United States Patent [19]

Evans

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[54] **METHOD OF AND APPARATUS FOR SENSING THE LOCATION, SUCH AS COORDINATES, OF DESIGNATED POINTS ON AN ELECTRICALLY SENSITIVE TOUCH-SCREEN SURFACE**

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[73] Assignee: **Microtouch Systems, Inc.,** Woburn, Mass.

[21] Appl. No.: **53,849**

[22] Filed: **May 26, 1987**

[51] **Int. Cl.**[4] **G08C 21/00**

[52] **U.S. Cl.** **178/19**

[58] **Field of Search** 178/18, 19; 340/706, 340/712

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,911,215	10/1975	Hurst et al.	178/18
4,198,539	4/1980	Pepper, Jr.	178/18
4,220,815	9/1980	Gibson et al.	178/18
4,233,522	11/1980	Grummer et al.	307/116
4,293,734	10/1981	Pepper, Jr.	178/18
4,353,552	10/1982	Pepper, Jr.	273/85
4,371,746	2/1983	Pepper, Jr.	178/18
4,680,429	7/1987	Murdock et al.	178/19

OTHER PUBLICATIONS

Interaction Systems, Inc., "The TK–1000 CRT Touch Development System Operators Manual", Newtonville, Mass., May 1983.

Sierracin/Intrex Products, "Transparent Electrically Conductive Film".

Sierracin/Intrex Products, "TransFlex:Unique Concepts in Membrane Switches, EMI Shielding and LCD Heaters".

Sun–Flex Co., Inc. "Touchpen On–Screen Digitizer", Novato, Calif.

Primary Examiner—Stafford D. Schreyer

Attorney, Agent, or Firm—Rines and Rines; Shapiro and Shapiro

[57] **ABSTRACT**

A method and apparatus are disclosed for determining the location of a designated point on an electrically sensitive touch-screen surface while minimizing aberrations introduced by non-uniformity in the field applied to the surface, by attaching a plurality of field-producing discrete point electrodes to widely spaced points on the surface in a predetermined geometric pattern and by measuring the currents drawn from the point electrodes upon the capacitive touching of a designated location on the surface.

36 Claims, 2 Drawing Sheets

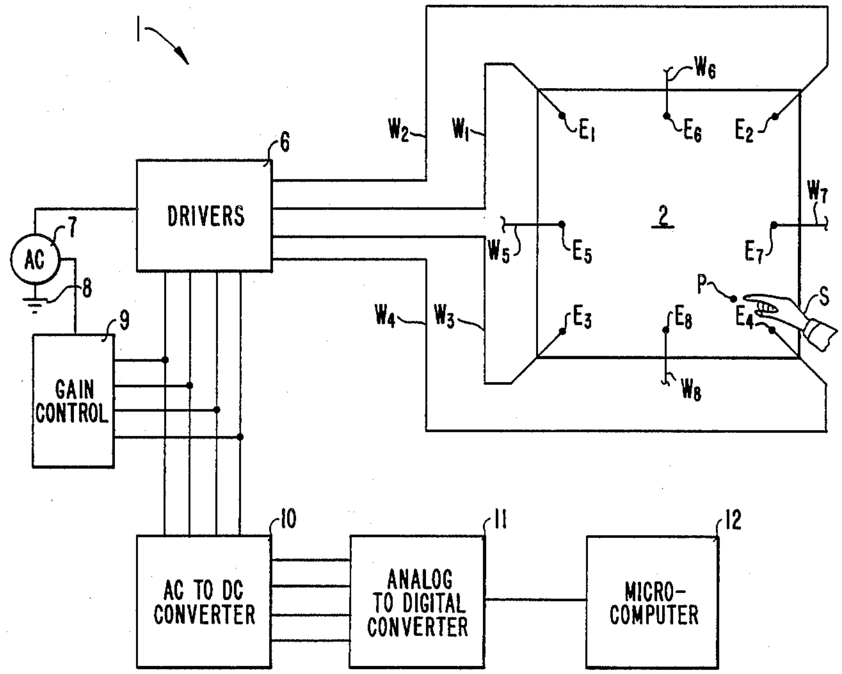
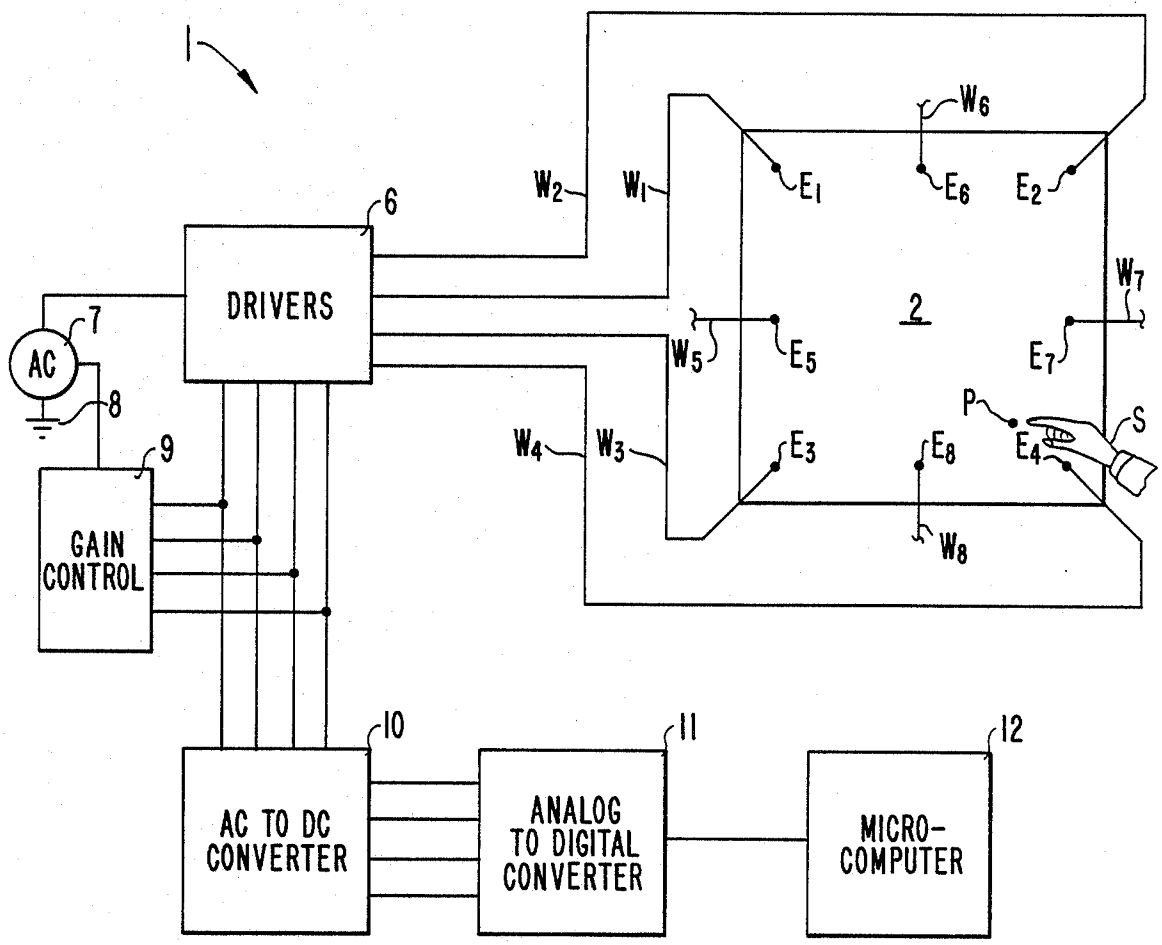


FIG. 1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ANALOG TO DIGITAL CONVERTER
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MICRO-COMPUTER

FIG. 2

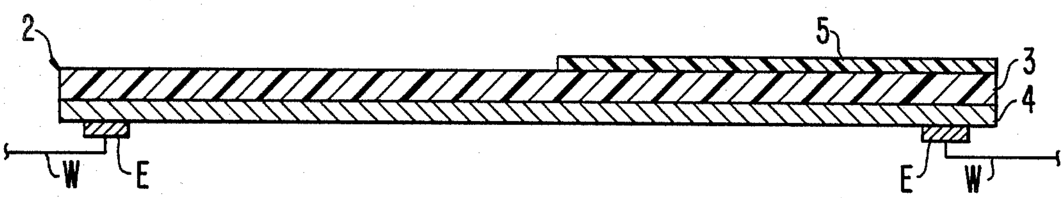
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FIG. 3

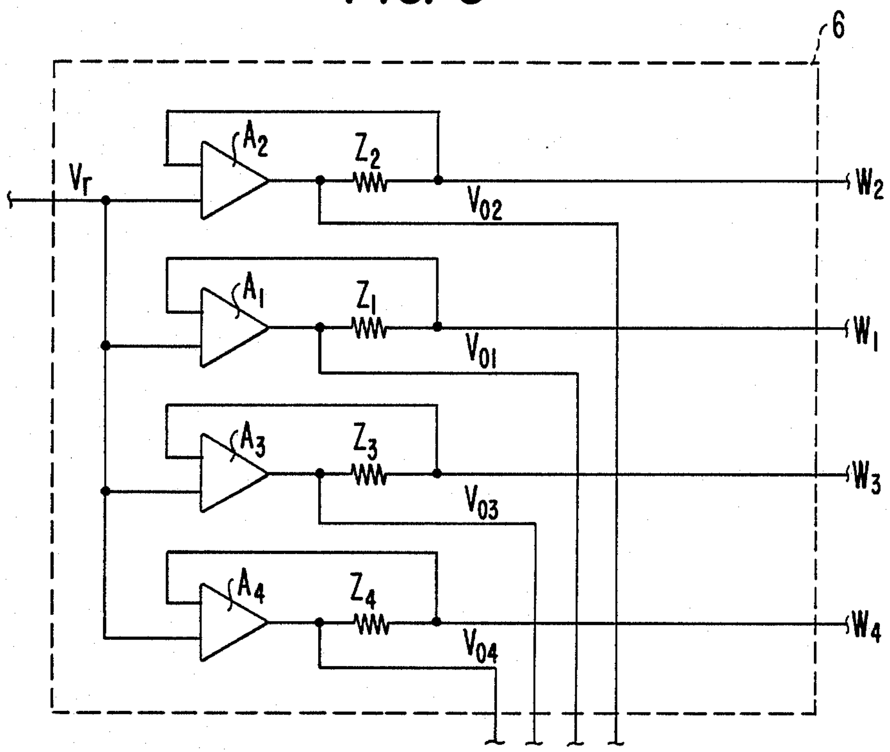
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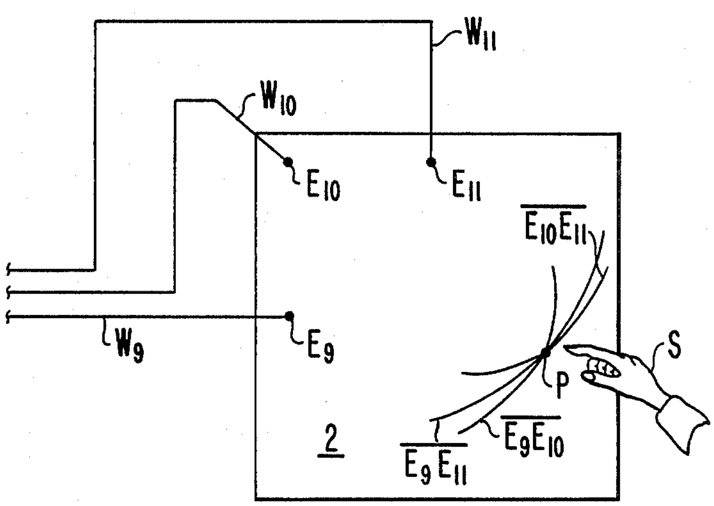
FIG. 4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METHOD OF AND APPARATUS FOR SENSING THE LOCATION, SUCH AS COORDINATES, OF DESIGNATED POINTS ON AN ELECTRICALLY SENSITIVE TOUCH-SCREEN SURFACE

The present invention relates to methods of and apparatus for sensing the location, such as coordinates, of designated points on an electrically sensitive touch-screen surface, such as capacitive touch-screen sensors and the like, being more particularly directed to reducing aberrations in linearity in the electrical sensing of locations over a large touch-screen surface, and to reducing cost of sensor manufacture.

Prior techniques for sensing discrete location on an electrically sensitive touch-screen surface include both resistive and capacitive methods. Resistive sensors generally have two surfaces, as of plastic and glass, at least one of which is deformable towards the other, with uniform or uniformly patterned coatings of a resistive material sandwiched therebetween. When pressure is applied to the flexible surface at a point, as by a stylus or finger, it deforms towards the opposing surface establishing contact between the opposing surfaces and thereby allowing sensing of the point of pressure. Such resistive sensors are described, for example in U.S. Pat. Nos. 3,911,215 and 4,220,815.

One disadvantage of the resistive screen sensor is the high cost of construction of the complex sandwich. Additional disadvantages include diminishing optical clarity when applied over a display device, such as a cathode ray tube. Finally, the durability of the resistive sensor is less than ideal in view of the susceptibility of the screen to cutting or scratching as with the nail of a finger or a sharp stylus, and because of fatigue problems in deformation.

Capacitive screens, on the other hand, generally minimize or ameliorate some of the aforementioned disadvantages of resistive screens. Such capacitive screen sensors usually require a single surface, such as glass, cloth or plastic, with a uniform resistive material coated or fused to one face of the surface, with the finger or a stylus establishing capacitive sensing when applied to the surface. Multiple electrodes are attached to the resistive material to render the screen electrically operative. Capacitive finger or stylus presence perturbs the electric field produced in the resistive material by the electrodes, enabling sensing so as to determine the position of the finger or stylus on the screen sensor. Among the numerous capacitive screen sensors that have been proposed is the arrangement described in U.S. Pat. No. 4,233,522, for example, which includes an array of touch-sensitive electrode switch cells, such as circular electrodes located on the screen surface. Touching the surface causes distortion of the electric field in the proximity of the nearest electrode, such distortion being greater than that near the other electrodes, thereby designating the nearest electrode as the area of the point of touching. Such a system inherently discretely divides the surface of the screen sensor into areas at least as large as the electrodes, preventing use for fine resolution. To obtain reasonable resolution, therefore, a large number of electrodes is needed, adding cost and complexity. Finally using electrodes on the sensing face of the screen sensor reduces the viewing clarity for underlying display screens.

Another type of electrode configuration for a capacitive screen sensor is that of Interaction Systems, Inc.

(ISI), 24 Munroe Street, Newtonville, Mass., as described in their May, 1983, publication entitled "The TK-1000 CRT Touch Development System Operators Manual". This screen sensor has four linear bar electrodes, each extending approximately the entire length of one of the four sides of the rectangular screen sensor surface. Although solving the screen transparency problem inherent in previously mentioned circular electrodes, certain difficulties are inherent in the linear bar type of screen sensor. The vertical pair of opposing electrodes, if used in the absence of a horizontal pair, creates a regular horizontal electric field across the surface, enabling the touching of a point of the field to establish the exact distance from each vertical bar with simple computations, and therefore providing high resolution horizontal location sensing on the surface. The use of a second set of horizontally oriented linear electrodes, however, at the top and the bottom of the screen, creates a non-orthogonal electrical distortion in the horizontal electrical field in the regions along the horizontal bar electrodes, causing sensing aberrations due to the lack of a regular field near the electrodes. Such distortion, producing sensing aberration, usually is more severe at the corners where the orthogonal bar electrodes reach closest proximity to each other. Pre- or post-distortion circuiting is used to try to reduce the effects of tis aberration, but at additional complexity and not to the degree desired.

Modification of the solid bar electrode configuration has been proposed, including segmenting the bar electrodes into a plurality of successive sections along each edge of a surface, such as in the TransFlex TM screen produced by Sierracin/Intrax Products, 20500 Plummer Street, Chatsworth, Calif. 91311, and shown in their publications "Transparent Electrically Conductive Film" and "TransFlex TM Unique Concepts in Membrane Switches, EMI Shielding and LCD Heaters", and also in U.S. Pat. Nos. 4,293,734, 4,353,552 and 4,371,746. Such use of multiple closely spaced linearly arranged successive electrode sections is, however, subject to the same above-described attendant aberration disfunctions as the solid bar electrodes.

Curved bar electrode configurations have also been suggested which may also be used in conjunction with curvilinear patterns of successive electrode sections as described, for example, in U.S. Pat. No. 4,198,539. The curved bar electrode system, however, is also subject to the field distortion and resulting sensing aberration near the electrodes, including particularly the lack of corner resolution, as described for the linear bar electrodes.

The present invention obviates the above-described limitations and disadvantages of prior touch screens. The invention reduces the electrodes to just widely separated "points" or very small discrete regions and enables the use of a minimal number of such point electrodes at that. The widely spaced point or discrete electrodes are coupled to a uniform resistive surface, with each point electrode of sufficiently small surface area and located at such a remote distance from the other point electrodes, that a regular electric field may be produced over the complete screen surface, minimizing any possible field distortions produced by the electrodes thereon. Specifically, in a preferred or best mode, four point electrodes are employed, one at each corner or edge of the screen sensor surface, with each point electrode thus as far from any other point electrode as is physically possible. Multiple overlapping or partially overlapping geometric patterns of corner-located point electrodes can, if desired, be used to achieve optimum resolution near any particular area of the sensor, as will later be described in more detail. Additional point electrodes may also be placed for special effects along the side edges of the geometric patterns. The point electrodes, moreover, need not be located exclusively at edge or corner locations with respect to the sensor surface, but may be arranged in any geometric shape which maintains symmetry with the sensor shape, sufficient to produce a regular field over the entire sensor surface. Preferably a regular geometric shape using at least three discrete electrodes may be used to provide optimum location sensing with a minimum of distortion over the entire sensing surface. Additional discrete point electrodes may be used to provide greater resolution of sensing, especially in the area near one of the discrete electrodes where some measurement ambiguity may occur. Such flexibility in electrode placement provides a substantial advantage over previous capacitive touch-screen sensors in that the previous touch-screen sensors limited the sensing area to within the area bounded by the field-producing electrodes. The present invention does not require such limitation. Since a regular field is produced over the entire surface area of the screen sensor, and the discrete electrodes are not used to bound the regular field, due to the minimal field distortion around the discrete electrodes, location sensing can be successfully accomplished both within and without the area bounded by the discrete electrodes.

Additionally, the sensing apparatus of the invention compares the draw of alternating field current from each of the point electrodes, thus providing a wide dynamic range of capacitance that can be effectively sensed. This will also permit the use of dielectric material separating the uniform resistive coating on the screen sensor surface from the stylus or finger used to designate a desired point or location on the surface without significant loss of resolution or sensitivity.

It is accordingly an object of the present invention to provide a new and improved method of and apparatus for touch-screen sensing, providing reduction in aberration produced in the sensing of discrete locations on the screen surface, and that shall not be subject to the above-mentioned prior art limitations, but that, to the contrary, provide a simple, durable and inexpensive means for accurately sensing the discrete location of indicated points on the sensing surface.

A further object is to provide such a novel method and apparatus that have sufficient clarity and transparency of screen sensor surface to provide clear viewing through the screen sensor when mounted over a display surface.

A further object is to provide a novel method of and apparatus for capacitively sensing the location of a designated point on a sensor surface both inside and outside of the area bounded by the field-producing electrodes, where desired.

A still further object is to provide a novel method of and apparatus for providing an improved degree of sensing resolution in a capacitive touch-screen sensor.

An additional object is to provide a novel capacitive touch-screen sensor that is useful over a wide range of capacitance, automatically compensating for variations in touch impedance, and useful with intervening material between the sensor surface and the stylus, if desired, to designate location on the surface—all without substantial loss in resolution or sensitivity.

Other and further objects will be explained hereinafter and are more particularly delineated in the appended claims.

In summary, however, from one of its important aspects, the invention embraces a method of reducing the aberrations produced by irregular electric fields produced on touch-sensing surfaces and the like, that comprises, applying a plurality of discrete point electrodes to widely separated points of the surface in a predetermined geometric pattern, driving the point electrodes with a common alternating-current voltage to generate a regular electric field over the surface, and simultaneously measuring the currents drawn through the point electrodes upon the capacitive touching of a designated point on the surface to locate such designated point. Preferred details, best mode embodiments and other features are hereinafter described.

The invention will now be described with reference to the accompanying drawings:

FIG. **1** of which is a schematic block diagram of an illustrative type of capacitive touch-screen sensor showing a four and eight electrode configuration and position sensing between the electrodes;

FIG. **2** is a longitudinal section of a capacitive touch-screen sensor partially covered by an intervening display material;

FIG. **3** is a schematic diagram of the discrete electrode drivers of the four-electrode configuration illustrated in FIG. **1**; and

FIG. **4** is a three-electrode configuration, similar to FIG. **1**, showing position sensing beyond the boundaries bordered by the electrodes.

Referring to FIG. **1**, a capacitive touch-screen sensor, generally designated **1**, is provided with a screen **2** shown in longitudinal section in FIG. **2**. The screen **2** is preferably made of a rigid transparent material, such as a plastic or glass sheet **3**, FIG. **2**, with a uniform coating of resistive material **4**, such as a coating of Indium Tin Oxide (ITO), fused to the screen **2**, of a sufficiently minimal thickness to provide transparent clarity through the coating **4**. The coating **4** may be on either side of the sheet **3** but is preferably placed on the front (bottom surface of the sheet **3** in FIG. **2**) to provide for maximum sensitivity to touch. The screen **2** may also be adapted with a partial or complete cover sheet **5**, which can be made of dielectric material, such cover sheet **5** permitting fixed visual information on the screen **2** during use. Preferably, the cover sheet **5** is substantially transparent to allow viewing through both the cover sheet and the screen **2**, and the cover sheet **5** is sufficiently thin to permit electrical capacitive touching contact between a stylus S, such as a finger, and the screen **2**, as shown in FIG. **1**.

Fixed in electrical contact to the resistive material coating **4** are a plurality of discrete electrodes E of predetermined size. The electrodes E should be of a sufficiently small size so as to minimize the area on the surface of screen **2** which is in close proximity to the electrodes and therefore subject to distortion, while being of sufficiently large size to minimize contact resistance with the coating **4**. It has been found that a circular dot or "point" electrode with a diameter of between 0.031 and 0.250 inches is acceptable with a preference for a point electrode of 0.125 inches in cross-dimension or diameter. As the electrical distortion produced by the presence of the electrode exists substantially for only a few cross-sections or diameters from the electrode, such discrete point electrodes widely separated

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