Augmenting Capacitive Touch with Piezoelectric Force Sensing

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Abstract

In this work, force touch sensing is achieved in conventional capacitive touch panels, by employing piezoelectric materials. To achieve high sensitivity and stability in force detection, deep analysis of employing piezoelectric material in interactive displays is provided, together with possible solutions for piezoelectric principle related force sensing issues.

Author Keywords

Touch panel, piezoelectric material and force sensing.

1. Introduction

Force touch interactivity is a recent embedded function in commercial mobile phones. Detection of force in touch screen panels (TSPs) is mainly achieved by capacitive or piezoelectric means. In the former, a force touch event increases the capacitance value due to the decreased distance between the electrodes. In the latter, charges are generated due to the force induced strain. The amount of charge generated is proportional to the strength of the applied force. The converse is also possible in which the strength of force is deduced by integrating the measured charge induced [1].

In previous work [2], we reported that TSPs using a piezoelectric layer can provide higher force touch sensitivity than the capacitive counterparts. In this work, we provide design considerations when piezoelectric material is used in touch panels for force sensing (stack-up is conceptually shown in Fig. 1 (a), the corresponding equivalent circuit is shown in Fig. 1 (b)), together with corresponding simulation and experimental results.

2. Stress Non-uniformity over the Full Touch Panel

Due to the boundary condition of a touch panel, the response to force touch can give rise to different strain levels at different touch locations. This becomes an important design consideration when high uniformity of force touch detection is expected. In this section, simulation results from COMSOL are used for analysis.

A 5.5 in touch panel is investigated with 9×9 touch locations eventually distributed among the touch panel, as shown in Fig 2 (a). The touch panel's cross section is described in Fig. 2 (b). The electrodes are on and underneath the piezoelectric layer. As the thickness of the electrodes is much smaller than that of the piezoelectric layer and the glass panel, they do not influence the mechanical analysis and thus its neglected – see Fig 2 (b). The dimension of each layer of the touch panel is given in Fig. 2 (c). Their mechanical properties (e.g. Young's modulus) are described in [2]. From the simulation results shown in Fig. 2 (d), it is observed the stress values are higher near the supporting frames. Specifically, the highest stress value is 18.2 kPa, obtained at the four corner locations. In contrast, when the force touch event happens at the center of the touch panel, the induced stress value is only 6.4 kPa. The simulation results imply that a mapping table containing scaling factors is needed in order to achieve uniformity over the full panel.

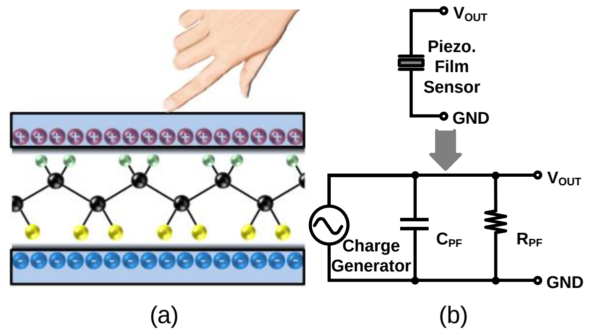


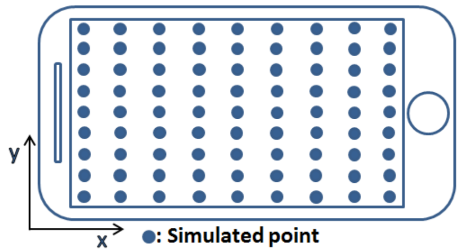
Figure 1. (a) Proposed sandwich structure for force sensing in an interactive display. (b) Corresponding equivalent circuit.

3. Force Touch Detection with Different Touch Directions

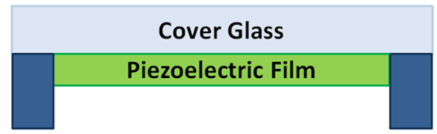
Two factors strongly influence the detection accuracy; charger noise and the direction of the force touch event. In this section, experimental results are provided to analyse the influence of these factors.

A test-bed is built as shown in Fig 2. It consists of three main components: touch panel position control system (Fig. 2 (b)), stable force source and accurate force sensor (Fig. 2 (c)). First, we examine how detection accuracy is influenced by the charger noise. A force touch signal of10Hz and 1N is used in the experiment. In Fig 2 (d), it is observed that the force touch induced signal maintains at a similar value (3.7V) even if the charger noise is strong (0.6V peak-to-peak). This is due to the frequency of the charger noise (50Hz), as it is a multiple of the frequency of the force touch event. The same value is added to the force touch induced signal, hence can be treated as a DC offset. However, if force touch signal is performed at indefinite time intervals, different charger noise values are added to the force touch signal, resulting in large fluctuation. This is demonstrated in Fig 2 (e). From the force sensor output, we see that force touches of similar strength values do not give the same response. The difference between the highest and lowest signals is 0.35V. Thus charger noise reduction techniques (e.g. correlated-double sampling [3]) are required to maintain the force touch detection accuracy.

As conceptually depicted in Fig 2 (f), when a user taps on a touch panel, the directions can be changed. This can result in different levels of stress on the piezoelectric layer. We investigate three angles, 90°, 80° and 70°. We can observe that the highest touch signal value is 0.67V when a 90° touch event is performed and then the signal value decays with the decrement of the touch angle, indicating that although users perform the same force strength, the system may give different output due to the change in the angle of force touch.



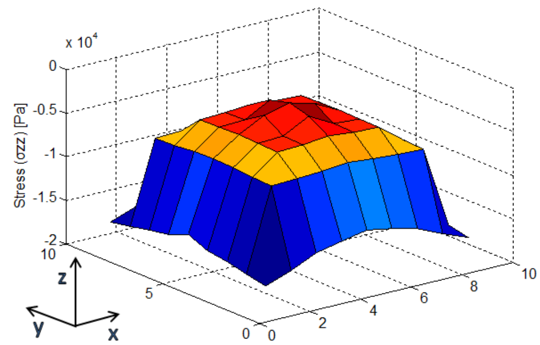
(a)



(b)

	Length	Width	Thickness
Cover Glass	122mm	70mm	0.5mm
Piezo. Film	122mm	70mm	0.1mm

(c)



(d)

Figure 2. (a) Simulated touch locations, 1mm radius touch object with 1N force. (b) Cross-section of the simulated touch panel. (c) Simulation parameters. (d) Simulation results with fully clamped boundary condition.

4. Static Force Touch and Stress Propagation from Adjacent Locations

Besides the non-uniformity force touch detection over the touch panel, there are two main issues waiting to be addressed when piezoelectric material is used for force sensing in interactive displays. First the piezoelectric material cannot detect static force touch events. This can be explained in Fig. 1 (b). As the equivalent circuit of the piezoelectric material based force sensor is a high-pass filter, the low frequency signal, especially DC signal (static force touch) cannot be delivered to the readout circuit. As conceptually depicted in Fig. 4 (a), although the force touch event lasts for a certain time period (from t1 to t1+Δt2), the force induced electric signal only exists for a shorter time period (from t1 to t1+Δt1), depending on the properties of the touch panel and force touch event. The experimental result shown in Fig. 4 (b) illustrates this situation. From the Fig. 4 (b), we can observe that only positive part of the force touch signal exists, when static force touch is applied. When the static force touch is released, the polarization of the piezoelectric material changes back, thus giving rise to the negative part of the force touch signal. Although using positive and negative components to interpret the existence of static force touch signal is possible, it is still very challenging to interpret a static force touch event when the force touch signal is released slowly.

The second challenge is the force touch induced stress propagation. When the force touch is applied to the touch panel at a specific location, the propagated stress at other locations can result in electric output. Although the propagated stress induced electric signal can be small, it is difficult for the system to distinguish if a light force touch happens or an adjacent heavy touch occurs, as conceptually shown in Fig. 4 (d). To provide customers good user experiences, issues of using piezoelectric material for force touch sensing in interactive displays need to be considered and addressed.

5. Summary

High sensitivity force touch detection is a critical demand for smart phones. This article successfully demonstrates force touch detection in a piezoelectric material based touch panel. To achieve high sensitivity and uniformity on force touch sensing, design considerations are provided. The work presented here has significant meaning in providing customers with advanced experience in force touch detection in interactive displays.

6. Acknowledgement

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7. References

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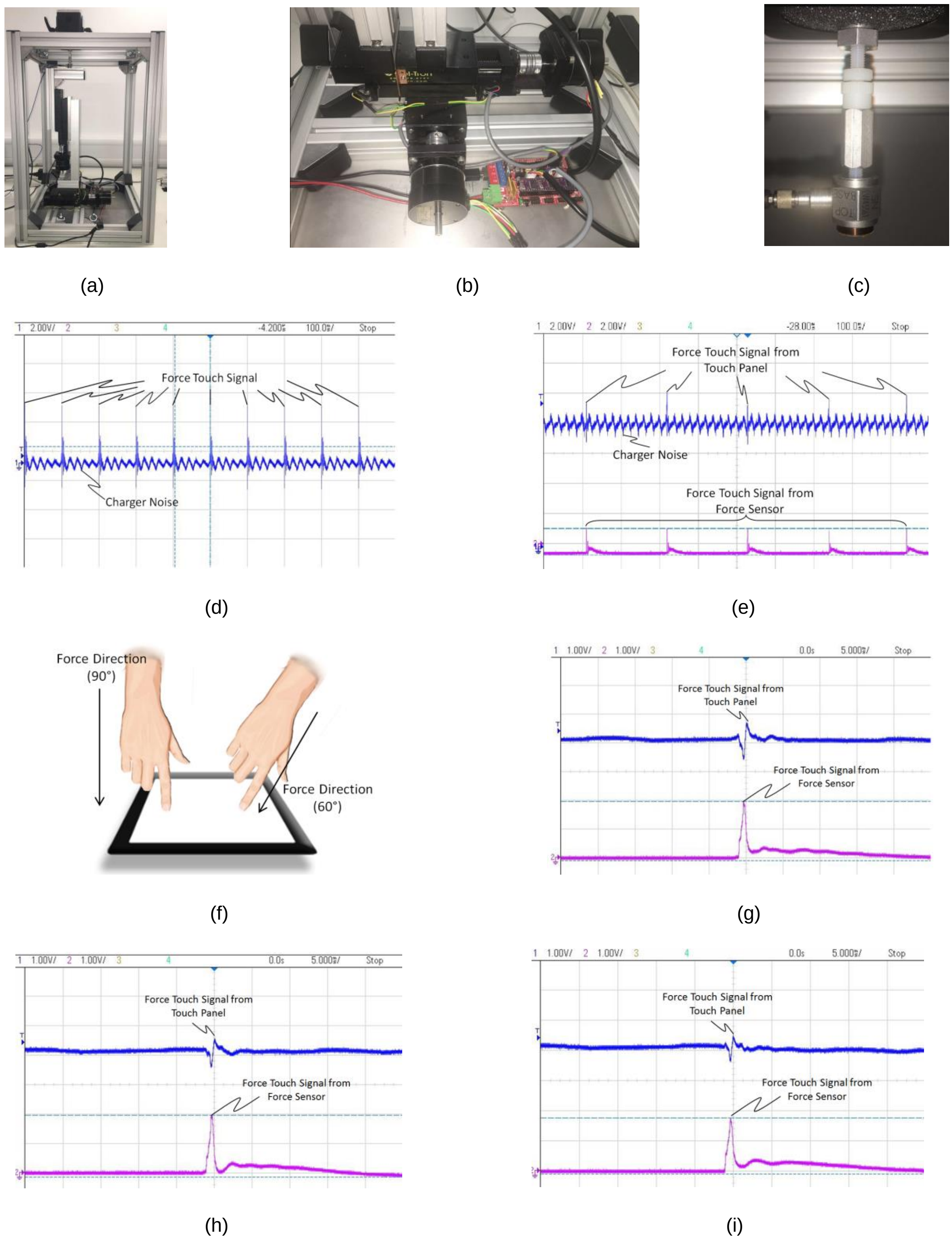
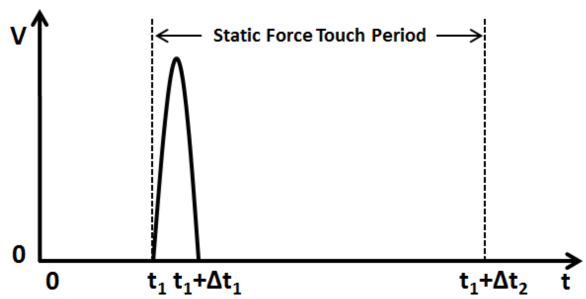
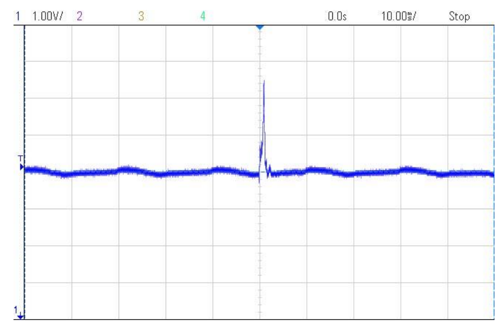


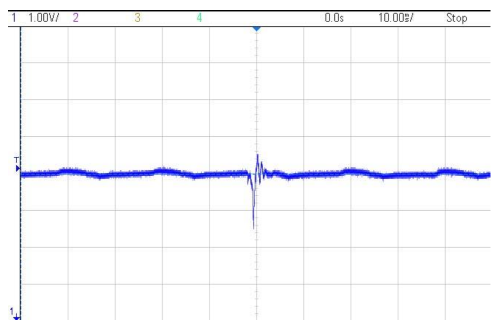
Figure 3. (a) Testbed. (b) Three-motor based position control system. (c) Shaker for stable force output and force sensor for accuracy force strength control. (d) 10Hz touch events with charger noise. (e) Randomly performed touch events with charger noise. (f) Conceptually depicted scenario of the same force strength from different angles. (g) Experimental result of 90° performed touch event. (h) Experimental result of 80° performed touch event. (i) Experimental result of 70° performed touch event.



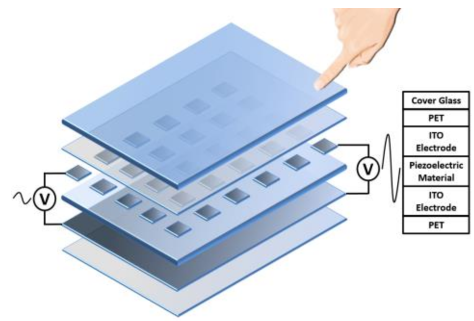
(a)



(b)



(c)



(d)

Figure 4. (a) Conceptual depiction of the relationship between static force touch and its induced electric signal. Experimental results of a static force touch; (b) press action and (c) release action. (d) Conceptual depiction of issue of stress propagation.