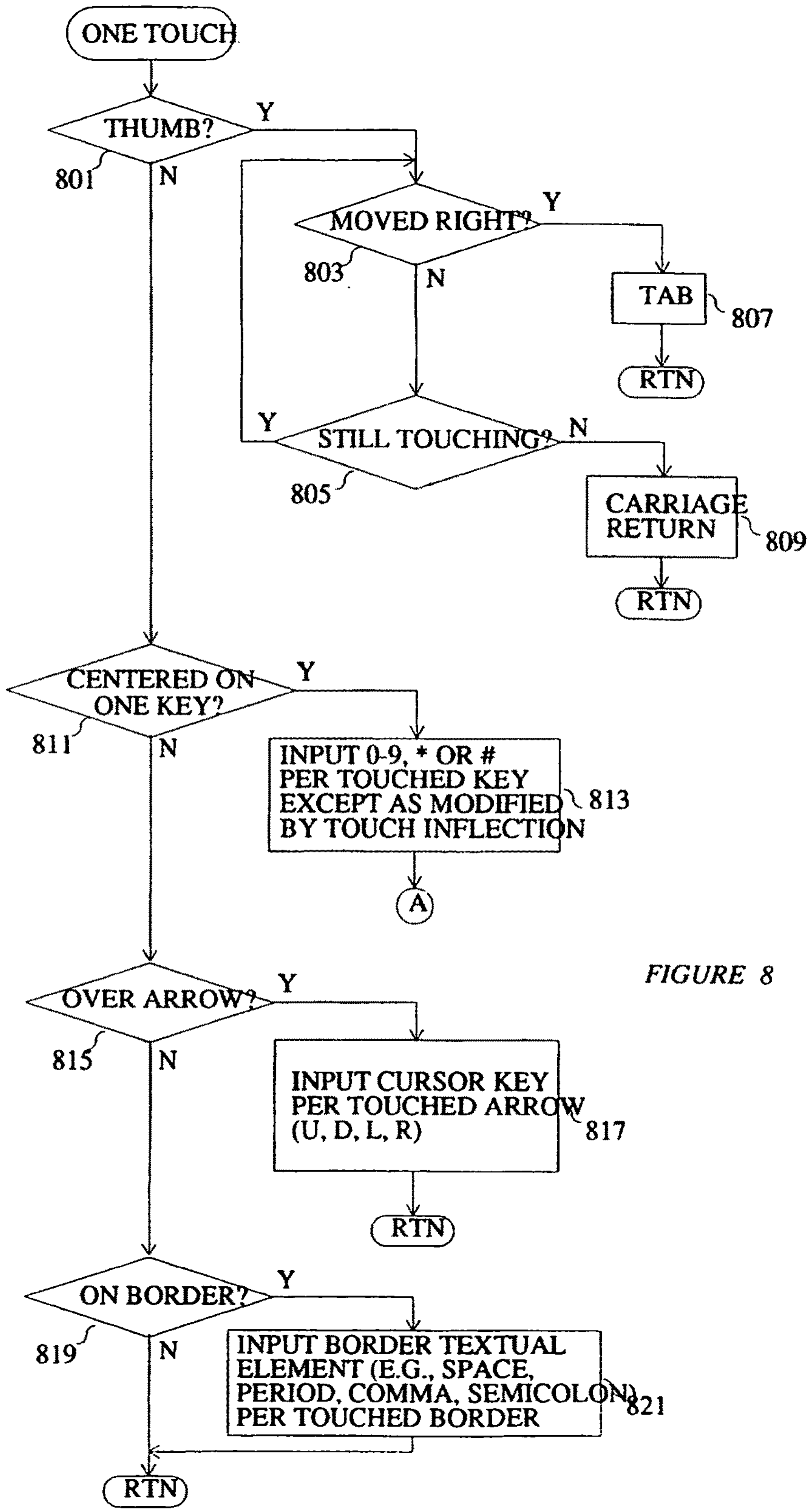
ONE TOUCH
THUMB?
Y
801
N
MOVED RIGHT?
Y
803
N
TAB
807
RTN
Y
STILL TOUCHING?
N
805
CARRIAGE RETURN
809
RTN
CENTERED ON ONE KEY?
Y
811
N
INPUT 0-9, * OR # PER TOUCHED KEY EXCEPT AS MODIFIED BY TOUCH INFLECTION
813
A
OVER ARROW?
Y
815
N
INPUT CURSOR KEY PER TOUCHED ARROW (U, D, L, R)
817
RTN
ON BORDER?
Y
819
N
INPUT BORDER TEXTUAL ELEMENT (E.G., SPACE, PERIOD, COMMA, SEMICOLON) PER TOUCHED BORDER
821
RTN

FIGURE 8

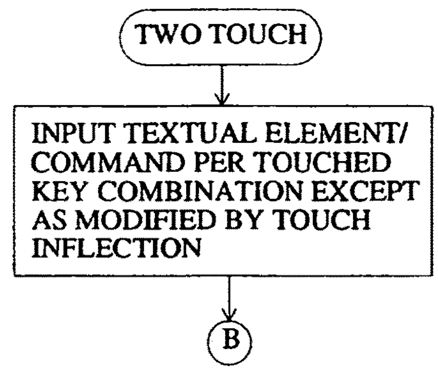

FIGURE 9

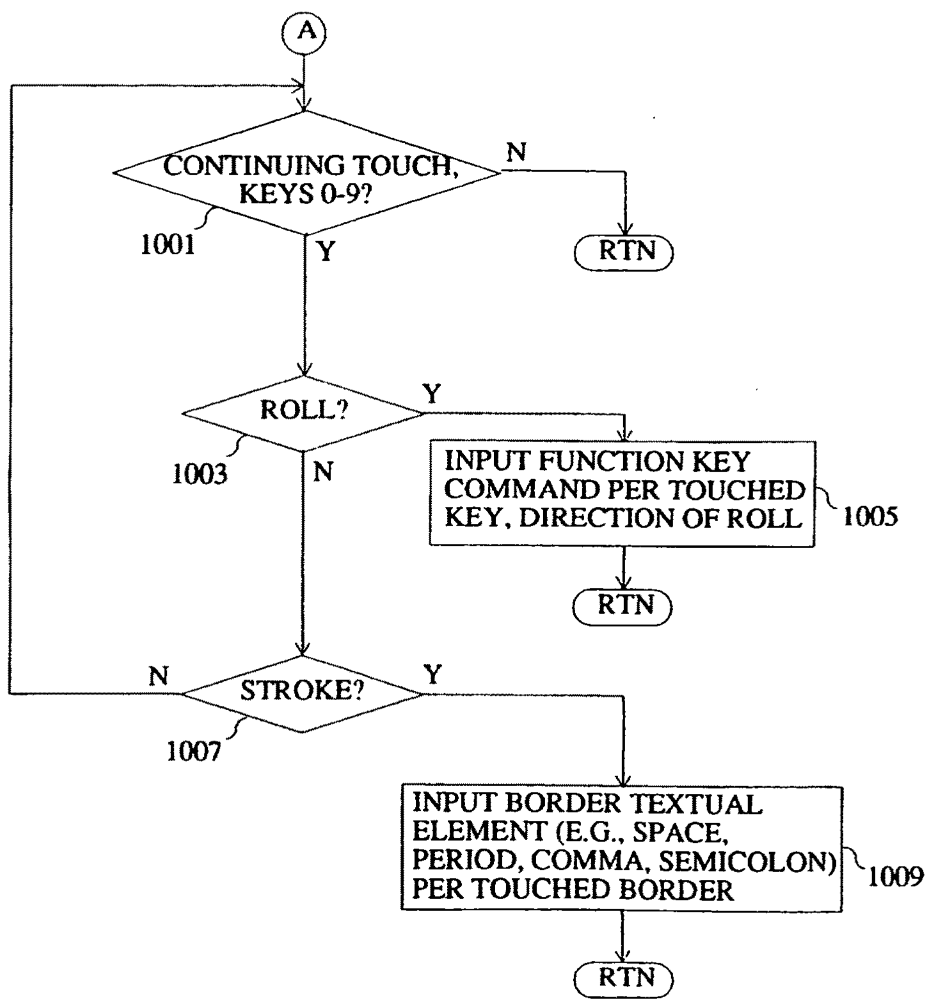

FIGURE 10

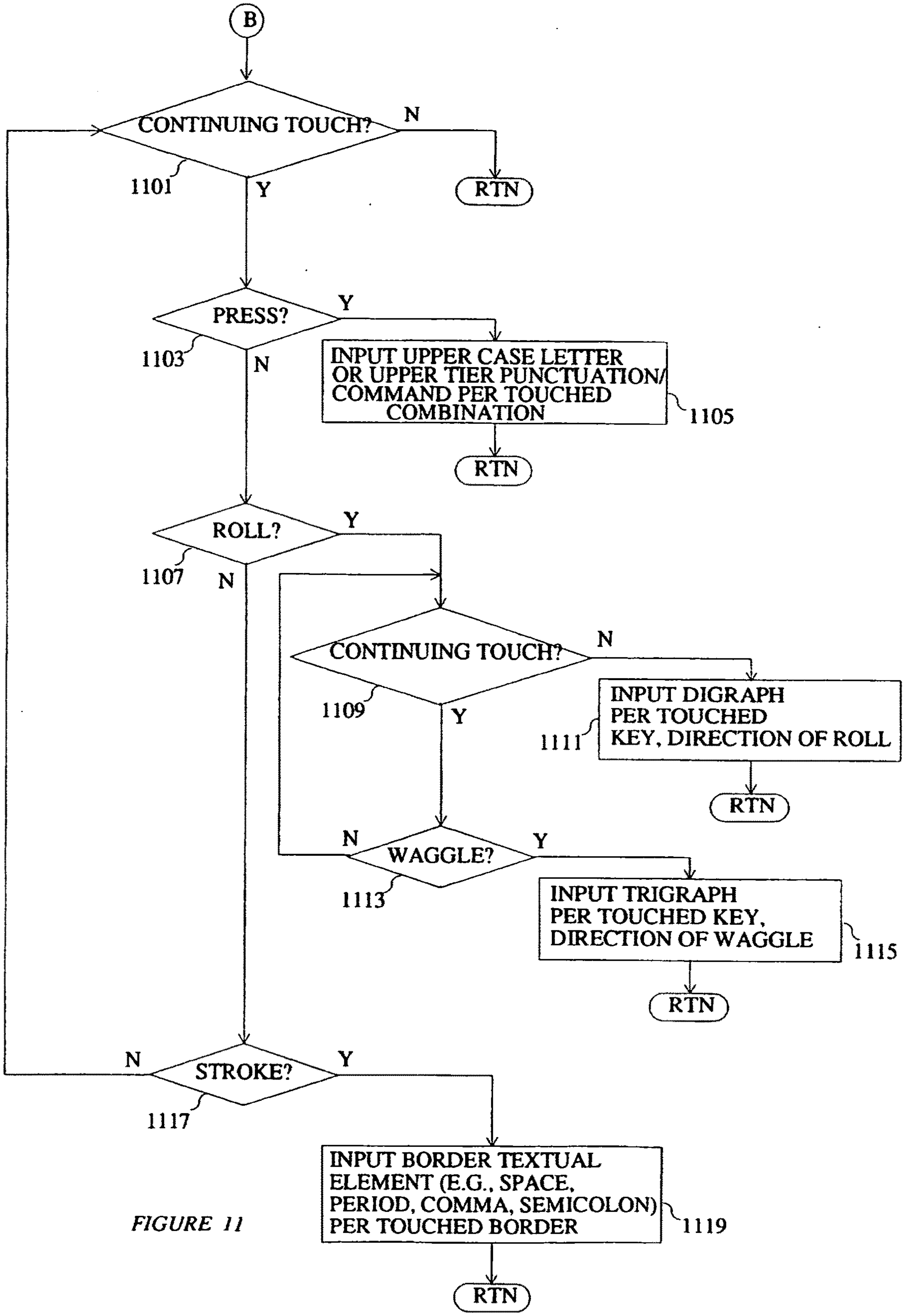
B
CONTINUING TOUCH?
N
1101
Y
RTN
PRESS?
Y
1103
N
INPUT UPPER CASE LETTER OR UPPER TIER PUNCTUATION/ COMMAND PER TOUCHED COMBINATION
1105
RTN
ROLL?
Y
1107
N
CONTINUING TOUCH?
N
1109
Y
INPUT DIGRAPH PER TOUCHED KEY, DIRECTION OF ROLL
1111
RTN
N
WAGGLE?
Y
1113
INPUT TRIGRAPH PER TOUCHED KEY, DIRECTION OF WAGGLE
1115
RTN
N
STROKE?
Y
1117
INPUT BORDER TEXTUAL ELEMENT (E.G., SPACE, PERIOD, COMMA, SEMICOLON) PER TOUCHED BORDER
1119
RTN

FIGURE 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/18517

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :GO9G 5/00
US CL :345/173
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 345/173, 179, 168, 169, 171, 172, 145, 146, 157

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,128,672 A (KAEHLER) 07 July 1992, abstract, Figs. 1-6.	1-54
Y	US 5,087,910 A (GUYOT-SIONNEST) 11 February 1992, col. 7, lines 13-28.	1-54
Y	US 4,914,624 A (DUNTHORN) 03 April 1990, abstract, Figs. 1-2.	1-54

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 FEBRUARY 1997	19 MAR 1997

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	XIAO WU
Facsimile No. (703) 305-3230	Telephone No. (703) 305-4721

Form PCT/ISA/210 (second sheet)(July 1992)*

PCT

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(21) International Application Number: PCT/US96/20664

(22) International Filing Date: 23 December 1996 (23.12.96)

(30) Priority Data:
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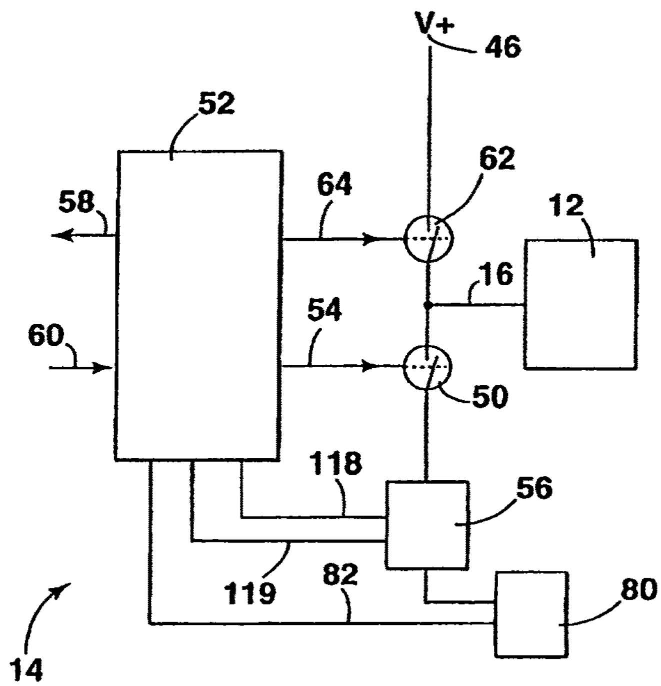
(54) Title: CHARGE TRANSFER CAPACITANCE SENSOR

(57) Abstract

A capacitive field sensor (14) employs a single coupling plate (12) to detect change in capacitance to ground. The apparatus comprises a circuit (46, 62) for charging a sensing electrode (12) and a switching element (50) to remove charge from the sensing electrode (12) and to transfer it to a charge detection circuit (56). The time intervals employed for the charging and discharging steps can vary widely and can be selected to be less than a characteristic conduction time associated with a shunting conductor, such as a sheet of water. Thus, the sensor (14) can detect the presence of an object or user near the plate without being subject to measurement artifacts arising from standing water such as may occur in a controller for a water basin.



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TITLE OF THE INVENTION: Charge Transfer Capacitance Sensor

TECHNICAL FIELD:

The present invention deals with capacitive field sensors employing a single coupling plate to emit and detect a field disturbance.

BACKGROUND ART

Many methods of measuring capacitance are known to the art. Of relevance to the present disclosure are those inferring the value of a capacitor under test from measurements of the time required to charge or discharge the circuit element under controlled conditions. Notable among these are:

US 5,329,239, wherein Kindermann et al. disclose a microprocessor controlled multimeter charging an unknown capacitance from a constant voltage source when a first switch is closed and discharging it through a selected resistor when a second switch is closed.

US 5,294,889, wherein Heep et al. disclose a measurement circuit using a constant current source to discharge the unknown capacitor.

US 5,159,276, wherein Reddy describes a circuit for detecting leaks by measuring the capacitance of a permeable coaxial cable with a switched constant current source DC coupled to the cable

Capacitive field sensors are commonly used in a wide variety of applications, such as security systems, door safety systems, human interfaces such as keypads, material handling controls, and the like. Such sensors can be divided into three broad classes: 1) those that emit and sense an electric field using separate coupling plates; and 2) those that employ a single coupling plate to emit and detect field disturbance; and 3) those that passively detect electric fields generated by, or present on, or ambient fields disturbed by, the object sensed.

Many existing sensors employing a single coupling plate employ AC field techniques, and connect the coupling plate to an AC source, such as an RF signal source. Fluctuations of the signal level at the coupling plate are monitored to detect the proximity of an object that absorbs the electric field. Various known sensors of this sort include:

- A sensor employing a capacitive bridge circuit to detect the signal fluctuations. In this case the bridge is used to suppress background capacitance and to allow for high gain amplification of the relatively small changes in the signals on the plate.
- A sensor placing the plate in a tuned circuit, so that changes in plate capacitance caused by moving proximate objects slightly alters the tuned circuit's resonant frequency, which may be monitored by various means.
- A sensor in which the plate is connected to an RC network, a time constant of which changes responsive to a change in capacitance on the plate. A variation of this type of sensor uses a fixed current source to charge the plate; and determines capacitance changes by measuring the changes in the charging rate from a reference slope. Commonly the rate is determined with the help of a voltage comparator and a

reference voltage.

It is well known that sinusoidal AC signals are not a prerequisite for such sensors, and that other wave shapes can also be conveniently used, e.g. square waves or pulses, with the same essential effect.

Problems with existing designs include:

- emission of radio frequency interference -- particularly with either pulsed or CW RF designs;
- susceptibility to external non-capacitive coupling, such as purely resistive paths from the plate to earth, which disturb the measurement process;
- high susceptibility to moisture in the region of the plate;
- inability to monitor small changes in the capacitance of large objects, or of objects providing large background capacitances;
- inability to automatically adapt to variations in the initial plate capacitance, especially if the overall possible range of such capacitance is large; and
- inability to tolerate adjacent sensor crosstalk.

Of the above cited problems, that of susceptibility to external non-capacitive coupling deserves special mention. While resistive paths to earth can sometimes be overcome by appropriate insulation or by a change in physical configuration of the sensing environment, in many instances this is simply not possible. For example, in controlling a water faucet with a sensor using the entire faucet as the plate, ambient water will cause an unpredictable and time-varying capacitance to earth. Because of water splashing around the base of the spout and because of conduction through the water in the pipe, this varying impedance will be present even if the pipe is plastic. In any prior art sensor such conduction paths -- even though non-capacitive in nature -- will effect the sensing circuit adversely. For example, if the sensor employs an RC circuit or variation thereof, the stray conduction path will rob the plate of charging current and will thus alter its apparent time constant. In tuned detection or bridge circuits, capacitive coupling to the plate will in and of itself become a fluctuating reactance in the presence of an external fluctuating conductance path, and will render the circuit worthless. Moreover, it is clear that there is no value of coupling capacitance for which this is not so.

The shortcomings of prior art capacitive sensors have led many designers of proximity control systems that need to function in the presence of water, or other weakly conducting liquid media, to employ sensors projecting an energetic beam into a sensing zone and measuring the reflection of that beam as an indicator of a user's presence. Such systems have employed visible and near-infrared light, microwaves, and ultrasonic acoustic projected beams. Notable among such prior art in the area of controlling water-supply equipment are:

- US 5,033,508, US 4,972,070 and US 4,872,485, wherein Laverty teaches various aspects of infra-red control systems for the control of a water fountain;
- US 5,025,516, wherein Wilson teaches a convergent optical beam arrangement for the control of a wash-basin water fountain.
- US Patent Application Serial Number 08/266,814, filed 12/30/94, wherein the applicant in the present case teaches an adaptive infrared faucet controller responsive to both proximity and motion. The teachings of US Patent Application Serial Number 08/266,814 are herein incorporated by reference.

DISCLOSURE OF THE INVENTION:

The present invention cures the above defects in the prior sensing art, and provides a sensor operable with a wide variety of sensing plate configurations. Such a sensor can be connected to a wide variety of objects and is not limited to the use of a prefabricated plate. Such objects might include door mounted safety sensing strips, safety zone floor mats and strips, automatic faucets and water fountains, valuable fixed objects that are to be protected from theft or tampering, moving or flowing industrial materials, commodities having a variable level within a hopper or tank, etc.

The present invention employs the measurement of electric charge imposed upon, and shortly thereafter removed from, a sensing electrode (conventionally referred to as a "plate"). The sensing electrode may be an actual metal plate having a predetermined size and shape, or may be an entire conductive object, such as a faucet or a metal door. The time interval employed for the charge / discharge cycle can vary according to specific requirements. For example, it is known from experiment that sensing intervals of less than several hundred nanoseconds (ns) or less act to suppress the detection of localized amounts of moisture or standing water (the pulse width selected for this purpose will vary with the environment of the measurement, and is often less than one hundred nanoseconds). Larger measurement intervals will increasingly make such a sensor 'reach through' moisture and standing water (or 'through' internal water content in an object sensed), to detect what appears to be higher and higher levels of apparent capacitance. A 100 nsec duration is approximately optimal when sensing a user's hand proximate the spout of a wash-basin that may have water standing thereabout. Other objects may require different durations.

Apparatus of the invention comprises a circuit for charging a sensing electrode, and a switching element acting to remove charge from the sensing electrode and to transfer it to a charge detection circuit. Although the charging circuit may be as simple as a resistor or other type of current source, a better implementation uses a second switching element to charge the plate to a known voltage.

A preferred embodiment of the invention comprises a holding capacitor to measure the charge drained from the plate. In this embodiment, a microprocessor can collect a number of readings and perform signal averaging and nonlinear filtering to effectively compensate for both impulse and stochastic noise, thereby allowing an increased effective gain of the sensor.

A charge subtractor is optionally employed to subtract charge from the holding capacitor, thereby increasing dynamic range and canceling offset effects that may be introduced from charge injection by the switch(es) or from background levels of plate capacitance and the wiring thereto.

In a preferred embodiment, algorithms stored in a computer memory are employed to provide for automatic calibration of the sensor, to track circuit drift, to track environmental changes, and to provide output processing as may be required for a particular application.

It is an object of the invention to provide capacitive sensing means for the control of a water delivery valve, the sensing means acting, when the valve is closed, to determine when the valve should be opened responsive to a user's approach, the sensing means acting, when the valve is open, to determine the duration during which the valve should be held open responsive to the user's continued presence proximate the valve.

It is an additional object of the invention to provide capacitive sensing means for the control of a water delivery valve, the sensing means comprising a capacitor plate DC-coupled to a charge measurement circuit.

It is yet a further object of the invention to provide capacitive sensing means for the control of a water delivery valve, the sensing means comprising a pulsed source of charging or discharging current, the pulse source supplying pulses of a different duration (or pulsewidth) when the valve is opened than when the valve is closed.

It is a still further object of the invention to provide capacitive sensing means for the control of a water delivery valve, the sensing means insensitive to the presence of standing water within a supply pipe or external to, but adjacent, the piping through which the water is delivered.

BRIEF DESCRIPTION OF DRAWINGS:

Figure 1 is an electrical schematic representation of a sensing plate surrounded by a water film providing an electrically conducting path from the plate to earth.

Figure 2 is a simplified electrical schematic view of the water film of Fig. 1.

Figure 3 shows a curve characterizing the temporal response characteristics of a shunting conductor of interest.

Figure. 4 is a block diagram of a sensor having a single switch or switching element, a plate-charging circuit (which may be a resistor or other current source).

Figure 5 is a block diagram of a circuit similar to that of Fig. 3, but having a second switch to provide charging. An optional charge subtraction circuit is shown in phantom in Fig. 4.

Figure 6 is a timing diagram showing control of the two switches of Fig. 5.

Figure 7 is a detailed circuit schematic of a sensor conforming to Fig. 45

Figure 8 is a partially cut away elevational view of a drinking fountain controlled by apparatus of the invention.

Figure 9 is a cut-away view of a sensor of the invention controlling water flow through a wash-basin faucet.

Figure 10 is a schematic block diagram of an embodiment of the sensor of the invention that includes circuits to allow the modification of pulse durations, which is useful in the control of water-basin faucets.

MODES FOR CARRYING OUT THE INVENTION:

Turning initially to Fig. 1 , one finds an electrical schematic of a sensing system of the invention 10, wherein a sensing plate 12 connected to a sensor circuit 14 by a wire or cable 16 is surrounded by a conductive water film 18 shown with a dash-dot line. The water film 18 is shown in contact with both a spout 21 of a water faucet and another metallic object 20 connected to an earth ground 22. That is, regardless of the physical details of the conduction processes, the sensing plate 12 is connected to a shunting conductor 18 having time-dependent conduction properties to be discussed in greater detail hereinafter. Also shown is an object 24 (which may be a person intending to use the spout 21), the object 24 approaching the plate 12 along a path indicated with the arrow 26 in Fig. 1. The plate 12, the water film 18, and the metal object 20 may be atop a nonconductive surface 28, depicted with a dashed line in Fig. 1. The schematic of Fig. 1 is representative of a water faucet being used as a bulk proximity sensor, wherein the pipe connecting the spout 21 to the water supply comprises a short piece of plastic tubing for electrical isolation, and where water splashes have accumulated as a film 18 disposed on a counter-top 28 around the base of the spout 21.

A slightly different model of the electrical conduction and reactance paths around plate 12 and object 24 of Fig. 1 is shown in Fig. 2. As is well known in the electrochemical arts, a body 18 of water shunting the plate 12 to ground can be modeled as a two dimensional array of infinite series of resistors 30 and capacitors 32 connected between the plate 12 and earth 22. As shown in Fig. 2, the appropriate sensing model also includes a second conductive path 33 connecting the sensing plate 12 to earth 22. This second path comprises a parallel combination of a resistance 34 and a capacitance to earth 36. For modeling purposes, the infinite series can be conveniently reduced to an approximation shown in Fig. 2, where a finite series of resistors and capacitors 30 and 32 is shown. It should not be assumed from the numbering scheme that all resistors 30 or capacitors 32 are equal in value; they assuredly are not, and indeed vary considerably. The capacitance between the plate 12 and the object 24 (i.e., the electrical quantity to be detected by the sensor circuit 14) is represented in Fig. 2 with the reference numeral 40. It is also noted that the object 24 has a capacitance to earth 42, at least part of which is free space capacitance.

From this model it can be easily seen that there is a strong frequency dependence of the effective total capacitance measurable on plate 12. If an ac voltage is applied to the plate 12, at very low frequencies, the capacitors 32 can all charge and discharge fully on each sinusoidal cycle with little phase delay. At increasing frequencies, the capacitors 32 become increasingly difficult to charge through the resistances 30; that is, the RC network acts as a low-pass filter having an upper cut-off at a characteristic frequency – or, equivalently, there is a characteristic time constant for an ionic conductor such that the conductor will appear to not respond to pulsed signals having a duration significantly less than the time constant. Furthermore, the degree to which the capacitors 32 contribute to the measurable capacitance value of 12 is graduated from one extreme to the other. Only the fixed capacitances 36, 42, and 40 remain constant with respect to frequency. Thus, it appears that a capacitive proximity sensing approach that would achieve a desired independence from the effects of the incidental presence of an ionic conductor could be based on the use of short pulse durations in the detection circuit, the pulse durations being chosen to be short enough that the ionic species present do not contribute to the measurement (which, as noted supra, has been found to require pulses having a duration generally less than several hundred nanoseconds or so, and often less than one hundred nanoseconds). Moreover, as will be disclosed in greater detail hereinafter, operating the sensor at a plurality of frequencies or pulsewidths is advantageous in situations in which the amount of ambient water changes in a foreseeable way – e.g., a different charge and/or discharge duration may be preferred for sensing a user's approach to a faucet than for sensing the user's continued presence proximate the faucet.

Turning now to Fig. 3, one finds a curve illustrating the temporal response of a shunting conductor 18 of interest – e.g. a sheet or film of water spilled about a spout 21 or a portion of water contained in a pipe 41 intermediate a valve 43 and a spout 21. This temporal response was elucidated with pulsed capacitance measurements (using apparatus disclosed in detail hereinafter) and shows the apparent capacitance measured with pulses having a variety of durations. When the pulses used in the measurement are shorter than a first predetermined value, indicated as τ_1 in Fig. 3, the shunting conductor 18 does not contribute to the measurement and the apparent capacitance value, C_1, is relatively low. When pulses longer than a second predetermined value, τ_2, are used, the time-dependent shunting conductor 18 contributes to the measurement and a higher apparent capacitance, C_2, is observed. Both the values of τ_1 and τ_2 and the exact shape of the curve 45 are expected to depend on a variety of factors including the choice of geometry of the shunting conductor 18, the composition of the conductor (e.g., the salinity of water standing in a pipe), and the ambient temperature. Moreover, because the generally smooth and continuous nature of the response curve 45, a wide range of values for the pulse width can be selected for a given measurement. For a case of particular interest, that of water spilled about a spout 21, τ_1 is on the order of 100 nsec, while τ_2 is on the order of 1 μsec.

As noted supra, the resistance 34 between the sensing plate and earth 22 may be highly variable, depending on the purity and size of the water film 18 splashed about the plate 12 (which may be the spout 21) as well as depending on the degree of contact between the film 18 and a grounded conductor 20. This value may change from one moment to the next, and will also change with variations in ambient temperature. Even the bulk capacitance 36 between the sensing plate 12 and ground 22 may vary with time – e.g., if an additional object such as a paper towel is left draped over the spout 21.

Turning now to Fig. 4 , one finds a block diagram of one embodiment of the sensor 14 of the invention. In this embodiment a voltage-limited current source 44 (which in the simplest variation is simply a resistor connected to a fixed voltage source 46) feeds a charging current to the plate 12. The current supplied by the source 44 is selected so that the plate 12 is charged to a predetermined fraction of the supply voltage V+ during a first interval during which a discharging switch 50 is open. At the end of the charging interval the discharging switch 50, which is preferably controlled by a microprocessor 52 via a control line 54, closes briefly. This rapidly discharges the sensing plate 12 into a charge detector 56, the amount of charge so transferred being representative of the capacitance of the sensing plate 12. The charge-discharge process can be repeated numerous times, in which case the charge measurement means 56 aggregates the charge from the plate 12 over several operating cycles. After a predetermined number of cycles of charge and discharge, the charge detector 56 is examined for total final charge by the controller 52, and as a result the controller 52 may generate an output control signal on an output line 58 – e.g., which may be used to cause a faucet 21 to open. As is common in the control arts, the controller 52 may also comprise one or more control inputs 60, which may include sensitivity settings and the like. After each reading, the controller 52 resets the charge detector 56 to allow it to accumulate a fresh set of charges from the plate 12. Alternatively, the controller 52 can take a reading after each individual cycle of the discharging switch 50, and then integrate (or otherwise filter) the readings over a number of cycles prior to making a logical decision resulting in a control output. Also, as will be understood by those skilled in the art, various combinations of signal integration cycles by the charge detector 56 and by internal algorithmic processes in the controller 52 may be used.

The choice of time periods over which changes in capacitance are measured distinguishes between "proximity" and "motion" sensing methods. Proximity sensors are ideally those measuring a change in capacitance with respect to an invariant reference level. To avoid problems with component aging and drift effects, a practical adaptive proximity sensor is one measuring a change of capacitance with respect to a slowly varying reference level – e.g., a variation occurring over a time period significantly longer than the maximum time a user 24 would interact with a controlled mechanism. (A sensor of this sort is disclosed in the inventor's co-pending application 08/266,814).

Motion sensors, on the other hand, are those measuring only a rapid change in capacitance – e.g., those responsive to the absolute value of the algebraic difference between capacitance values measured at two instants exceeding a predetermined value. Correspondingly, motion sensors may be configured to average several readings taken during a requisite short sensing interval in order to avoid problems with noise.

It is noteworthy that there is no coupling capacitor between the sensor circuit 14 and the plate 12. In the presence of external conductances and reactances to earth such a coupling capacitor would inject its own reactance into the system, and the sensor would no longer merely be reading charge on plate 12, but would also be reading charge bled onto the coupling capacitor from other sources. The total charge measured in such an arrangement would vary with the values of the resistance 30 and capacitance 32 of the water film and with the direct resistance to ground 34 of the sensing plate 12.

It may be noted that the circuit of Fig. 4 is unable to handle cases in which the magnitude of the direct resistance to earth 34 is so low as to prevent the plate 12 from becoming fully charged. Calculations must be made to ascertain that this conductance path 34, if present, cannot interfere with valid signal readings by loading the current source 44. Also, since no provision is made in the circuit of Fig. 4 to shut off the current source 44, when the discharging switch 50 closes it will conduct charge from the source 44 into the charge detector 56 as well. This additional charge can usually be accounted for as a fixed offset.

A preferred embodiment of the invention is schematically depicted in Fig. 5 . Here a second, charging, switch 62 is employed in place of the current source 44. The charging switch 62, like the discharging switch 50, is preferably a low resistance switching element, such as a transistor, operating under control of the microprocessor 52 via a charging control line 64, to charge the plate 12 very quickly to the known voltage V+. Should there be a conductive path offered by a low direct resistance 34, the current flow through the resistance 34 is not able to significantly drop the voltage impressed on plate 12, provided that the relative impedances of the direct resistance 34 and of the charging switch 62 are highly disparate.

Turning now to Fig. 6 , one finds a timing diagram depicting a preferred mode of closing and opening the charging 62 and discharging 50 switches in sequence. As shown by the top trace 70, the charging switch 62 closes at a first time, indicated as t_1, thereby connecting the plate 12 to the voltage source 46 so that the plate 12 charges quickly (as illustrated by a trace labeled with reference numeral 72) and reaches saturation at or before a second time t_2 (The rate of rise of the waveform 72 depends on the bulk capacitance of the plate 12, and the internal resistance of the charging switch 62) at which the charging switch 62 disconnects the plate 12 from the source of DC voltage 46. After a brief delay (t_3-t_2), which may be a few nanoseconds, and which is chosen to prevent switch crossover conduction, the discharging switch 50 (shown in waveform 74) closes at t_3 , thereby connecting the plate 12 to the charge measurement means 56 so as to rapidly discharge the plate 12. The waveform labeled with reference numeral 76 shows the rise of charge in the charge detector 56 after the discharging switch 50 closes.

Because the switches 62, 50 have intrinsic internal capacitances which inject charge into the charge detector 56, and because the plate 12 may have a very large inherent capacitance 36, it is often desirable to cancel these charges as fully as possible to prevent saturating the charge detector 56 with these background signals. To this end, a charge subtractor 80 is provided in some embodiments of the invention. When pulsed by a buck line 82 from the controller 52 (shown as waveform 84 in Fig. 6) the charge subtractor 80 subtracts charge from the charge detector 56. With such a circuit, the output of the charge detector 56 would look like waveform 86 of Fig. 6, rather than like waveform 76. Because only the charge detector's offset is affected by the charge subtractor 80, there is no change in gain of the charge detector and the overall system sensitivity remains unaffected.

The effect of the circuit of Fig. 5 in wet environments is to prevent capacitors 32 from charging very much, because they are resistively coupled by resistors 30 and the charge pulse 70 is short. Likewise, during the discharge pulse 74, any charge on the capacitors 32 will have difficulty in being conducted through the resistors 30 in time to measurably affect the charge on the charge detector 56. By rapid charge and discharge, the effect of resistances 30 is to remove the parasitic capacitances 32 from the measurement, while the bulk capacitances 36, 42, and 40 are always measured. Similarly, the direct resistance 34 plays an insignificant role, because the discharge occurs fast enough and immediately follows the charging pulse, the tendency is for the charge not to be bled away by the resistor 34 in time to significantly affect the measured result. AC coupling the sensor circuit 14 to the plate 12 by placing a conventional blocking capacitor (not shown) in the line 16 would destroy all these advantages by injecting a new reactance into the system. The effects of this reactance would be highly dependent on variations in circuit elements 30, 32, 34 that one wishes to exclude from the measurement. Thus, the system must remain DC coupled to be effective in wet environments.

It is noteworthy that the method of the invention can invoke controllably charging and discharging a sensing plate 12 where at least one of the charging and discharging steps is done during a time interval shorter than a characteristic conduction time of a shunting conductor. In the preferred embodiments, both the charging and discharging steps are carried out with fast pulses. The discussion supra with respect to Fig. 4 , however, presented an arrangement in which a long (essentially infinite) charging step was combined with a short discharging interval. The complementary situation, that of using a brief charging interval combined with a long discharge period would also be effective to provide a means of making a reproducible capacitance measurement usable for control applications in the presence of a shunting conductor 18.

Fig. 7 shows a schematic circuit diagram of an actual circuit employed to sense proximity of a user 24 to a faucet. In this embodiment the switches 62 and 50 are p- and n-channel mosfet transistors of types BSS110 and BSN10, respectively, both of which have integral source-drain diodes 88, 90. A resistor 92 (which typically has a value of twenty four ohms) adds damping and prevents ringing in the line 16 running to the plate 12. A second resistor 94 (which has a typical value of fifty one thousand ohms) acts to drain residual charge from the plate12 when neither of the switches 62 ,50 is conducting. Radio frequency interference is minimized by the provision of resistors 96,97 (which preferably have values of about one hundred ohms) to limit the rise and fall times of the signal on the cable 16, by limiting the gate charge rate on the switches 62 and 50. A diode 98 is preferably provided to turn off the charging switch 62 abruptly prior to the discharging switch 50 turning on a few nanoseconds later. Pulse networks 100, 102, which preferably employ 74AC00 type nand gates for pulse forming and driving, generate approximately 100ns pulses (i.e., waveforms 70, 74, where waveform 70 is inverted)) for the charging 62 and discharging 50 switches. Because the pulse network 102 acts subsequently to the network 100, its output pulse is slightly delayed. The charge subtractor circuit 80, in this embodiment, employs an NPN transistor (preferably a type 2N918) to subtract charge from the charge detector 56 on every pulse edge. The choice of the capacitance value in the charge subtractor 80 and of the system voltage determine the amount of charge subtracted on each pulse. In addition, an amplifier circuit 104 (having a gain of approximately two hundred and sixty in a preferred case), is used with an 8-bit DAC to provide an adjustable measurement offset of the signal. The analog to digital converter 116 integral to the preferred microcontroller 52 (a type PIC16C74) is only 8 bits, and thus has limited dynamic range. By adding a large external gain with offset capability, the system obtains an 8-bit 'window' subrange into a 13-bit measurement space (3 offset bits are used for overlap within each 8-bit window subrange).

The preferred charge detector 56 comprises a capacitor 106, which has a value of 0.05μF in one embodiment. A reset mosfet transistor 108, preferably of type BSN10, is used to reset the charge detecting capacitor 106 after each pulse, or burst of pulses, used in a measurement is read through the amplifier subsystem 104. Because the discharging switch 50 is preferably implemented as a mosfet having an internal diode 88, it is important not to allow the voltage on the charge detecting capacitor 106 to rise beyond about 0.5 volts, lest excessive conduction leakage occur, which would reduce the effective gain. If the voltage on the charge detecting capacitor 106 rises too high, the charge subtractor circuit 80 should be modified to provide more charge subtraction for each pulse, and/or the charge detecting capacitor should be increased in value. The latter approach will spoil gain as well, but will increase the tolerable load capacitance range.

Optionally, an electrostatic discharge protection device 110 can be used to prevent damage to the circuit from body static. It may be composed of one or more conventional diodes, a zener diode, or other clamping element.

In operation, the controller 52 operates according to the settings of switches on the control input lines 60 for sensitivity, time delays, and the like. A program stored in read only memory 112 governs the operation of the microprocessor. Periodically, for example once every ten milliseconds, the controller 52 issues a command to pulse-generating circuit 100, causing one or more pairs of successive pulses 70 (inverted) and 74 to be applied to the two mosfet switches 50, 62. These pulse-pairs may be supplied singly, or as burst of pulse pairs issued within a short time (e.g., several tens of microseconds), depending on the measurement environment. The controller issues the appropriate measurement offset on appropriate control lines 114, and after a brief delay to allow the circuit to settle, an analog to digital converter (ADC) 116 integral to the controller 52 digitizes the voltage on an input line 118 and thereby supplies a digital representation of the charge aggregated in the charge measurement means 56 to the controller 52. Following this, the reset line 119 is asserted and the reset mosfet 108 resets the detecting capacitor 106.

Internally to the controller 52, the digital output data from the ADC 116 may be averaged with prior and future samples of the signal. If an appropriately averaged result exceeds a predetermined threshold value, an output on the control line 58 may be asserted as long as the condition persists. Of course, other known output processing options may also be employed. One could, for example, use a one-shot at the output; delay the output by some period; provide an output having a maximum duration; etc. Moreover, the decision algorithms carried out by the controller 52 may also be selected from many known forms, including digital (Z-transform) filters, boxcar averaging, peak detection, peak suppression, median filtering, and the like. Newer forms of heuristic processing that depend on signal strength , change, and history, such as fuzzy logic, may also be employed.

Although specific methods have been detailed herein for creating the various circuits, it can be readily appreciated that there exist many known alternative means for implementing them. For example, although the charge detector 56 can be implemented using more complex circuits involving current mirrors and various types of integrators, the essential function remains the same. Likewise, the charge subtractor 80 may be implemented in an alternative manner. The amplifier sub-circuit 104 is not an essential circuit. It can be replaced with an analog to digital converter 116 of sufficient resolution and speed. Even the controller 52 functionality can be implemented in either digital or a combination of digital and analog hardware, as opposed to being a microprocessor, and in any such form would still be well within the spirit and scope of the invention.

Spectrally the RF field generated by the sensor is heavily bandwidth limited due to the rise and fall time limitations imposed by the resistors 96, 97 connected to the gates of the charging 62 and discharging 50 switches. Additionally, the spectral output is extremely broad, flat, and weak because the repetition rate is typically very low, the pulse spacing wide, and the currents and voltages very low. There are no resonant circuits to boost currents and voltages, and there are no pronounced spectral peaks. Even though rise and fall times may approach 20 ns, a pulse spacing of 10 ms gives a fundamental frequency of 100Hz. By employing time-domain pulse techniques, the spectral output of the sensor 10 is widely spread and weak. It is difficult to detect beyond a few feet.

An additional advantage of the invention is that it permits multiple units to be employed in near proximity without cross interference. This favorable result arises because the pulse density is so low. Pulse spacings can be made pseudo-random or simply different so as to avoid interference. The probability of two single pulses from adjacent ones of the preferred sensor occurring at the same instant is about 100nsec/10msec or 1 chance in 100,000. Even if multiple pulse bursts having 50 pulses per burst are used, the odds are 1 in 2,000. Assuming a 'direct hit' between two adjacent units, software algorithms can completely ignore the singular false data point (e.g., with a median filter).

As has been noted previously, it is most advantageous to couple the circuit 14 to the plate 12 without a blocking capacitor. The issue of plating caused by electrolytic current from the sensor is a natural attendant concern, but in the preferred embodiment the average current and voltage are so minuscule as to be overwhelmed by natural currents caused by dissimilar metals electrolysis. If a five volt system uses 100 nsec pulses every 10 ms (i.e., a duty cycle of or 1 part in 100,000), a quick calculation reveals that in twenty years the total plating time exposure to the five volt source will be 1.8 hours. The measured resistance through water, for example in the case of a faucet, can be as low as ten thousand ohms to ground, most of which is through a short section of water contained in the plastic pipe 41 feeding the spout. The current at 5 volts will be no more than 500μA, for a net plating exposure of under 0.9 mA-hr., which is far below any reasonable level of concern.

Another concern which may be raised is that of electrical exposure to the human body, especially in wet environments. At the duty cycles used, the average voltage is roughly 100μV, which is inconsequential. In a worst case sensor failure, one might produce an unblocked 5 volt signal on the plate. This voltage is less and far more current limited than that commonly available from a 9 volt transistor battery or a 12 volt car battery, which are accepted as not being capable of causing a shock hazard even in wet environments.

Example – Control of a water fountain

Turning now to Fig. 8 , one finds a drinking fountain 120 comprising electrically-powered refrigeration equipment 122 to cool water, and a tank 124 to store cooled water for dispensing. Fountains of this sort conventionally are of mostly metallic construction, comprising a stainless steel or heavily plated metal basin 126 having a drain connection 128 at a low point thereof, and having a spout 130 (which is conventionally called a bubbler in the water fountain art) arranged to spray water in a arcuate path thereinto when a solenoid-operated valve 43 is opened. For safety purposes, electrical components – e.g., the chiller 122 and the solenoid valve 43 – are grounded (e.g., by connecting a metal case 134 of the fountain 120 to an inlet metallic cold water line 136). It will be understood that alternate grounding means (e.g., connecting a chassis of a fountain 120 having a plastic case 134) can be employed.

It is known in the prior art to provide motion or presence sensors for water fountains -- e.g., the teachings of Laverty in US 5,033,508 and US 4,872,485. But prior art controllers (which have mostly relied on the use of projected infra-red beams to define a sensing area) have been excessively sensitive to motion in the general area of the fountain and have tended to turn on when someone walks by, unless time delays are supplied to ensure that an approaching person stays near the fountain long enough to be considered a prospective user. Such time delays are frequently perceived as a nuisance by thirsty people who may have to wait for the time-outs before being able to drink. Capacitive sensing is not known to have been employed for the control of such equipment due to the inability of prior art capacitive measurement apparatus to deal with varying impedances associated with water splashing about the fountain.

The present invention provides an automatic control system and method for a modified water fountain that supplies water when a user approaches the basin 126 and bubbler 130 of a structurally modified water cooler and brings some portion of his or her body (e.g., the mouth or a hand) close to the basin 126 or bubbler 130 from above. A water fountain 120 made in accordance with the invention measures change in the capacitance between the basin 126 and the 24 user as he or she approaches. This system has been shown to provide sensing means for a water fountain that will hold the delivery valve 43 open as long as the user is present. In using the apparatus of the invention to control a water fountain 120, one first breaks all metallic paths connecting the basin to earth, leaving one with only the parasitic ionic conduction paths connecting the basin 126 to ground. As disclosed hereinbefore, the system and apparatus of the invention are effective at overcoming the effects of these conduction paths. In a preferred embodiment, insulating standoffs 140 are interposed intermediate the basin 126 and the grounded case 134 or chassis of the fountain 120; a section 41 of the inlet piping, intermediate the solenoid valve 43 (which has a grounded housing) and the bubbler 130, is made of a suitable electric insulator. A portion of the drain line 144 adjacent the basin 126 is also made of an insulating material. It may be noted that the use of plastic pipe intermediate the valve 43 and spout 130 and the use of plastic drain pipe for the drain line 144 are common in the prior art, so that the principal structural modification to a prior art water cooler 120 is to provide electric insulation intermediate the case 134 and basin 126 so that the basin 126 (or the combination of the basin 126 and bubbler 130) can act as the sensing plate.

Example.– Controlling a wash-basin faucet

Turning now to Fig. 9 one finds a partially sectional view of a wash basin 150 mounted in a counter 28 and having a metallically conductive body, the body comprising both the water spout 21 and the sensing capacitor plate 12. A drain line 144 is attached to the basin 150 in a conventional manner. The spout 12 is plumbed to an electrically operated valve 43 controlled by a sensor circuit 14 conveniently installed with the valve 43 and a battery 152 in a tamper-resistant enclosure 154 such as the one disclosed by the inventor in his US application S/N 08/458,429. A dielectric tubular member 41 (which is usually a piece of plastic pipe, but which may be configured as a gasket, as an O-ring interposed between two metal pipes, or in some other form known to the art) connects the spout 21 and the valve to ensure that there is no metallic conductive path between the spout 21 and an electrical ground 22 (e.g., as may be provided by a metallic inlet pipe 136). In the dual pulse width embodiment of the invention described hereinafter, the metallic drain strainer 156 or pop-up drain closure (not shown) is grounded. The spout 21, electrically connected to the sensor circuit 14 by a wire 16, serves as the sensing plate 12 for detection of an object 28 (such as a user's hand

24) proximate the spout 21.

A schematic view of a dual pulse-width circuit embodiment preferred for use in controlling the faucet of a wash basin is illustrated in Fig. 10. An essential feature of the dual pulse width embodiment is means 160 permitting the controller 52 to alter the pulsewidths applied to the charging 62 and discharging 50 switches. By using two or more pulse widths, it is possible for the controller 52 to learn more about the object being sensed 28 than simply proximity. For example, in the case of a faucet, a short pulse width can be used during quiescent periods when the valve 43 is closed. Short pulse widths are optimal for detecting the approach of a person's hands, as they ignore signals from water splashes 18 around the spout 21. Once the water is turned on, the sensor 10 can switch to a wide pulse width and use the low-pass electrical characteristics of the water to 'reach through' the water stream itself to the user's hand 24, and thereby to sense whether it is in the water stream. This is a useful feature because many people reach deeply into the basin 150 while washing – i.e., their hands 24 are farther from the spout 21 while they wash than when waved near the spout 21 to initiate water flow. It has been experimentally determined that the signal detected from a person in this manner is quite large, and in fact is much larger and more variable than that from water splashes. Thus the sensor 10 can easily determine that the user is still making use of the water stream. It is noteworthy, however, that the drain strainer 156 or other metallic body at the base of the basin 150 must be grounded if wide pulses are to be used. If this is not done, the large signal component associated with the drain elements 144, 156 swamps the signal due to the user's hand 24 and the water, once turned on, continues to run. Once the water solenoid is turned off, a narrow pulse is again used to detect a user's approach with great selectivity. In cases where only the narrow pulse width is employed, it is of no consequence whether the drain screen 156 is grounded or not, as the sensor 10 will ignore the effects of water, while responding to the user's hand 24 being near the spout 21. In such single pulse width system, of course, the user's hand 24 would have to remain near the spout 21 in order to keep the water flowing.

As a minor variation of the circuitry depicted in Figs. 7and 10, it should be pointed out that variable pulse widths can be obtained by using a suitably fast microcontroller 52 and synthesizing the pulsewidths directly in software. Alternatively, digital hardware can be used to create variable length widths based on multiples of a clock interval. Battery operation of the sensor 10 can be simply obtained by employing a power switch to de-power various circuits elements (such as amplifier circuit 104) during the relatively long waiting periods between low duty cycle pulses, and putting the controller 52 into a sleep mode to conserve power between pulses. In practice, a sensor circuit would include various means to drive a solenoid valve, relay, motor, or other device from an output line 58; such circuits are highly application dependent and are well known in the industry. Moreover, the control inputs 58 can take many forms, as is well known in the trade.

Although the present invention has been described with respect to several preferred embodiments, many modifications and alterations can be made without departing from the invention. Accordingly, it is intended that all such modifications and alterations be considered as within the spirit and scope of the invention as defined in the attached claims.

INDUSTRIAL APPLICABILITY:

The invention provides widely useable capacitive sensors. In many of the applications the capacitive sensor senses the proximity or motion of a person and provides a control output responsive thereto. Applications of this sort include the control of solenoid operated valves in water fountains and wash basins as well as security systems, door safety systems, and computer input devices including both keypads and pointing devices.

What is desired to be secured by Letters Patent is:

CLAIMS

1) Apparatus for measuring the capacitance to ground of a plate, the plate connected to a shunting conductor substantially conducting electrical current pulses having durations greater than a first predetermined value, the shunting conductor substantially not conducting current pulses having durations less than a second predetermined value, the apparatus comprising:

a source of DC current charging the plate;

a source of a voltage pulse having a duration less than the second predetermined value;

a discharging switch having an open state and a closed state, the discharging switch moving from its open to its closed state responsive to the voltage pulse, the discharging switch connecting the plate to a charge measuring means when in the closed state, the discharging switch otherwise not connecting the plate to the charge measuring means.

2) Apparatus of Claim 1 wherein the shunting conductor comprises water.

3) Apparatus of Claim 1 wherein the charge measurement means comprises a capacitor and wherein the discharging switch comprises a transistor.

4) Apparatus of Claim 1 further comprising a microprocessor having an input from the charge measurement means, the microprocessor acting under control of a stored program to control the source of the pulse to close the discharging switch a predetermined number of times, thereby aggregating charge in the charge measurement means, the microprocessor subsequently receiving the input..

5) Apparatus of Claim 1 further comprising a microprocessor acting under control of a stored program to control the source of the pulse to close the discharging switch a predetermined number of times, wherein two sequential ones of the times are separated by an interval of pseudo-random duration..

6) Apparatus for measuring a capacitance to ground of a plate, the plate connected to a shunting conductor substantially conducting electrical current pulses having durations greater than a first predetermined value, the shunting conductor not conducting current pulses having durations substantially less than a second predetermined value, the apparatus comprising:

a source of dc voltage;

pulse generating means generating a charging pulse and a subsequent discharging pulse, at least one of the charging and the discharging pulses having a duration less than the second predetermined value;

a charging switch having an open state and a closed state, the charging switch moving from its open to its closed state responsive to the charging pulse, the charging switch connecting the voltage source to the plate when in its closed state, the charging switch otherwise disconnecting the voltage source from the plate;

a discharging switch having an open state and a closed state, the discharging switch moving from its open state to its closed state responsive to the discharging pulse, the discharging switch connecting the plate to a charge measuring means when in its closed state, the discharging switch otherwise not connecting the plate to the charge measuring means;

whereby a quantity of charge representative of the capacitance of the plate transferred to the charge measurement means.

7) The apparatus of Claim 6 further comprising a controller having an output responsive to a change in the measured capacitance, the change associated with motion of an object proximate the plate.

8) The apparatus of Claim 6 wherein the charge measurement means comprises a charge detecting capacitor.

9) Apparatus of Claim 8 further comprising an analog to digital converter electrically connected intermediate the charge detecting capacitor and a microprocessor, the analog to digital converter controlled by the microprocessor to provide a digital representation of a voltage across the detection capacitor.

10) The apparatus of Claim 8 further comprising a charge subtractor controlled by the microprocessor to subtract a predetermined quantity of charge from the charge detecting capacitor.

11) The apparatus of Claim 8 wherein the charge measurement means further comprises a reset transistor and wherein both the charging and the discharging switches comprise transistors.

12) Apparatus of Claim 6 further comprising means controlling the pulse generating means to supply a predetermined number of the charging pulses and the same predetermined number of the discharging pulses, each of the discharging pulses being generated subsequent to one of the charging pulses and before the next sequential one of the charging pulses, whereby the charging and discharging switches close in sequence the predetermined number of times.

13) Apparatus of Claim 6 further comprising means controlling the pulse generating means to wait an interval having a pseudo-random duration subsequent to the charging and discharging switches closing in sequence the predetermined number of times and to thereafter again supply the predetermined number of the charging and the discharging pulses.

14) Apparatus of Claim 6 further comprising means controlling the pulse generating means to supply a predetermined number of the charging pulses and the predetermined number of the discharging pulses, each of the discharging pulses being generated subsequent to one of the charging pulses and before the next sequential one of the charging pulses, whereby the charging and discharging switches close in sequence the predetermined number of times.

15) Apparatus of Claim 6 wherein the shunting conductor comprises water spilled about a spout and wherein the charge measurement means supplies an input to a controller having a stored value representative of a predetermined value of the input , the controller providing a control output controlling an electrically-actuated valve to open when the input exceeds the predetermined value, the valve, when open, supplying water to the spout.

16) Apparatus of Claim 15 wherein the spout comprises a bubbler portion of a water fountain, wherein the plate comprises a metallic basin of the water fountain, the basin having no metallic electrical connection to a grounded metallic portion of the water fountain.

17) Apparatus of Claim 15 wherein a metal body adjacent a wash-basin comprises the spout and the plate, the apparatus further comprising a dielectric tubular member conveying water from the valve to the spout..

18) Apparatus of Claim 6 wherein the charging pulse has a duration less than the second predetermined value.

19) Apparatus of Claim 18 wherein the discharging pulse has a duration less than the second predetermined value.

20) Apparatus of Claim 6 wherein the discharging pulse has a duration less than the second predetermined value.

21) A method of measuring the capacitance to ground of a plate connected to ground by a shunting conductor substantially conducting electrical current pulses having durations greater than a first predetermined value, the shunting conductor substantially not conducting current pulses having durations less than a second predetermined value, the method comprising the steps of:

a) closing a charging switch to connect the plate to a source of charging voltage for a charging interval having a predetermined charging duration and thereafter opening the charging switch to disconnect the plate from the voltage source;

b) closing a discharging switch to connect the plate to a charge measurement means having an output representative of the electrical charge transferred thereinto, the plate connected to the charge measurement means for a discharging interval having a predetermined discharge duration, and thereafter opening the discharging switch; and

c) reading the output of the charge measurement means,

wherein at least one of the charging and discharging durations is less than the second predetermined value.

22) The method of Claim 21 wherein both the charging duration and the discharging duration are less than the second predetermined value..

23) The method of Claim 21 wherein the step of closing the discharging switch is carried out only after the charging switch has been opened to disconnect the plate from the voltage source.

24) The method of Claim 21 comprising an additional step b1 intermediate step b) and step c) of repeating steps a) and b) a predetermined number of times before carrying out step c).

25) The method of Claim 21 comprising additional steps b1 and b2 intermediate steps b) and c) of:
b1) waiting for a delay time interval having a duration less than the first predetermined value, and
b2) repeating steps a), b) and b1) a predetermined number of times before doing step c).

26) The method of Claim 21 comprising additional steps b1 and b2 intermediate steps b) and c) of:
b1) waiting for a delay time interval having a duration greater than the first predetermined value, and
b2) repeating steps a), b) and b1) a predetermined number of times before doing step c).

27) The method of Claim 21 wherein the charge measurement means comprises a charge detecting capacitor, and wherein step c) comprises the substeps of : c1) connecting the charge detecting capacitor to an analog-to-digital converter; c2) digitizing the magnitude of a voltage on the detection capacitor; and c3) communicating the digitized voltage to a microprocessor.

28) Apparatus for controlling the actuation of an electrically-operated valve supplying water to a spout, the controller controlling the valve to be open responsive to the presence of a user proximate the spout, the apparatus comprising:

a capacitor plate;

a means of generating electrical pulses;

a source of DC voltage;

a charging switch intermediate the voltage source and the plate, the charging switch having a closed state electrically connecting the source to the plate and an open state electrically disconnecting the source from the plate, the charging switch switching between the closed and the open states responsive to a first pulse from the pulse generating means;

a discharging switch intermediate the plate and a charge measuring means having an output, the discharging switch having a closed state electrically connecting the plate to the charge measuring means and an open state electrically disconnecting the plate from the charge measuring means, the discharging switch switching between the closed and the open states responsive to a second pulse from the pulse generating means; and

control means storing a predetermined electric charge value, the control means receiving the output of the charge measuring means and controlling the valve to be open if the output from the charge measuring means is greater than the predetermined charge value, the control means otherwise controlling the valve to be closed.

29) Apparatus of Claim 28 wherein the spout comprises a water fountain bubbler, wherein the plate comprises a portion of a basin of the water fountain, the basin of the water fountain having no metallic conducting path to a grounded metallic portion of the water fountain.

30) Apparatus of Claim 28 further comprising a dielectric tubular member connected intermediate the valve and a metal body, the metal body comprising both the spout and the capacitor plate, the metal body electrically connected to the controller.

31) Apparatus of Claim 28 wherein the first pulse has a first duration when the valve is closed and a second duration, longer than the first duration, when the valve is open, and wherein the second pulse has a third duration when the valve is closed and a fourth duration, longer than the third duration, when the valve is open.

32) Apparatus of Claim 28 wherein the control means comprises means replacing the stored predetermined charge value with a second stored predetermined charge value responsive to an input representative of a change in an ambient condition.

33) A method of measuring the change of capacitance to ground of a conducting plate and of controlling the actuation of an electrically-operated valve supplying water to a spout responsive to the measured change, the method comprising the steps of:

a) closing a charging switch and thereby connecting the plate to a source of dc voltage for a charging interval having a first predetermined duration;

b) opening the charging switch at the conclusion of the charging interval;

c) closing a discharging switch and thereby connecting the plate to a charge measurement means for a discharging interval having a second predetermined duration;

d) opening the discharging switch;

e) connecting the charge measurement means to a controller and reading from the charge measurement means a first quantity of charge transferred thereinto;

f) comparing a first predetermined charge value stored in the controller with the first quantity of charge read from the charge measurement means; and

controlling, by means of an electrical output from the controller, the valve to open and thereby supply water to the spout if the first quantity of charge exceeds the predetermined charge value, otherwise controlling the valve to be closed and to not supply water to the spout.

34) The method of Claim 33 wherein the charging switch comprises a first transistor switched by a first pulse having a pulsewidth equal to the first duration, and the discharging switch comprises a second transistor switched by a second pulse having a pulsewidth equal to the second duration, the first and the second pulses supplied by a pulse generating means controlled by the controller; and wherein the charge measurement means comprises a detection capacitor and a reset transistor.

35) The method of Claim 33 wherein one of the first and the second durations is less than a characteristic time constant associated with a water film shunting the conducting plate, the water film conducting pulses having durations greater than the characteristic time constant, the water film not conducting pulses having durations less than the characteristic time constant.

36) The method of Claim 33 wherein one of the first duration and the second duration is less than a characteristic time constant associated with a body of water shunting the conducting plate, the water conducting pulses having durations greater than the characteristic time constant, the water not conducting pulses having durations less than the characteristic time constant, the method further comprising additional steps taken after step g) when the valve is controlled to be open of:

h) closing the charging switch and thereby connecting the plate to the source of dc voltage for a longer charging interval having a third predetermined duration greater than both the characteristic time constant and the first predetermined duration;

i) opening the charging switch at the conclusion of the longer charging interval;

j) closing the discharging switch and thereby connecting the plate to the charge measurement means for a longer discharging interval having a fourth predetermined duration greater than both the characteristic time constant and the second predetermined duration;

k) opening the discharging switch;

l) connecting the charge measurement means to the controller and reading from the charge measurement means a second quantity of charge transferred thereinto;

m) comparing a second predetermined charge value stored in the controller with the second quantity of charge read from the charge measurement means; and

n) holding the valve open if the second quantity of charge exceeds the second predetermined charge value, otherwise controlling the valve to be closed.

37) The method of Claim 36 comprising an additional step d1) intermediate steps d) and e) of repeating steps a) through d) a first predetermined number of times before doing step e).

38) The method of Claim 36 comprising an additional step k1) intermediate step k) and step l) of repeating steps h) through k) a second predetermined number of times before doing step l).

39) The method of Claim 33 comprising an additional step d1) intermediate steps d) and e) of repeating steps a) through d) a predetermined number of times before doing step e).

40) The method of Claim 33 wherein one of the first duration and the second duration is less than a characteristic time constant associated with a body of water shunting the conducting plate, the water conducting pulses having durations greater than the characteristic time constant, the water not conducting pulses having durations less than the characteristic time constant, the method further comprising additional steps taken after step g) when the valve is controlled to be open of:

h) waiting a predetermined interval;

i) repeating steps a) through e) and thereby reading from the charge measurement means a second quantity of charge;

j) comparing the second quantity of charge with the first quantity of charge and;

controlling, the valve to close if the absolute value of the algebraic difference between the first and the second quantities of charge is less than a second predetermined value.

41) A method of measuring a capacitance of a plate, the method comprising the steps of:

a) setting an output of a charge detector to a first predetermined voltage;

b) charging the plate from a DC voltage source to a second predetermined voltage;

c) connecting, for a predetermined discharging interval, the plate to the charge detector; and

d) digitizing the output of the charge detector;

e) storing the digitized output of the charge detector as a value in a memory operatively associated with a microprocessor;

f) setting the output voltage of the charge detector to the first predetermined voltage;

g) repeating steps b) through d); and

h) combining, by means of an algorithm performed by the microprocessor, the current digitized output of the charge detector and the value earlier stored in the memory.

42) The method of Claim 41 further comprising a step subsequent to step c) and prior to step g) of waiting for an interval of pseudo-random duration.

43) The method of Claim 41 further comprising a step intermediate steps b) and d) of reducing, by means of a charge subtractor circuit, the output voltage of the charge detector by a predetermined incremental value.

44) The method of Claim 41, wherein the plate is connected to a shunting conductor substantially conducting electrical current pulses having durations greater than a first predetermined duration, the shunting conductor substantially not conducting current pulses having durations less than a second predetermined duration, and wherein the predetermined discharging interval is shorter than the second predetermined duration..

45) The method of Claim 41 further comprising a step intermediate steps c) and d) of repeating steps b) through c) a predetermined number of times.

46) The method of Claim 41 further comprising a step b1) intermediate steps b) and c) of: b1) disconnecting the plate from the DC voltage source.

47) A method of measuring a capacitance of a plate, the method comprising the steps of:

a) setting an output of a charge detector to a first predetermined voltage;

b) connecting the plate to a source of DC voltage for a charging interval having a first predetermined duration;

c) connecting, for a discharging interval having a second predetermined duration, the plate to the charge detector;

d) disconnecting the plate from the charge detector; and

e) digitizing the output of the charge detector, the digitized output representing the capacitance;

f) storing the digitized output of the charge detector as a value in a memory operatively associated with a microprocessor;

g) repeating steps b) through e); and

h) combining, by means of an algorithm performed by the microprocessor, the current digitized output of the charge detector and the value earlier stored in the memory.

48) The method of Claim 47 further comprising a step following step d) of repeating steps b) through d) a predetermined number of repetitions.

49) The method of Claim 47 further comprising a step intermediate steps b) and e) of reducing, by means of a charge subtractor circuit, the output voltage of the charge detector for a predetermined incremental value.

50) The method of Claim 47, wherein the plate is connected to a shunting conductor substantially conducting electrical current pulses having durations greater than a first predetermined duration, the shunting conductor substantially not conducting current pulses having durations less than a second predetermined duration, and wherein the predetermined discharging interval is shorter than the second predetermined duration..

51) The method of Claim 47 further comprising a step b1) intermediate steps b) and c) of: b1) disconnecting the plate from the DC voltage source.

52) A method of measuring a capacitance of a plate by using a DC voltage source and a charge detector, the method comprising the steps of:

a) setting an output of the charge detector to a first predetermined value;

b) charging the plate from the DC voltage source to a second predetermined value;

c) connecting, for a predetermined discharging interval, the plate to the charge detector;

d) repeating steps b) and c) a first predetermined number of times, the first predetermined number equal to or greater than zero;

e) measuring the output of the charge detector;

f) storing the measured output as a representation of the capacitance;

g) repeating steps a) through f) a second predetermined number of times, thereby obtaining one more than the second predetermined number of representations of the capacitance; and

h) combining the one more than the second predetermined number of representations of the capacitance to create an aggregate representation of the capacitance.

53) The method of Claim 52 where the first predetermined number of times is zero.

54) In a control system sensing the proximity of an object by measuring a capacitance to earth of a plate and generating an output when a change in the capacitance exceeds a first predetermined value, a capacitance measurement method comprising the steps of :

a) setting an output of the charge detector to a second predetermined value;

b) charging the plate from the DC voltage source to a third predetermined value;

c) connecting, for a predetermined discharging interval, the plate to the charge detector;

d) repeating steps b) and c) a first predetermined number of times;

e) measuring the output of the charge detector; and

f) storing the measured output as a representation of the capacitance.

55) The method of Claim 54, further comprising the steps, subsequent to step f) of:

g) repeating steps a) through f) a second predetermined number of times, thereby obtaining one more than the second predetermined number of representations of the capacitance; and

h) combining the one more than the second predetermined number of representations of the capacitance to create an aggregate representation of the capacitance

AMENDED CLAIMS

[received by the International Bureau on 29 May 1997 (29.05.97); original claim 53 cancelled; original claims 1-21,28-31,41,44,47,50 and 52 amended; remaining claims unchanged (8 pages)]

1) In a capacitive sensor that measures the capacitance to a ground of a plate, the plate electrically connected to the ground by a shunting conductor that is not a part of the sensor, the shunting conductor substantially conducting electrical current pulses having durations greater than a first predetermined value. the shurting conductor substantially not conducting current pulses having durations less than a second predetermined value, a improved capacitive measurement means comprising:

a source of DC current charging the plate;

a source of a voltage pulse having a duration less than the second predetermined value;

a discharging switch having an open state and a closed state, the discharging switch moving from its open to its closed state responsive to the voltage pulse, the discharging switch connecting the plate to a charge measuring means when in the closed state, the discharging switch otherwise not connecting the plate to the charge measuring means.

2) The capacitive sensor of Claim 1 wherein the shunting conductor comprises water.

3) The capacitive sensor of Claim 1 wherein the charge measurement means comprises a capacitor and wherein the discharging switch comprises a transistor.

4) The capacitive sensor of Claim 1 further comprising a microprocessor having an input from the charge measurement means, the microprocessor acting under control of a stored program to control the source of the pulse to close the discharging switch a predetermined number of times, thereby aggregating charge in the charge measurement means, the microprocessor subsequently receiving the input..

5) The capacitive sensor of Claim 1 further comprising a microprocessor acting under control of a stored program to control the source of the pulse to close the discharging switch a predetermined number of times, wherein two sequential ones of the times are separated by an interval of pseudo-random duration..