the display panel **104** is an LED display, neither a reflector nor a backlight is required since the individual pixel elements of the LED display emit their own light.

[0021] As mentioned above, the display panel **104** may be either LCD-based or LED-based. An LCD display panel uses a liquid crystal layer that can be either optically transparent or opaque depending on application of an electric field through the liquid crystal layer. On the other hand, an LED display panel has a plurality of barely-visible light emitting diodes (LEDs) that emit light at a particular color when an electric current is applied.

[0022] The digitizer panel **106** provides the touch-sensitivity to the touch-screen display. Specifically, the digitizer panel **106** converts a detected contact position into an input understandable by a controller. Several methods of detecting contact, or touch, are well known in the art, including resistive, capacitive, near-field, surface acoustic wave and infrared.

[0023] A resistive digitizer is constructed of a glass panel that is covered with two conductive layers separated from each other by an insulating spacer. Touching the panel brings the two conducting layers into contact, after which the touch is detected by a change in the applied voltage. A controller analyzes the resulting change in order to calculate the contact coordinates.

[0024] In a capacitive digitizer, a conducting layer having a constant voltage applied thereto is placed on a glass panel and covered by an insulating film. When a user touches the panel, an induction current is induced in the conducting layer. Circuits located at each corner of the digitizer panel measure the change. A controller calculates, from the relative differences in charge at each corner, the coordinates of the touch event.

[0025] In near-field imaging, a conducting layer of special internal structure has an applied constant voltage, which generates an electric field near the panel surface. A finger or stylus approaching the panel surface introduces distortion into this field, measuring the relative differences of the distortion with circuits placed at the panel corners allows a controller to determine the position of the contact.

[0026] In surface acoustic wave digitizers, a source of ultrasound (piezoelectric cell) generates a stationary acoustic (ultrasonic) field in a glass panel. A finger or stylus touching the surface absorbs ultrasound and, hence, modifies this field. The change is detected by ultrasonic sensors (piezoelectric sensor) whose positions determine the touch site.

[0027] Infrared digitizers employ pairs of linear arrays of point IR radiation sources and sensors arranged opposite to each other along the boundaries of the screen, close to its surface. Each array of sources illuminates the opposite array of sensors, one pair being situated on the horizontal boundaries and the other, on the vertical boundaries. Any object introduced into the near-surface region shadows the corresponding zone in the array of sensors, thus locating the touch site.

[0028] Of the above-described digitizer technologies, resistive, capacitive and near-field digitizers lend themselves most readily to being used with the present invention.

Magnetic Bead Tactile-Feedback Unit

[0029] Referring to FIG. **2**, a generalized cross-sectional view is provided of an embodiment of a tactile-feedback touch-screen **200**. The tactile-feedback touch-screen **200** includes the conventional subassemblies, such as a backlight **202**, display panel **204**, and digitizer panel **206**.

[0030] Additionally, a gel layer **208**, containing a plurality of transparent magnetically attractive particles **210** is positioned over the digitizer panel. One such appropriate material is the iron-oxide glass beads disclosed in "Magnets-Value of the First Step" written by Ronald F. Ziolo, Ph.D. and published in *R&D Innovator* Vol. 3, No. 11, Nov. 1994. An array of electromagnets **212** form a deforming layer **214** that is positioned behind the display panel **204** and backlight **202**. The gel layer **208** and deforming layer **214** constitute a tactile-feedback unit **216**. When one or more electromagnets **212** are energized, a portion of the gel layer **208** above the energized electromagnet deforms to form a dimple **216**.

[0031] The number of electromagnets **212** is dependent on application requirements of the tactile-feedback touch screen. Typically, there would be a very small number of tactile zones on the screen (vs. the LCD resolution). For example, a 320×240 QVGA screen might only require twelve electromagnets positioned around the edges (four on a side) as it is unlikely that a small screen would contain more than this number of interface elements. Alternatively, in applications where the touch screen is large and interface elements vary in size and position, significantly more electromagnets **212** can be used.

[0032] Applying a pulse-width modulated drive signal to the corresponding electromagnet **212** will modulate the concavity of the dimple **216** formed over the electromagnet **212**. In this manner, variable tactile profiles can be implemented. For example, if an interface element is associated with an operation that takes some time, the panel can communicate this back to the user by modulating the concavity of the dimple **216**, once touched, until the operation is complete. The same sort of mechanism can be used to provide silent feedback that a requested operation has been completed, such as in the case of issuing a silent panic signal.

Hydrogel Tactile-Feedback Unit

[0033] In an alternative embodiment shown in FIG. **3**, instead of the deforming layer **214** and the gel layer **208** of the magnetic bead embodiment, a gel layer **302** having a transparent honeycomb structure is disposed immediately behind a front protective film **304** forming the outer most surface layer of the screen.

[0034] A first matrix of electrodes **306** (i.e., front electrode layer) is formed on a front surface of the gel layer **302** and a second matrix of electrodes **308**(i.e., rear electrode layer) is formed on a back surface of the gel layer **302**. One set of electrodes oriented in the horizontal direction and the other set of electrodes oriented orthogonally in the vertical direction.

[0035] Both sets of electrodes are printed, sputtered or photolithographically etched on a transparent substrate. Sputter or vapor deposition are the standard processes at this time however any appropriate method can be utilized. The front electrode layer **306** is deposited on a flexible plastic/rubber layer. The rear electrodes are deposited on a more rigid material forming the rear electrode layer **308**. In this configuration, the present embodiment maximizes the outward deflection of the surface, for a given drive signal.

[0036] An acceptable material for fabricating the electrodes is (w/w) 90% In_2O_3 with 10% SnO_2, commonly known as ITO. However, materials such as poly(3,4-ethylenedioxythiphene), commonly called PEDOT, or related compounds such as PEDOT:PSS or PEDOT-TMA ("Olig-