DISPLAY WITH DUAL-FUNCTION CAPACITIVE ELEMENTS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/078,337 filed on Jul. 3, 2008, the contents of which are incorporated herein by reference in their entirety for all purposes.

FIELD OF THE INVENTION

[0002] This relates generally to displays having pixels that include capacitive elements, and more particularly to displays in which capacitive elements of the pixels that form part of the display system that generates an image on the display also form part of a touch sensing system that senses touch events on or near the display.

BACKGROUND OF THE INVENTION

[0003] Many types of input devices are presently available for performing operations in a computing system, such as buttons or keys, mice, trackballs, joysticks, touch sensor panels, touch screens and the like. Touch screens, in particular, are becoming increasingly popular because of their ease and versatility of operation as well as their declining price. Touch screens can include a touch sensor panel, which can be a clear panel with a touch-sensitive surface, and a display device such as a liquid crystal display (LCD) that can be positioned partially or fully behind the panel so that the touch-sensitive surface can cover at least a portion of the viewable area of the display device. Touch screens can allow a user to perform various functions by touching the touch sensor panel using a finger, stylus or other object at a location dictated by a user interface (UI) being displayed by the display device. In general, touch screens can recognize a touch event and the position of the touch event on the touch sensor panel, and the computing system can then interpret the touch event in accordance with the display appearing at the time of the touch event, and thereafter can perform one or more actions based on the touch event.

[0004] Mutual capacitance touch sensor panels can be formed from a matrix of drive and sense lines of a substantially transparent conductive material, such as Indium Tin Oxide (ITO), often arranged in rows and columns in horizontal and vertical directions on a substantially transparent substrate. It is due in part to their substantial transparency that capacitive touch sensor panels can be overlaid on a display to form a touch screen, as described above. However, overlaying a display with a touch sensor panel can have drawbacks, such as added weight and thickness, and decreased brightness of the display.

SUMMARY OF THE INVENTION

[0005] This relates to displays including pixels with dual-function capacitive elements. Specifically, these dual-function capacitive elements form part of the display system that generates an image on the display, and also form part of a touch sensing system that senses touch events on or near the display. The capacitive elements can be, for example, capacitors in pixels of an LCD display that are configured to operate individually, each as a pixel storage capacitor, or electrode, of a pixel in the display system, and are also configured to operate collectively as elements of the touch sensing system. In this way, for example, a display with integrated touch sensing capability may be manufactured using fewer parts and/or processing steps, and the display itself may be thinner and brighter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** illustrates a partial circuit diagram of an example LCD display including a plurality of LCD pixels according to embodiments of the present invention.

[0007] FIGS. **2**A and **2**B illustrate example regions formed by breaks in vertical and horizontal common voltage lines according to embodiments of the invention.

[0008] FIG. **3** illustrates partial circuit diagrams of a pixel **301** of a drive region and a pixel **303** of an example sense region.

[0009] FIG. **4**A illustrates example signals applied to the pixels of a drive region during an LCD phase and during a touch phase according to embodiments of the invention.

[0010] FIG. **4**B illustrates example signals applied to the pixels of a sense region during an LCD phase and during a touch phase according to embodiments of the invention.

[0011] FIG. **5**A illustrates details of an example operation of a storage capacitor of a drive region during a touch phase according to embodiments of the invention.

[0012] FIG. **5**B illustrates details of an example operation of a storage capacitor of a sense region during a touch phase according to embodiments of the invention.

[0013] FIG. **6**A illustrates a partial view of an example touch screen having regions of pixels with dual-function capacitive elements that operate as LCD elements and as touch sensors according to embodiments of the invention.

[0014] FIG. **6**B illustrates a partial view of example touch screen including metal traces running in the border areas of the touch screen according to embodiments of the invention.

[0015] FIG. **6**C illustrates an example connection of columns and row patches to the metal traces in the border area of the touch screen according to embodiments of the invention.

[0016] FIG. **7** illustrates a top view of an example column and adjacent row patches according to embodiments of the invention.

[0017] FIG. **8**A is an example plot of an x-coordinate of a finger touch versus mutual capacitance seen at a touch pixel for a two adjacent touch pixels in a single row having wide spacings according to embodiments of the invention.

[0018] FIG. **8**B is an example plot of an x-coordinate of a finger touch versus mutual capacitance seen at a touch pixel for a two adjacent touch pixels in a single row having wide spacings where spatial interpolation has been provided according to embodiments of the invention.

[0019] FIG. **8**C illustrates a top view of an example column and adjacent row patch pattern useful for larger touch pixel spacings according to embodiments of the invention.

[0020] FIG. **9**A illustrates an example touch screen including sense (or drive) regions formed as columns and rows of polygonal regions (bricks) according to embodiments of the invention.

[0021] FIG. **9**B illustrates a close-up view of a portion of the example touch screen of FIG. **9**A.

[0022] FIG. **9**C illustrates a portion of example touch screen of FIG. **9**A including bricks associated with columns C**0** and C**1** and connecting yVcom lines coupling the bricks to bus lines according to embodiments of the invention.

[0023] FIG. **10** illustrates a portion of example zig-zag double interpolated touch screen that can further reduce the