Touch Screen Panel by using Liquid Crystal Capacitance Variation embedded in LTPS AMLCD

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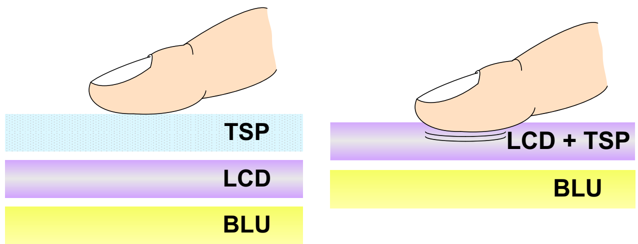
Abstract

We present a new touch screen method, which utilizes the variation of liquid crystal capacitance according to the touch event on the screen. It is integrated in the AMLCD with the conventional LTPS process. Its resolution is same as the display resolution as well as performs the multi-touch sensing function basically. The design concept and the operation are verified with the SPICE simulation.

1. Introduction

Touch screen technology is rapidly expanding into many other industries such as automotive, healthcare, mobile phone and game in these days because it provides such an intuitive user interface that can be the most convenient input system ever suggested. That is, just pushing the button-like shape displayed on the screen allows users to communicate with the machines.

Many researches are proceeding on the technology of touch screen panel (TSP) now, but there are two different approaches as shown in Fig. 1. One is that TSP is attached on the top of display. This type has several different methods employed by TSP currently on the market: resistive, capacitive, surface acoustic wave and infrared light [1]. Though it has good sensing resolution, it could reduce brightness and contrast ratio of display, and increase total cost of panel [2]. Thus, in order to solve above problems, the type of integrating TSP into AMLCD was proposed. It has also several different methods using such as photosensors, liquid crystal capacitance as a touch sensor [2, 3]. However, in the integrated TSP using photosensors, unintended shadow may cause to reduce the precision of tracking positions. Moreover, the multi-touch sensing function, which can obtain the information of more than one position at the same time, is required enormously by the customers since it makes TSP perform various interesting functions on many applications [4, 5]. Most of technologies introduced above, however, are not able to support the multi-touch sensing function.



a) TSP on LCD b) TSP into LCD

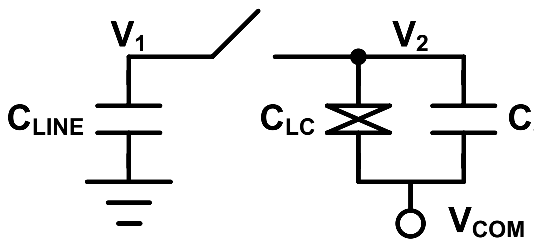
TSP : Touch Sensing Panel
LCD : Liquid Crystal Display
BLU : Backlight Unit

Fig. 1 Cross Sections of TSP a) on the LCD and b) into the LCD

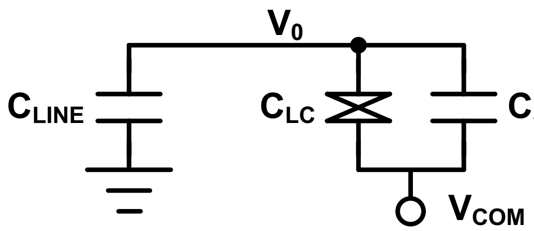
In this paper, we present a novel touch screen method which is integrated in LTPS (Low Temperature Polycrystalline Silicon) AMLCD. Since its touch sensor is the liquid crystal capacitance in a display pixel, it does not suffer from unintended-shadow problem so that it can have good precision. It can realize touch sensing resolution as high as display resolution as well as multi-touch sensing function.

2. Touch Sensitive System by using Liquid Crystal Capacitances in Pixels

The liquid crystal alignment in a pixel is dependent on the applied voltage between the electrodes. A touch event causes to change the alignment state of the liquid crystals to vary its dielectric constant as well as to reduce the distance between electrodes. The significant capacitance change happens in accordance with a touch event. We utilize the change of the liquid crystal capacitance of a pixel to detect touch events on the screen [2].



a) opened



b) closed

Fig. 2 Charge-sharing between the line capacitance, C_{LINE}, and the pixel capacitance, C_{LC} and C_{ST}

As shown in Fig. 2, there are two capacitances of the line capacitance C_{LINE} and the pixel capacitance which is the sum of liquid crystal capacitance C_{LC} and storage capacitance C_{ST}. They are disconnected to each other by the opened switch at first. Both of them are pre-charged by different voltages, V_1 and V_2 respectively. Once the switch closes, then the charges from both capacitances are sharing with each other resulting in the new voltage level, V_0. If the liquid crystal capacitance is changed by a touch event, V_0 will be different with that of a pixel which is not touched. We can obtain the touching information at the screen surface from this difference.

3. Proposed Pixel Structure and Operation

If the liquid crystal capacitance of a pixel increases by the factor of α in accordance with a touch event, the voltage difference of V_0 between touched and not-touched is simply expressed as below:

$$\Delta V_0 = \left(\frac{(\alpha C_{LC} + C_{ST})}{C_{LINE} + (\alpha C_{LC} + C_{ST})} - \frac{(C_{LC} + C_{ST})}{C_{LINE} + (C_{LC} + C_{ST})} \right)(V_1 - V_2). \tag{1}$$

Both terms of the right side on eq. (1) should be as large as possible in order to detect a touch event. To obtain the maximum value of the difference V0, the line capacitance and the pixel capacitance should be similar. However, we assumed that the target model is middle/small size screen for mobile display. The line capacitance is 10pF, and the variation factor α of the liquid crystal capacitance by touch is 2. The liquid crystal capacitance and the storage capacitance of each pixel are 0.3pF and 0.2pF respectively in our simulation. It is enough to combine several pixels temporarily during the touch sensing periods to obtain ΔV_0 to detect the touch event on the screen at the outside of panel.

Fig 3 is the equivalent circuit of the proposed structure which is called the Combined Pixel Structure (CPS). Since ΔV_0 should be supposed to be detectable at the readout node, it is not necessary for ΔV_0 to become maximized. Thus, in this scheme, 3 pixels which consist of one dot play a role of one unit cell for touch sensing, and the number of TSCAN signals is same with that of SCAN signals. The touch sensing resolution is equal to the display resolution.

As shown in Fig 4, the timing diagram, SCAN signal is composed of two pulses. The first one is for sensing the variation of liquid crystal capacitance by a touch event. The second one is intended to charge up pixel capacitance for display. During T1, all switching TFTs(SW3) of n^{th} line are turned on, and their pixel capacitances are charged up to V1. At the same time, V2 is set on the line capacitance in accordance with CLK signal. As soon as the data line is disconnected with the each pixel capacitance as SCAN(n) goes up in the period of T2, 3 pixels in a row are combined by TSCAN(n) so that the charges in each capacitance are shared to form new voltage level, V0. If the pixel capacitance which is defined as the liquid crystal capacitance and the storage capacitance is increased by the touch event, newly formed voltage level at the end of readout line would be V0*. At the period of T3, SW3s are turned on as SCAN(n) goes down, and the voltage for display information is written at each pixel capacitance. During T4 period, switching TFTs of nth line are turned off, and their pixels are dedicated to express their own gray scales. The pixels of $n{+}1^{th}$ line repeat in the same manner by the SCAN(n+1) until T6 period. Therefore, touch sensing function is possible for only 2 pulse periods, and one unit cell for touch sensing acts as display pixels for the rest of one display period.

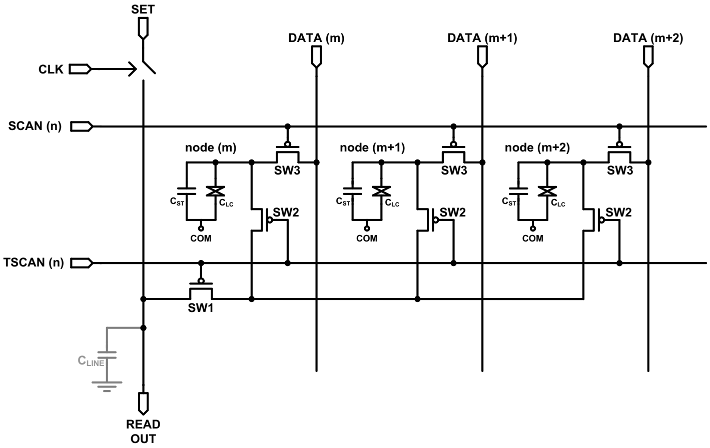


Fig. 3 The proposed pixel structure to combine pixel capacitors temporarily

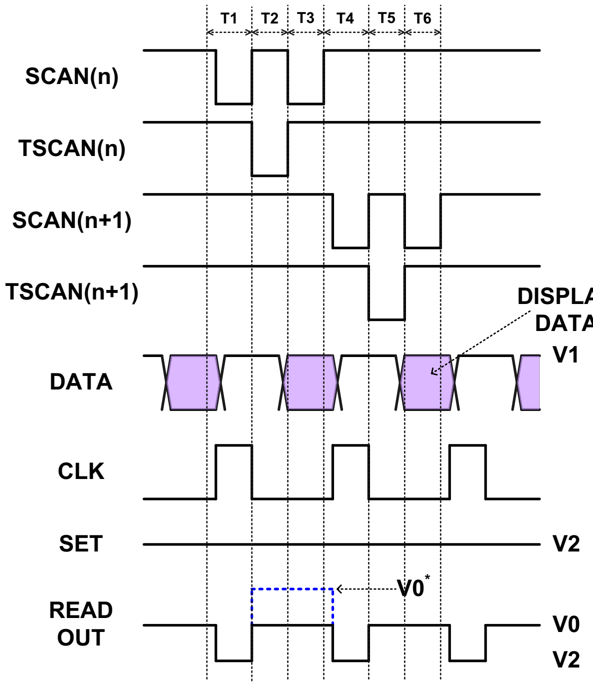


Fig. 4 Timing diagram of a proposed TSP

4. Results and Discussion

The operation of the touch sensing function with the liquid crystal capacitance of pixels was verified by SmartSPICE simulation using the LTPS TFT model parameters.

The pulse width of SCAN signal is around 3.7 µ sec since the current capability of poly-crystalline TFT is so superior that each capacitance can be charged up during that time. The swing range of SCAN signal is from -5V to 15V. Data signal consists of two values such as V1 and display data voltage. The value of V1 for touch sensing is set to 10V. Display data is alternating from 7V to 3V at this simulation. The value of V2 which is for setting the READOUT line capacitance is 0V. The difference between V1 and V2 can be set in order to obtain enough sensing margin.

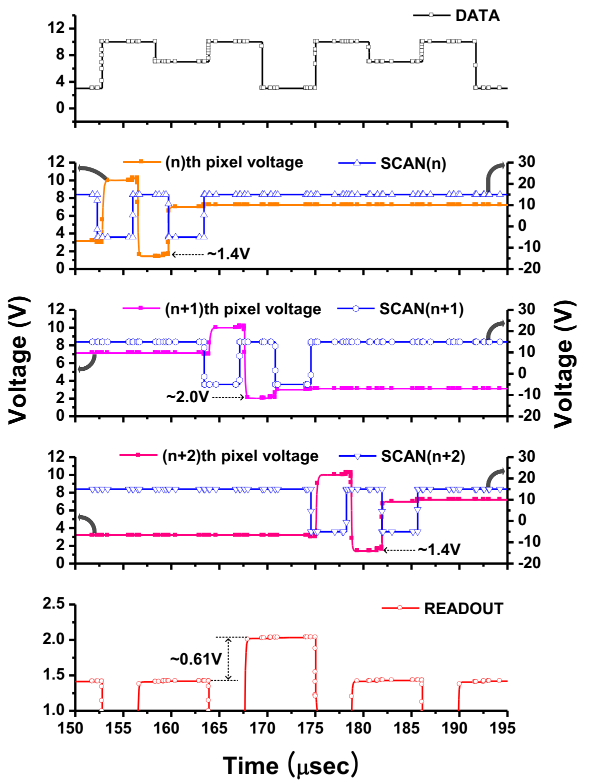


Fig. 5 The voltage waveforms of each pixel capacitance, the SCAN signals, the DATA, and the READOUT

From n^{th} to $n{+}2^{th}$ pixels, the voltage waveforms of each pixel capacitance, the SCAN signals, and DATA waveforms are shown in Fig. 5. During the period between two pulses of the SCAN signal, which is T2 or T5 in the timing diagram, we can observe that the pixel capacitances are connected with the line capacitance so that the new voltage level V0, which is dependent to the touch event, is formed.

At this simulation, we assume that the n+1th unit cell is touched. Therefore, each voltage of the pixel capacitance from nth to n+1th is around 1.4V, 2.0V, and 1.4V respectively. This can also be observed at the READOUT signal graph. Each pixel keeps 3V or 7V, which is the display data, after SCAN signal. That is, touch information on the screen can be collected during two pulses as well as each pixel expresses its gray scale after the SCAN signal.

The output from the READOUT line is shown in Fig. 5. The voltage difference of READOUT line between touched and not-touched is over 500mV. By detecting voltage differences, the touch events are able to be digitalized. Therefore, we can implement touch screen function using the change of liquid crystal capacitance in pixels by touch.

As display data is written on the pixel capacitor according to SCAN signal during the display period, the touch information on each unit for touch sensing can be extracted in accordance with TSCAN signal for the touch sensing period. That is, it can sense touch events in one frame time just like taking a picture of the variation of pixel capacitances. Thus, it can perform the multi-touch sensing function. It can also realize touch sensing resolution as high as display resolution.

5. Summary

In this paper, we have introduced a new touch sensitive method using the variation of the pixel capacitance and its pixel structure, which is designed to combine several pixels temporarily during the touch sensing periods. The operation of touch sensing was verified by SPICE simulation and the distinguishable voltage difference between when the screen is touched and not touched was successfully achieved. Currently, we are fabricating a test panel using the capacitance change of liquid crystals in accordance with the touch event and the result will also be reported.

6. References

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