Design of a Detection System for Projected Capacitive Touch Screen based on PSoC

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***Abstract* — This paper presents a two-chip control scheme based on Programmable System-on-Chip, PSoC, for a projection detection system of touch screens. It uses cross scanning scheme technology with data processing to change the value of mutual induction converted into a capacitance change of the system clock period numbers. This paper describes the testing methods, hardware architecture, a touch point positioning algorithm, a multi-point touch algorithm and data analysis of the results of the whole system.**

Keywords - projected capacitive touch screen; ITO; mutual capacitance; ghost; multi-touch

I. INTRODUCTION

Touch screen has been widely used in mobile phones, PAD and computers. Touch screen can be divided into resistive, capacitive, infrared and surface-acoustic wave based on the induction principle [1]. Capacitive touch screen has the advantage of wear-resistant, long life, low power consumption, high sensitivity, noise rejection capability and support for multi-touch. When a finger or other conductor is near the projected capacitive touch screen, electric field at the touching point will be affected, resulting in increasing in the self-capacitance and reducing in the mutual capacitance at touch point.

This paper proposes a two-chip control program. It used a cross scanning technology and data processing to convert the change of the mutual induction capacitance into a change in the system clock period number.

II. STRUCTURE OF PROJECTED CAPACITIVE TOUCH SCREEN

In this paper, the typical diamond-shaped projected capacitive touch screen panels is taken for example, and changes in the electric field of the touch is analyzed. Diamond projected capacitive touch screen is shown in Figure 1. The touch screen is three-layer structure: the intermediate layer is an insulating layer, the upper and lower layers are indium tin oxide (ITO) layer. Capacitive touch screen ITO is M row diamond induction piece of string and N column diamond induction piece of string embedded sequence and into each other, a row or a column of ITO diamond induction piece of string to ground capacitance of the capacitor, a row and a column about the intersection of ITO diamond induction block the capacitance between the mutual capacitance. Thus, a total of M + N self-capacitance and M * N mutual capacitance. Whether it is collected from the self-capacitance or mutual capacitance, it requires M + N lines connected to the control chip.

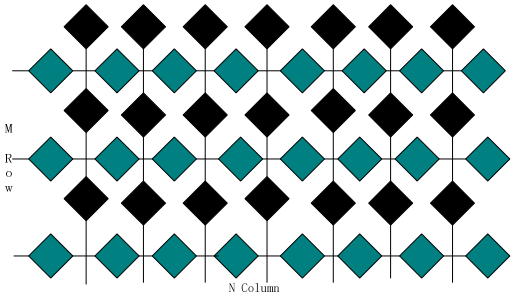

Figure 1. Plan view of diamond projected capacitive touch screen

For the self-capacitance, when fingers touch sensitive piece of grounding body, the human finger is a conductor and is equivalent to the capacitor in parallel with a finger capacitance CF, therefore, the self-capacitance increases; For mutual capacitance, when fingers are close to or touching the touch screen, because the human body finger acts as a conductor, from the original transferring block to the receiving block, part of the electric field or power line is induced to transfer to the finger, so the electric field or power lines between the two sensing blocks is weakened or reduced, equivalent mutual capacitance reduction. Anyway, fingers touching the induction to the self-capacitance and mutual capacitance has distinct effects, and self-capacitance increases with the mutual capacitance decreasing.

III. DETECTION METHOD FOR MUTUAL CAPACITANCE SENSING VALUE

Mutual capacitance value of the touch sensing module may be obtained from cross-scan. Count value of each sensor is obtained by cross-scanning within an interval of time, and through the software whether there is a touch of a finger is determined by the change of the count value. So, scanning the entire screen will scan all the intersection totally for M * N times.

Each intersection block of rows and columns themselves are self-capacitance. There is mutual capacitance between

rows and columns. Sensing module also has a block resistance. The self-capacitance of an unit block of rows and columns are, respectively Cr and Cc. The mutual capacitance of the rows and columns is expressed as Crc. The sensing resistor block are represented by Rr and Rc of rows and columns . The unit block model and circuit model are shown in Figure.2.

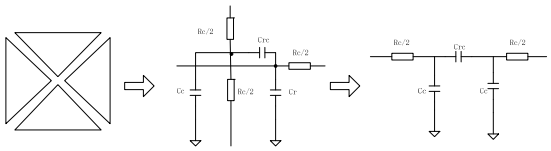

Figure 2. Unit block model and circuit model.

A high frequency square wave excitation signal is sent to the line X screen driven by the PSoC chip. Since the mutual capacitance exists, the screen may receive the same frequency signal as the transmitted signal at the column Y. Mutual capacitance at the intersection of row and column Cm is approximately equal to Crc. Self-capacitance of rows and columns are no longer Cr and Cc, but the equivalent self-capacitance Csr and Csc; Resistance of rows and columns is no longer Rr/2 and Rc/2, but from the emission of the line to the intersection line resistance Rsr and from receiving endpoint to the intersection column resistance Rsc.

The column Y receives the signal as same frequency as the transmitted signal from the line X, at the same time, there is an alternating current from row Tx to row Rx. The size of the alternating current is directly related to the mutual capacitance Cm. The greater Cm is, the greater current is, on the contrary, the smaller the current is. The alternating current into direct current through the rectifier/filter. The direct current is converted into a direct voltage through the I/U conversion. The direct voltage is converted into a digital signal by the A/D conversion . The data processing converters the change in the value of Cm into the change the of the system clock period. Acquisition principle diagram of mutual capacitance Cm is shown in Figure 3.

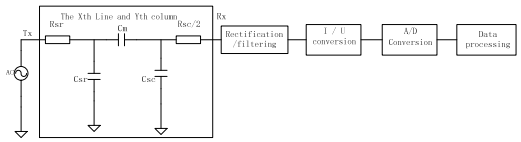

Figure 3. Acquisition principle diagram of mutual capacitance Cm.

When a finger touches the touch screen, Cm reduces and self-capacitance Csr and Csc increased. Reducing of mutual capacitance and increasing of self-capacitance result in decreases in the current from row Rx to row Tx, and ultimately the value of A/D conversion is reduced. PSoC chip software control cross point scanning circuit make it all cross points on the screen to scan and monitor each intersection of A/D conversion values. If it exceeds a preset threshold value, there is considered to have a finger touch. The signal size of the intersection, combined with the size of the adjacent intersection signal changes to a finger touch position to pinpoint. [2]Because transmission and reception are sharing proceed, it can eliminate "ghost" to achieve the two more simultaneous touch.

IV. HARDWARE DESIGN OF PROJECTION TOUCH SCREEN DETECTION SYSTEM

A. Hardware Design of Detection System.

The Design of the detection system uses a dual-chip control program. the controller of the Capacitive touch screen group use PSoC chip FT5206 based on 8051,and the host MCU use the chip 8051.Hardware system diagram is shown in Figure 4.

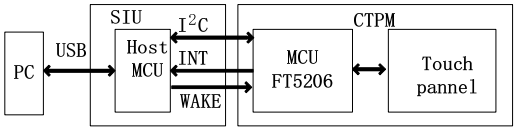

Figure 4. Diagram of Hardware system in detection system .

In the Figure 4, CTPM is capacitive touch screen module, and SIU is adapter board of SPI/I2C/UART signal converting into USB signal. The design uses I2C converting to USB.

Working process of hardware system: when a finger touches TP touch screen, the touch is detected by FT5206, getting the packet of a frame of touch resulting; FT5206 sends the INT (interrupt) signal to MCU in the SIU, and notices the MCU to receive the data in the SIU. Via a serial port, CTPM sends the I2C data of touch packet to the SIU board, at the same time the MCU in SIU feedbacks a WAKE (WAKE up) signal to FT5206, makes FT5206 change from sleep mode into active mode, and SIU puts data to the PC by USB, PC for users to analyzing data. PC puts data to SIU board through the USB interface. SIU board transfers I2C data to CTPM through the serial port.

B. Framework of PSoC FT5206MCU.

The program design, the PSoC of touch screen control chip for the acquisition mutual capacitance Cm is FocalTech company's FT5206. The internal chip includes a AFE controller, a DSP, a Modulator and Demodulator, as well as the Tx and Rx module, containing 12 successive approximation ADC, have the I2C serial port or SPI or UART, support 3.8 inches below the touch panel, which can realize real multi-touch within five and can get 15*10 of mutual capacitance data. The chip MCU module has compatible enhancements on the basis of 8051: There is a large program and data memory support; in addition, multiplication and division to accelerate the implementation of MDU and touch detection algorithm; Flash ROM storage program and some of the key parameters. Communication protocol software runs on the microcontroller to help achieve the exchange of data between host processors, running on the microcontroller firmware on the complex signal processing algorithms to further process the received capacitance signal, detection is stable and reliable. [3] FT5206 MCU architecture is shown in Figure 5.

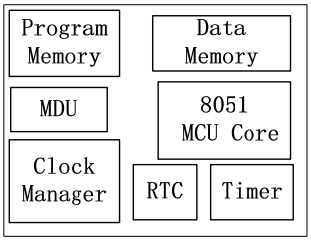

Figure 5. FT5206 MCU architecture.

V. TOUCHING COORDINATE POSITIONING ALGORITHM OF CAPACITIVE TOUCH SCREEN

Current drawn from the four sides of the touch is as the output current of capacitive touch screen, and the model is shown in Figure 6.

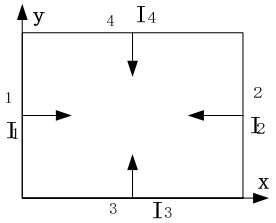

Figure 6. Model of current input.

The touch panel is surrounded by four straight electrodes 1-4. Capacitive touch screen get a high frequency voltage source at work. Four electrodes output current is set by I_1、I_2、I_3 and I_4 .The size of the touch panel is $L_1 \times L_2$ .The electrode junction 1 and 3 of the coordinate is origin and their positioning coordinates conversion formulas is shown in formula (1).

$$\begin{cases} x = L_1 \dfrac{I_2}{I_1 + I_2} \\ y = L_2 \dfrac{I_4}{I_3 + I_4} \end{cases} \tag{1}$$

If choosing center coordinate origin of touching face, the coordinate conversion formula is positioned as formula (2).

$$\begin{cases} x = \dfrac{L_1}{2} \dfrac{I_2 - I_1}{I_1 + I_2} \\ y = \dfrac{L_2}{2} \dfrac{I_4 - I_3}{I_3 + I_4} \end{cases} \tag{2}$$

VI. MULTI-TOUCH ALGORITHM

By some intelligence judgment, the step design recognition algorithm can focus efficiently search for the correct solution in the solution composed of multiple solutions, and projected capacitive touch screen will need to detect finger touch sensing in a set of multiple sensing electrodes. Therefore, the step design recognition algorithm is applied to projected capacitive touch screen to improve the detection efficiency of projected capacitive touch screen.

Principles of the step design recognition algorithm: In the value not exceeding the scope of the premise capacitive screen, from touch-screen center and the periphery, we began to draw lines to identify multi-touch. Set the touch screen boundary coordinates (x1, y1) and center coordinates (x2, y2) as the starting coordinates, calculating coordinates increment, set the single-step direction, set up the search step length L for maximum value, set up horizontal and vertical line, select basic incremental coordinates, then the search step length L according to the geometric pattern of male than for a 1/2, until the end of the step length L fell to 1 search, which, in turn, determine whether there is a touch point on the touch screen and touch point of recognition.

The first step is to set the longest search step length L for step length, the first comprehensive search, and make a note of its maximum position.

The second step is to reduce the longest search step length L, and make the maximum position as departure station. Select the second sequences for the second full search to write down its maximum position.

The third step is to search repeatedly until the search step length L down to 1. At the end of the search it returns the last search the maximum position for the final result and calculate the testing number [4].

The step design recognition algorithm can effectively eliminate misjudgment by the local extreme result and make the system can find the global maximum value accurately and reliably to prevent certain local interference.

VII. CONCLUSION

RawData is unprocessed raw data by each node coordinate collecting when CTPM is in factory mode, RawData is adjusted by offset; DiffData is the difference between the data at each point of the original data and data obtained by subtracting the Base, that touch the amount of change, adjusted by the feedback capacitor Cap_internal[5-7]. When Cap_internal changes, usually RawData will change, but RawData mainly is controlled by the Offset parameter. RawData is shown in Figure 7.

RawData	1	2	3	4	5	6	7	8	9	10	Offset
1	7834	7818	7706	8337	7548	7744	7422	7731	7627	7669	0
2	8079	7978	7766	8494	7777	7978	7695	7987	7924	8006	0
3	8093	7997	7774	8518	7813	8000	7719	8014	7932	8019	0
4	8109	8014	7803	8540	7831	8016	7742	8041	7975	8044	0
5	8132	8049	7817	8554	7851	8031	7756	8043	7996	8053	0
6	8155	8060	7824	8577	7879	8043	7772	8065	8024	8088	0
7	8171	8094	7842	8581	7896	8058	7791	8088	8070	8105	0
8	8280	8145	7880	8630	7930	8077	7808	8072	8024	7912	0
9	8300	8164	7903	8647	7953	8109	7829	8096	8068	7974	0
10	8316	8186	7928	8660	8009	8145	7862	8131	8105	8005	0
11	8330	8198	7897	8647	7989	8128	7856	8125	8114	8008	0
12	8329	8207	7916	8647	7959	8085	7828	8111	8091	7998	0
13	8317	8210	7915	8640	7982	8098	7814	8096	8078	7982	0
14	8295	8019	7977	8658	7802	8131	7843	8141	7877	7959	0
15	12323	7880	12269	12593	8013	12317	12137	12402	8202	12431	0
Offset	0	0	0	0	0	0	0	0	0	0	95.3%

Figure 7. RawData.

From the above chart shows that data adjustment accurate was 95.3%.The majority of RawData value standard

quiescent point is near 8000 that meets acquisition value to fall within the range of 7,000 to 10,000, only a small part of the value is not within this range, so the touch screen portion of the raw data processing is to meet the requirements.

For the product FT5x06, when no hand to touch the test data, the feedback capacitance is set to 0, but there are still a touch variation, there is error. So the touch variation value needs to be improved. DiffData change is very small, for the influence of the touch screen is very small[8-10].

When the fingers, as a result of Tx feedback capacitance (aucRowCAC) and the change of the Rx feedback capacitance (aucColCAC), cause DiffData data changes. Keep our capacitance under 40, after touching DiffData values increase with the increase of capacitance, shown in red area. In accordance with our touch capacitance change, after DiffData change request.

Whether the single-touch or multi-touch, can be identified. The resulting multi-touch tangible results is shown in Figure 8.0.

Differ	1	2	3	4	5	6	7	8	9	10	Cap
1	-52	-46	-48	-44	-46	-52	-53	-57	-70	-95	0
2	-41	-45	-47	-39	-38	-41	-36	-44	-52	-64	0
3	-43	-49	-43	-37	-28	-16	22	-28	-45	-56	0
4	-39	-66	-63	-36	-22	158	467	141	-29	-55	0
5	-34	-25	-29	-25	-11	90	399	237	-2	-48	0
6	-12	141	91	-19	-24	-30	-16	0	-15	-49	0
7	14	482	463	13	-25	-49	-60	-39	-29	-49	0
8	-12	64	132	1	-19	-33	-37	-32	-15	-41	0
9	-26	-14	-12	-18	-18	-27	-20	-21	-10	-35	0
10	-40	-24	-24	-27	-16	-27	-20	-21	-10	-29	0

Figure 8. DiffData change after Multi-touch.

ACKNOWLEGEMENTS

This work was funded by the project funds of Hainan Provincial Science and Technology Department, (No. 2015SF33, 20156226，20156228).

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