32.3: Simple Single-Layer Multi-Touch Projected Capacitive Touch Panel

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Abstract

A simple projected capacitive touch panel is developed. This touch panel is capable of detecting multi-point touch events. The device consists of a single piece of patterned transparent ITO glass and a sensing circuit. The applied driving signal is projected onto the sensing node in the form of an electric field. A charge sensing circuit is used to monitor the mutual capacitance between the driving and sensing nodes. This approach provides a simple and low cost alternative to current capacitive multi-touch panel design.

1. Introduction

Touch panel is increasingly attractive to researchers and display manufacturers in recent years. Currently, resistive touch panel is the most widely used. It is because the resistive technology has been well developed, allowing manufacturers to enjoy perfect balance between cost and performance. However, resistive touch panel does have some drawback; it can only track one touch event at a time and suffers in optical quality due to its two substrates structure [1]. Also, it is prone to be damaged by sharp objects or excessive touching force.

Although, resistive touch panel still remains the leader position in the market, there is always a need for simpler and better touch panel technology. One of the solutions is the capacitive touch panel. iPhone was the first consumer products employing multi-touch function based on projected capacitive technology [2,3]. Now multi-touch has become a major trend for new touch panel devices. However the capacitive touch panel currently configured suffers from optical quality problem. At this stage, there is still no touch technology that could achieve low cost, high optical clarity, simple structure, robust and also multi-point touch ready.

In this work, we propose a simple method to construct multi-touch panels. The panel is composed of a thin transparent ITO layer deposited on glass. This layer is patterned into a number of isolated segments with each segment connected to the external circuit. Unlike self-capacitive touch panel, there are driving and the sensing electrodes located at the same ITO layer. Hence, single substrate structure can be achieved without any assembling of substrates. Fabrication becomes easy, leading to cost reduction. And high transmittance can also be realized due to the use of only one glass substrate instead of two. Changes in mutual capacitance between these electrodes is then detected and reported to a custom made MCU-based controller to determine a touch event.

2. New Touch Panel Structure

The structure of the proposed touch panel is shown in Figure 1. It consists of a touch panel and a LCD underneath. The whole unit is assembled in a way that the ITO electrodes are sandwiched by its glass substrate and the LCD unit. The ITO pattern is prepared by standard photolithography.

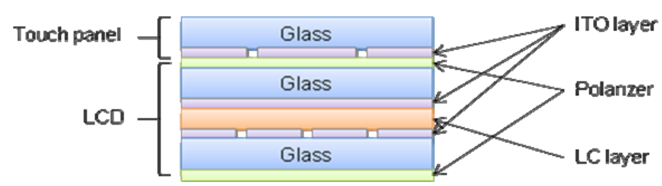

Figure 1. An overview of the proposed touch panel structure.

3. Touch Sensor Architecture

Base on the proposed structure, direct driving and multiplexing design are developed. Figure 2 shows the top view of the ITO pattern for both design approaches. Basically, both designs have the same sensor architecture, but different layout. Direct driving, or commonly known as a "matrix" touch panel, is normally used in applications such as keypad or other situations where a limited number of well-defined areas on a surface need to be made touch-sensitive. Figure 2b shows the multiplex design. This approach is more suitable to be used as a touch screen in a high resolution display.

The driving electrodes and sensing electrodes are spatially separated, therefore forming a capacitor in between. The driving electrode is driven by a voltage source, and the sensing electrode is connected to a capacitive sensing circuit.

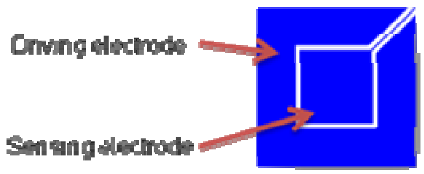

Figure 2a. Top view of the ITO electrodes pattern for direct driving design.

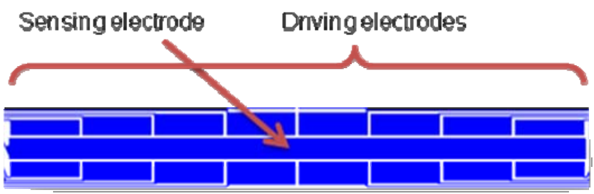

Figure 2b. A top view of the ITO electrodes pattern for multiplexing design.

4. Operating Principle

Figure 3 depicts a schematic model of the mutual capacitive touch panel. When no object is present, the capacitive coupling within C_{DS} stays fairly constant. When an object such as finger is placed close to the sensor, it disrupts the electric field, and effectively shunting the field to ground, so that the amount of electric field coupled to the sensing electrode decreases. In other word, the capacitance of C_{DS} drops.

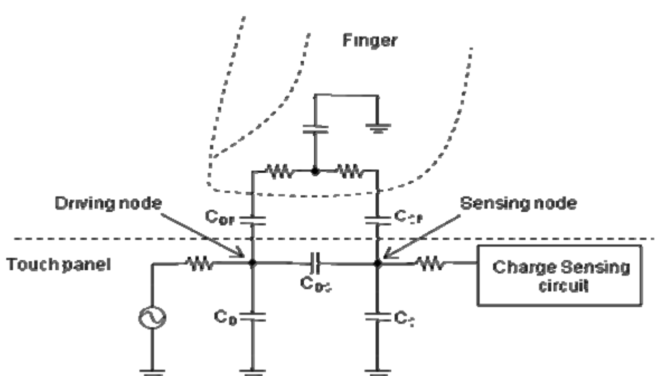

Figure 3. A schematic view of mutual capacitive touch panel model.

At close proximity, the capacitance between the object and the electrodes (C_{DF} and C_{SF}) increases significantly. Electric field from the driving electrode capacitively couples into the object, making the entire object an electric field emitter. The field received by the sensing electrode increases and effectively, C_{DS} increases. This phenomenon was called the shunting mode and the transmission mode by Zimmerman et al [4].

Actually both shunting mode and transmission mode occur simultaneously, but touch event mainly relies on the shunting mechanism. To ensure the touch panel operates properly, we have to prevent the transmission mode from dominating the touch event. In this case, the capacitance between the ITO electrodes and the finger (C_{DF} & C_{DS}) has to be small in comparison to C_{DS}, so that the human transmitter effect can be neglected. Thus,

$$C_{DS} >> C_{DF} \,\&\, C_{SF} \qquad (1)$$

and

$$C_{SF} \approx C_{DF} = \varepsilon \frac{A}{d} \qquad (2)$$

where A and d are the overlapping area and the separation between finger and electrode layer respectively.

Touch events can be detected by the drop in capacitance of C_{DS}, there are two methods to detect this change. The first one is to measure the voltage coupled at the sensing node. It requires the sensing circuitry to have high input impedance. The voltage of the sensing node can be given by

$$\Delta Vs = (1 + C_S / C_{DS})^{-1} \, \Delta V_D \qquad (3)$$

Thus C_{DS} is proportional to the AC component measured at the sensing node (ΔV_S). However, it is not useful because the signal obtained by this method is small and instantaneous. As well, fine control of C_{DS} and the stray capacitance C_S is also hard to achieve.

We adopted another method by measuring the change of charges flow. When a finger is placed close to the sensor, smaller amount of charges will flow through C_{DS}. Using a charge amplifier, or technically op-amp integrator, the charge flow can be stored and transformed into a readable voltage output. This output amplification can be tuned, as it is inversely proportional to the value of feedback capacitance in the charge amplifier circuit.

Both the direct drive and the multiplexing methods share the same concept in the controller unit. Figure 4 shows the system block diagram of the entire controller circuitry. After the charge amplifier circuit, signals are converted into voltage and are stored in a sample-and-hold circuit. An analog multiplexer is used to multiplex the signals into the ADC one by one for data conversion and analysis.

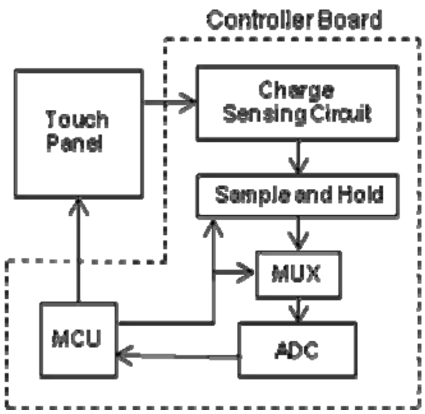

Figure 4. A system block diagram of the controller board circuit.

5. Results

An 8x8 multiplexing prototype touch panel has been made to verify the design concept. The panel has 8 parallel sensor electrodes, with each sensor surrounded by 8 sets of driving electrodes. The controller sends a driving signal to each set of driving electrodes one by one, while the non-driving electrodes are connected to ground. At the same time, the controller collects 8 data from the panel at the end of each driving. After the last set of driving is done, all together 64 data points will be obtained for a complete scan. The scanning rate can go to 100Hz, with a corresponding response time of 10ms. That will be fast enough for touch panel operation or tracking moving object on the panel.

Optical transparency is one merit of our proposed design, as panel structure involves only one layer of ITO. The transparency mainly depends on the thickness of the ITO layer. In this prototype, the ITO coating is 700A, and the measured light transmittance is 91%. Theoretically, higher light transmittance of up to 95% could be achieved with customization.

Figure 5 shows a drawing of the captured data when two fingers are put on the touch panel. Typically, a single touch could cover 4 to 5 sensors. Finger pressure, or more correctly the amount of skin area, is reflected by the drop in the charge amplifier output. These outputs were digitized, and hence, rescaled into output reading that is shown as depth.

According to the data arrangement, we could probably locate the hot spots. Image processing can be done for real time resolution enhancement. Some DSP algorithms such as sub-pixel interpolation have been reported [5,6]. But these operations require heavy processing power which are normally, accomplished by high speed controller ASICs clocked at hundreds of MHz. At this stage, we do not include that feature into our prototype. In principle, similar data processing can be done in our panel to achieve high resolution.

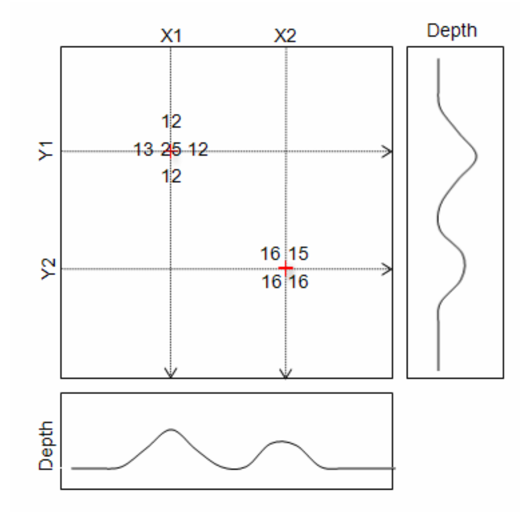

Figure 5. Data when touched by two fingers.

To ensure proper operation of the touch panel, we have to guarantee that it is operating in the shunting mode, instead of the human transmission mode. We calculated the critical separation between fingers and the ITO layer that is required to maintain shunting operation. From equations (1) and (2), if C_{DS} is 2pF, ε is 4 and the finger-to-electrode overlapping area A_{MAX} is $6x10^{-6}m^2$, the critical separation D_{MIN} is 0.1mm. The thickness of the protection glass is normally enough to prevent the transmission mode to dominate the effect. Table 6 summarizes the key specifications of the touch panel.

Summary of Key Specifications	
Resolution	8x8
Accuracy	< 5mm
Optical Transparency	91%
Response Time	< 10ms
Sensor Size	2.2” diagonal
Sensor Thickness	1.1mm
Touch Surface Thickness	Up to 3mm
Touch Methods	Finger, gloved hand
Surface Hardness	Glass
Interfaces	Serial
Controller	ATmega with custom-made system

Table 6. Summary of key specifications.

6. Advantages and Drawbacks

To be sure, there are certainly advantages and drawbacks in our design. Firstly, owing to the simple layering structure, high transparency of 91% has been achieved compared to 80% for traditional resistive touch. This is one of the main issues to mobile display for power-saving concern. Secondly, this is a low cost design that supports multi-touch function. Thirdly, the glass substrate used is resistant to scratch, resistant to chemical and uniformity over long duration of UV exposure. These factors are very important for durability.

However, limited size is a major issue in our proposed design. As panel size increases, more driving electrodes and sensing electrodes are required. This will increase the number of IO connections on the touch panel. One suggested solution is to use COG jumper to connect driving nodes together. So that the total number of external IO can be reduced, but this will certainly affect the cost.

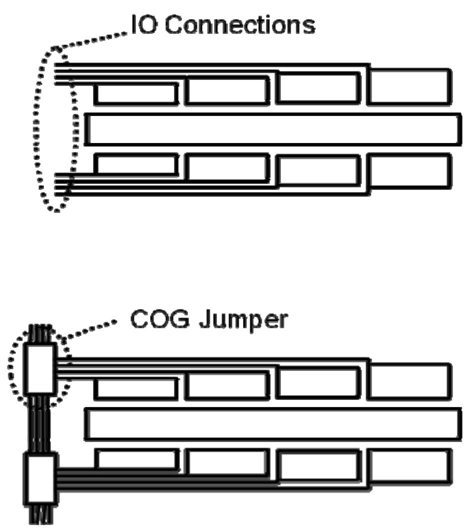

Figure 7. Example of adding COG Jumpers to reduce IO connection.

7. Conclusion

We have demonstrated a new touch panel that is capable of detecting multi-point touch event. The proposed touch panel is simple, has high optically clarity, low cost and durable. Such touch panel is particularly useful for small size and low power portable devices. It is also suitable for application specific LCD likes ATM or automobile display.

8. Acknowledgement

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9. References

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