

[0014] FIG. 6 shows, in schematic form, a force and touch sensitive display in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

[0015] The following description is presented to enable any person skilled in the art to make and use the invention as claimed and is provided in the context of the particular examples discussed below, variations of which will be readily apparent to those skilled in the art. Accordingly, the claims appended hereto are not intended to be limited by the disclosed embodiments, but are to be accorded their widest scope consistent with the principles and features disclosed herein.

[0016] Referring to FIG. 1, force and location display unit 100 in accordance with one embodiment of the invention comprises novel force and touch cell 105, display element 110 and controller 115. As shown, cell 105 is juxtaposed in front of display element 110 (from the perspective of user 120). For example, cell 105 may be laminated to the front of display element 110. Illustrative display element 110 includes, but is not limited to, various types of liquid crystal displays (“LCD”, plasma displays and cathode ray tubes (“CRT”). Functionally, controller 115 is similar to prior art controllers in that it provides signals to drive cell 105 and to relay and/or process signals received from cell 105 to a host computer (not shown). Such signals represent where and with how much force user 120 used to touch display 100. In another embodiment, display unit 100 may include, for example, a polarizer element between cell 105 and display element 110. Alternatively, the polarizer may be placed outside bell 105 to enhance the perceived contrast ratio of the display unit.

[0017] Referring to FIG. 2, novel force and touch cell 105 of FIG. 1 comprises first and second clear substrates (200 and 205), each of which has abutted to one surface a pattern of conductive traces (210 and 215) and which are separated by volume 220. Volume 220 includes a plurality of compressible media elements 225 which permit substrates 200 and 205 to move closer to one another as user 120 presses on display 100. In combination with drive signals from controller 115 (see FIG. 1) and conductive traces 210 and 215, as the separation between substrates 200 and 205 changes, so does the mutual capacitance between traces 210 and 215. It is the change in capacitance signals detected by controller 115 that represent where, and with how much force, user 120 touches display 100.

[0018] In one embodiment, clear substrates 200 and 205 comprise glass or optically clear plastic between approximately 0.3 to 0.5 millimeters (“mm” in thickness and may be of the type typically used in liquid crystal displays. Conductive traces 210 and 215 comprise patterned indium tin oxide or some other optically transparent or translucent conductor. Compressible media elements 225 may, for example, comprise polyurethane or silicone rubber in the form of elastomer dots or beads.

[0019] It has been found that the capacitance change between conductive traces 210 and 215 may be easily detected using glass substrates of the thickness identified above and separated by between approximately 2 to 20 microns (“ μm ”). Accordingly, in one embodiment compressible media elements 225 comprise elastomer dots that span

the gap from substrate 200 to substrate 205 (minus the thickness of conductive traces 210 and 215). By way of example, if substrate 200 is separated from substrate 205 by 10 μm , compressible media elements may be arranged and spaced as shown in FIGS. 3A and 3B. In one embodiment, compressible media elements may be applied to substrate 200 or 205 via a photolithographic or silk-screening process. In another embodiment, compressible media elements may be applied to both substrate 200 and 205. In this later implementation, the dots or beads formed on a first substrate (e.g., substrate 200) could be juxtaposed between dots or beads formed on the second substrate (e.g., substrate 205) so that, together, the pattern illustrated in FIG. 3 would be constructed. It will be recognized by those of ordinary skill that other patterns are possible without departing from the concepts described herein.

[0020] While not required, in one embodiment volume 220 is closed in a manner that permits fluid to fill the region between substrate 200 (and conductive traces 210) and substrate 205 (and conductive traces 215). One benefit of this configuration is that the refractive index of the fluid may be matched with the refractive index of the compressible media elements. When this is done, Snell’s law ensures that the compressible media elements will appear to vanish from a user’s point of view and, as a consequence, not distract from the user’s view of whatever is being presented on display element 110. One illustrative optical fluid is SL-5267 from SantoLight. One of ordinary skill in the art will recognize that thin-film reflective coatings may be applied to each interface to reduce the loss of light and mitigate refractive distortions. Illustrative antireflective coatings may contain magnesium fluoride, aluminum oxides, etc. and are typically applied in thicknesses of approximately 50 to 200 nanometers.

[0021] Referring to FIG. 4, the layout for conductive traces 210 and 215 are shown in accordance with one embodiment of the invention. In the illustrated embodiment, “top” traces 210 (i.e., those closest to user 120) comprise rows of pixel plates 400, drive frames 405 and inverted drive lines 410—each of which is electrically isolated by regions having no conductive material 415. “Bottom” traces 215 (i.e., those furthest from user 120) comprise sense lines associated with force detection operations (420) and sense lines associated with location detection operations (425). As shown in the illustrated embodiment, each force detection trace 420 has an output pad (430, 435 and 440) while a plurality of location detection traces 425 share a common output pad (445 and 450).

[0022] Referring to FIGS. 5A and 5B, a more detailed view of the architecture of FIG. 4 is provided. For one embodiment, the dimensions ‘a’ through ‘h’ identified in FIGS. 5A and 5B are listed in Table 1.

TABLE 1

Illustrative Dimensions		
Label	Description	Size
a	Capacitive plate (400)	4 mm
b	Capacitive plate (400)	4 mm
c	Drive frame - inverted drive line separation	0.25 mm
d	Inverted drive line (410)	0.25 mm
e	Conductive trace separation	30 μm