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Efficient Multi-Touch Detection Algorithm for Large Touch Screen Panels

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** Short Paper*

***Abstract*:** Large mutual capacitance touch screen panels (TSP) are susceptible to display and ambient noise. This paper presents a multi-touch detection algorithm using an efficient noise compensation technique for large mutual capacitance TSPs. The sources of noise are presented and analyzed. The algorithm includes the steps to overcome each source of noise. The algorithm begins with a calibration technique to overcome the TSP mutual capacitance variation. The algorithm also overcomes the shadow effect of a hand close to TSP and mutual capacitance variation by dynamic threshold calculations. Time and space filters are also used to filter out ambient noise. The experimental results were used to determine the system parameters to achieve the best performance.

***Keywords*:** Mutual capacitance, Detection algorithm, Multi-touch, Touch screen, Projected capacitance

1. Introduction

Capacitive touch screens are currently the most popular touch screen panels (TSP). Among the different types of capacitive TSPs, projected mutual capacitance TSPs are used most widely for middle-sized and small-sized mobile products, and are currently used in large PC monitors and TV screens. They have superior visibility and durability and have a multi-touch function. In mutual capacitance TSPs, touch detection is determined by measuring the change in the mutual capacitance [1, 2], which is susceptible to ambient noise. Ambient noise can be divided into two types; random and periodic. Random noise includes fluorescent noise and various ambient electromagnetic waves, whereas periodic noise includes display noise caused by VSYNC or HSYNC signals. Some issues of TSPs that affect their performance remain to be addressed. The dissimilarity over TSP and its high sensitivity to close objects also degrades their performance [1]. Therefore, this type of TSPs has a low signal-to-noise ratio SNR. Some ambient noise has such a great effect that the detection algorithm can recognize it as a touch event. Hardware for different controllers have been developed to overcome noise issues [3, 4] but this paper proposes a software algorithm. This paper is organized as follows. Section 2 presents the touch screen controller system and the sources of noise. A multi-touch detection algorithm is discussed in section 3. Section 4 provides the experimental results of the controller system. Finally the conclusions are presented in section 5.

2. Touch Screen System

Fig. 1 shows the controller testing a large mutual capacitance TSP (44×78 lines of silver nanowires) of 23 inches. The touch screen controller is a transceiver that sends a sequence of pulses to each TX line (row) and senses the signal over each RX line (column) to detect any difference in crossing the mutual capacitance between each TX and RX line. The driven signal is a sequence of pulses and the sensed signal has a spike shape, as shown in Fig. 2. The RC time constant of each line of a touch screen panel determines the value and shape of the output signal, which

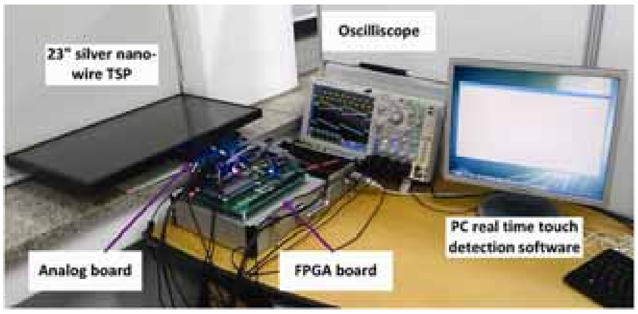

Fig. 1. Touch screen panel controller system.

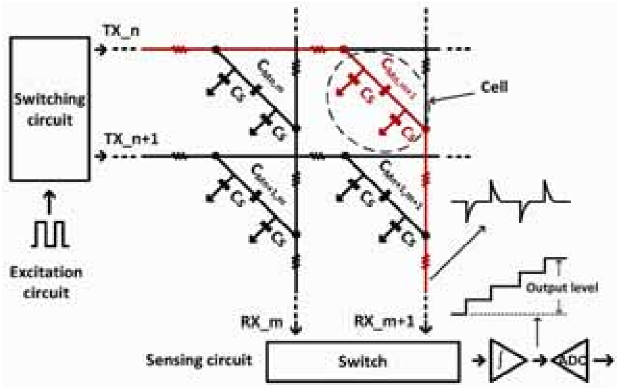

Fig. 2. Equivalent circuit of a selected block of TSP.

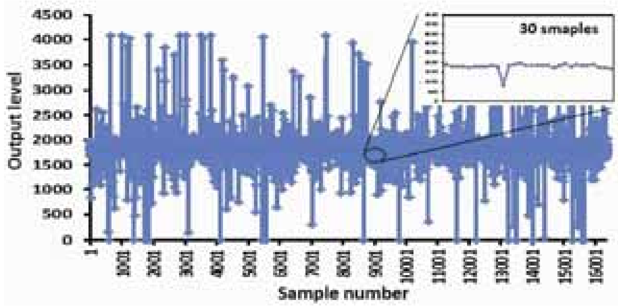

Fig. 3. Fluctuations of sensing data for one tested cell of TSP: 16000 samples within 51.2 msec are measured to analyze noise characteristics of TSP.

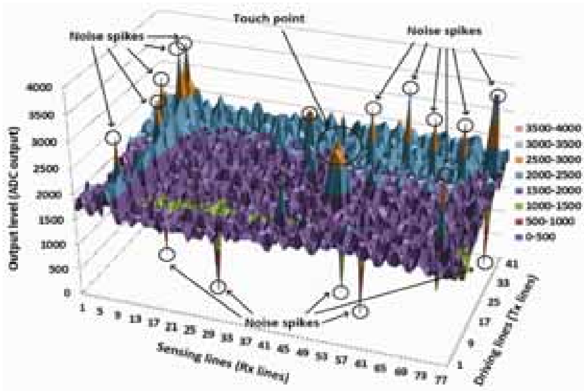

Fig. 4. Output level for one frame of the entire TSP showing the difference between the noise spikes and touch point.

results in output dissimilarity over the RX lines.

2.1 System Description

In this study, a controller consisting of Xilinx FPGA (Zynq) with an ARM Cortex A9 CPU for digital control logics, ADC and DAC, and an analog front-end circuit board that contains analog switches and sensing circuit was developed. The software algorithm was uploaded into the memory blocks inside FPGA and used by ARM CPU to detect the touch points and send them to a PC through a UART connection. Fig. 1 shows the controller testing a large mutual capacitance TSP (44×78 lines of silver nanowires) of 23 inches, and Fig. 2 shows the TSP equivalent circuit and input/output signals.

2.2 Noise Analysis of TSP

As described previously, the touch detection performance of mutual capacitance TSP is degraded substantially by the following three factors: Ambient noise, dissimilarity of resistance and capacitance of each input to the output path, and the sensitivity of mutual capacitance for close objects.

2.2.1 Dissimilarity of mutual capacitance over the entire TSP

Each TX and RX line can be considered a series of resistors and their cross section is a mutual capacitor. The mutual capacitance (C_M) varies over the TX and RX lines due to TSP manufacturing variations, whereas the wire resistance of each cell changes due to different TX and RX line lengths. Therefore, every cell has different capacitance and wire resistance, as shown in Fig. 2. This affects the output level of the cell tested due to a change in the charging/discharging time constant.

Sometimes a change in mutual capacitance from a cell to another over an entire TSP is larger than the change in capacitance due to a touch event. In this case, the required voltage range is large, which makes the design of the sensing circuit and ADC more difficult. Moreover it increases the algorithm complexity to overcome the problem of dissimilarity.

2.2.2 Ambient Noise

Random noise and periodic noise have some properties that are sometimes similar to a touch event. Therefore, it has a great effect on the touch screen performance, as shown in Fig. 3. Large spikes of noise affect the tested cell in a short period of time < 4.6 μsec (time span of 1 ~ 2 samples). In this experiment, a 12bit ADC of range 0~4095 and driving signal frequency 1.25 MHz with 2 integration steps have been used.

The level difference of the touch and un-touch cases is ~800 for the installed system, whereas noise spikes have higher magnitudes, as shown in Fig. 4. Noise spikes also affect smaller areas than a finger, which that can be

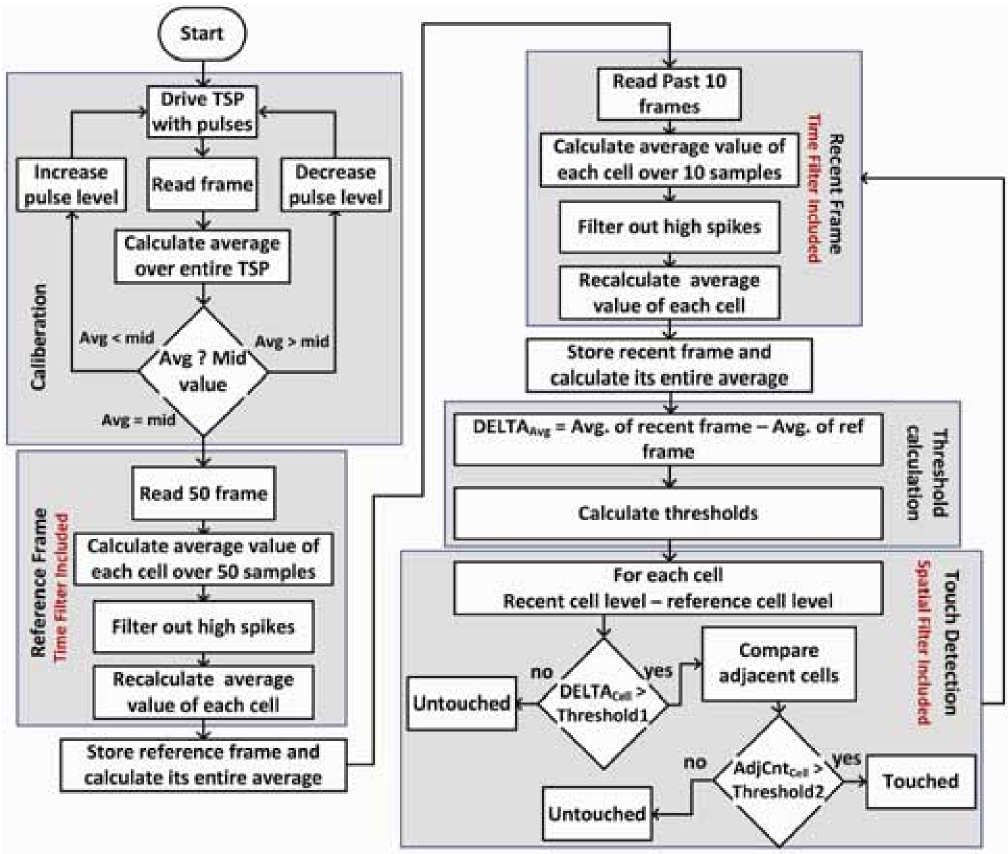

Fig. 5. Flow chart of the developed algorithm.

observed in Fig. 4.

2.2.3 Shadow effect

When the human body comes close to a certain area of TSP, its entire mutual capacitance changes slightly. Therefore, it may appear as if the entire TSP is partially touched. On the other hand, a touched finger causes a larger change in mutual capacitance that makes touch detection possible.

Touching a TSP with more fingers (two or more) causes a larger change in mutual capacitance in a larger area that makes the touch detection more difficult because all mutual capacitances varies greatly from the nominal values. This effect can also alter the difference level between the touched and un-touched conditions, which cause a malfunction of the system. This problem requires changes to the default parameters of the detection algorithm to work on that difference to determine the touched cells.

3. Multi-Touch Detection Algorithm

This section presents a touch detection algorithm that overcomes the performance problems described above. Fig. 5 presents the developed algorithm. The algorithm has a flow of a few steps to detect the difference in mutual capacitance of each cell.

The algorithm begins with a calibration step to overcome the TSP dissimilarity followed by generating a reference frame representing the idle (untouched) case. Subsequently, the controller begins to read a recent frame and calculate the threshold values. Finally it ends by comparing the recent and reference frames to determine the touched points. The following describes each step:

Calibration Step: The algorithm begins with a calibration step to adjust the voltage of the TX driving signals to fit the range of RX sensing circuit outputs throughout the TSP within the dynamic range of ADC. Using this step, the touch screen controller can drive different TSPs of a large manufacturing variations without a manual calibration.

Reference Frame Construction: This comprises a reference frame of the entire TSP, which represent a nominal un-touched frame to be used for comparison with each recent frame to detect the touched area.

Because of the dissimilarity of the mutual capacitance over TSP, representing un-touched case with one value, is not possible. Therefore, the reference frame needs to read and store the nominal values of the untouched case.

Time Filter: As analyzed above (Fig. 3), ambient noise affects random areas over the touch screen for a short period of time (2 samples at maximum). Therefore the moving window size for the time filter is chosen to be 10 consecutive frames (Fig. 6(a)) for accurate results without sacrificing the required detection speed (200Hz). The time filter removes the high noise spikes that have a large effect on the actual sensing signals.

Spatial Filter: The noise analysis in Fig. 4 shows that

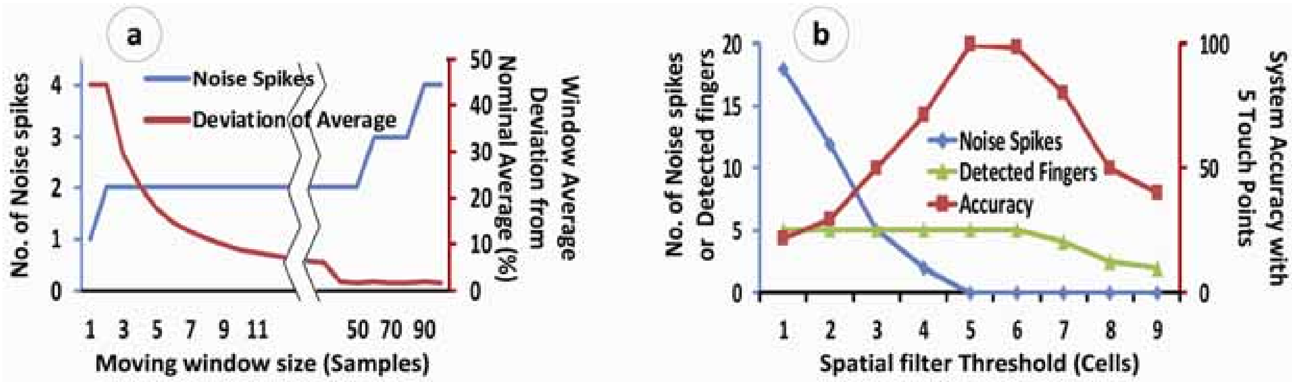

Fig. 6. System response with different time and spatial filter window sizes (a) Number of noise spikes appearing in the time filter of various window sizes, (b) Touch accuracy with spatial filter used to filter out noise.

the finger touches normally cover a larger area than the noise spikes. The analysis shows that the noise spikes affect one to three adjacent cells, whereas a finger touch affects more than five adjacent cells. A custom spatial filter was developed to evaluate the adjacent cells of each tested cell and determine the cell as noise if the number of adjacent cells with a large value is below a threshold. Through extensive experiments, it was found that a spatial filter size of 9 cells and a spatial filter threshold of 5 gave the optimal touch detection performance (Fig. 6(b)).

Dynamic Threshold Calculation: A variable threshold can effectively overcome the shadow effect. The algorithm calculates a dynamic threshold by taking the difference between the recent frame average and reference frame average. This is a variance value that compensates for the entire capacitance value fluctuations of the TSP caused by multi touch or human body proximity.

4. Experimental Results

This section presents some experimental results of the system shown in Fig. 1 based on the extracted parameters of time and spatial filters described in Fig. 6.

Through the experiments shown in Fig. 6(a), one selected cell has been driving with a sequence of pulses of 1.25 MHz and tested consecutively with two steps of integration. As a result, the deviation from the nominal average value decreased with increasing window size. A window size of 10 samples or more gave an average deviation below 10%, which ensured acceptable performance.

Fig. 6(b) presents the touch accuracy with a spatial filter used to filter out noise. This experiment was performed with five fingers touching the TSP. Changing the filter window size affected the performance of the system. The accuracy was a maximum (100%) with a threshold of 5 cells. The accuracy decreases with a threshold beyond 5 because the spatial filter begins filtering out some fingers.

Fig. 7 shows the extracted touch points for running the algorithm with five touch points.

Fig. 7. System response with five fingers touching the TSP.

5. Conclusions

The effects of various sources of noise on capacitive TSPs were analyzed, and the measured noise samples were characterized. The proposed touch detection algorithm overcomes serious problems of large TSPs; ambient noise, shadow effect, and the dissimilarity of mutual capacitance over the entire TSP. The experimental results showed that the proposed time and special filters remove large noise spikes. The dynamic threshold calculation alleviates the shadow effect, and automatic calibration scheme overcomes mutual capacitance variation of the TSP.

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