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The Design of Paper Calculator based on Capacitance Sensor

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Abstract

In order to improve the precision of paper packaging, a paper counting display device was designed based on STC12LE5A60S2 and capacitance sensor chip FDC2214.By measuring the capacitance variation caused by the different number of paper between two copper-coated plates, a regression algorithm was used to linearly fit the data, and the precise number of paper was realized.The results show that the maximum measuring range of this design is 0-70 pieces of A4 paper, and the maximum error is an average of 15 times of 1 counting deviation, and the deviation degree is not more than ±1 piece.

Keywords

Paper Counting; Capacitance Macro Measurement; Single Chip Microcomputer.

1. Introduction

The traditional paper measurement method is mostly to measure the thickness of a certain number of paper, and then count the number of sheets, with the thickness divided by the number of sheets can be obtained a piece of paper thickness.On this basis, if you want to know the number of paper, you need to measure the thickness of the unknown paper, and then divide by the thickness of a piece of paper to calculate the number of paper, this process is time-consuming and laborious, and there is a relatively large error, poor reliability[1-2].

As a means of measuring micro-displacement, capacitance micro-measurement technology has been widely used in recent years, especially in the field of micro-size measurement, and is gradually becoming an important direction of measurement research[3-4].Capacitive sensors have the advantages of good stability, high resolution, simple structure, high sensitivity and indirect contact measurement. They are widely used in thickness, pressure, displacement, acceleration, liquid level and other measurement environments.

This paper introduces a paper counting display device based on STM32 microcontroller and capacitance sensor chip FDC2214, through the circuit design and algorithm writing, to achieve precision paper counting function, will measure the number of accurate display, to achieve the purpose of precision measurement paper.

2. System Scheme Design

The whole device is divided into three modules, capacitor board, FDC2214 evaluation board, STM32 MCU. The capacitance board is mainly composed of two square metal plates with the same specification frame of 5 cm. Its main task is to act as a sensor for the change of the number of paper, to sense the change of the number of paper, and transfer the information to the next link. It will be used in combination with the FDC2214 capacitance sensor.

The FDC2214 capacitance sensor detects the change of paper quantity and returns the detected value to the MCU. STM32 microcontroller mainly processes the data transmitted by FDC2214, and then eliminates the interference through self-calibration algorithm, calculates the number of paper through questionnaire and function correction method, and sends the final result to the serial screen. The serial screen is a man-machine interaction module, which can display the

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data of the single chip microcomputer and return the data of the single chip microcomputer. The overall design scheme is shown in Figure 1.

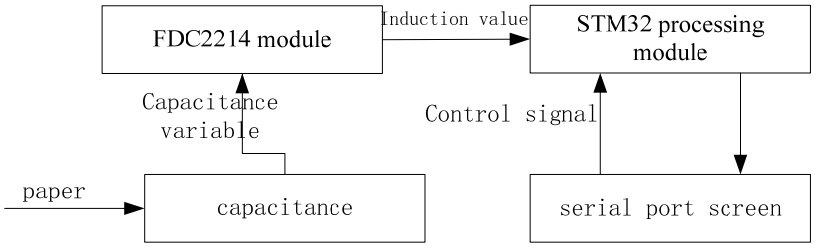

Figure 1. Paper counting design scheme

2.1. Hardware Module Design

The paper test area of the display device is a planar capacitance sensor composed of two parallel plates, which is responsible for detecting the change of capacitance value between the two plates. It is transmitted to FDC2214 module through wires. After calculation, FDC2214 module sends the detected paper capacitance value data to the single chip microcomputer, which can identify and judge it. Transmit the results to the LCD display. The operation of calibration and measurement is controlled by external buttons.

Two channels in the capacitive sensor module are used for data acquisition, which effectively saves system resources and improves system operation efficiency. Even in a noisy environment, the performance of the chip does not change due to environmental reasons. The input end of the resonant circuit is connected with the inductor and capacitor, forming the LC resonant circuit, generating the oscillation frequency, and calculating the measured capacitance according to the change of the frequency value.Refer to the chip manual [5], in which the capacitance calculation formula is:

$$C_{SENSOR} = \frac{1}{L*(2\pi * f_{SENSORx})^2} - C \tag{1}$$

the frequency of FDC2214 sensor is expressed as:

$$f_{SENSOR\ x} = \frac{CHx\_FIN\_SEL * f_{REF\ x} * DATA\ x}{2^{28}} \tag{2}$$

$$DATA_{\ x} = \frac{f_{SENSOR\_X} * 2^{28}}{f_{REF\_X}} \tag{3}$$

STM is responsible for signal processing and coordinated control of the whole system. The device is designed with two different modes of calibration and measurement for users to choose from. When in calibration mode, the measurement and display circuit can realize the "self-calibration" function of the device and short circuit detection, that is to say, before the formal test, need to obtain the calibration information of the measurement; When the device is in the measurement mode, accurate detection of any number of paper can be realized by keystroke control. After a period of limited training and correction, the paper number in the counting device can be measured and judged accurately.

2.2. Soft System Test Solution

(1) Press the "self-calibration" button to measure the number of papers placed between the two plates of 1., 5, 10, 20, 30, 40 and 50, and then adjust the corresponding data.

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(2) short connect the two plate AB electrodes to see whether the display will show short circuit and the buzzer sound.

(3) put different paper between the two plates, gradually add from a start, has been added to ten sheets, in each increase of paper, need to be fixed plate, then start the measurement, first observe the number of measured paper shown, whether the buzzer sound prompt, repeat this measurement ten times, Each recording needs to record the time from the button to the buzzer.

(4) Measure the given number of sheets ranging from 10 to 30 between the two plates. The test procedure is the same as (3).

(5) Measure more than 30 sheets of paper between the two plates. The test procedure is the same as (3).

3. Test and Result Analysis

3.1. Test Steps

(1) Check the circuit. Before the test began, we first connected all the test instruments. Circuit connection energized after a period of time to see the whole circuit short circuit phenomenon, for a period of time after the circuit run normally, if the screen flickers press reset after will stop flashing, first of all, before starting the calibration data will direct contact between two plates, if the screen short circuit the normal operation of the whole circuit can be completely.

(2) calibration. During calibration, the left and right keys are used to add and subtract and change the number of sheets, and the down key is used to change the function key. During data calibration, the product needs to add up one sheet by one. When the number reaches 70 sheets of A4 paper, press the middle key to confirm, and press the key to save the calibration amount.

(3) Measurement. After the paper calibration data is saved, the paper quantity test shall be conducted. Every time A4 paper is placed, the test shall be conducted by pressing the middle key between the upper plate and the paper pressing point, and the test results will be displayed on the LED screen.

3.2. Results Analysis

50 pieces of standard A4 paper were measured, among which the test results were divided into three categories, the accuracy of the test within 10 pieces of paper, the accuracy of the test within 10 to 30 pieces of paper and the accuracy of the test over 30 pieces of paper were counted, and the following three tables were made for statistical comparison of the obtained data.

First of all, 10 sheets of paper were used for testing, and the test results were counted, as shown in Table 1.

Table 1. 10 A4 paper test forms

paper number	1	2	3	4	5	6	7	8	9	10
average time/s	1	1	1	1	1	1	1	1	1	1
sum	10	10	10	10	10	10	10	10	10	10
correct number	10	10	10	10	10	10	10	10	10	10
Wrong number	0	0	0	0	0	0	0	0	0	0
Accuracy %	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

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Under the same conditions, 1-10 pieces of A4 paper were tested for 10 times respectively, which could be quickly and accurately identified, and the accuracy could reach 100% within 10 pieces of paper. Table 2 shows the measurement data of 10~30 sheets.

Table 2. Test form on A4 paper within 30

paper number	12	14	16	18	20	22	24	26	28	30
average time/s	1	1	1	1	1	1	1	1	1	1
sum	10	10	10	10	10	10	10	10	10	10
correct number	10	10	10	10	10	10	10	10	10	10
Wrong number	0	0	0	0	0	0	0	0	0	0
Accuracy %	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

According to the accuracy, we can know that the number of papers tested can be quickly and accurately identified in this range, and the accuracy can reach 100% in this range.

More than 30 pieces of standard A4 paper were used for measurement, and the test data were shown in Table 3 below.

Table 3. More than 30 A4 paper test forms

paper number	31	33	35	37	39	41	43	45	47	49
average time/s	1	1	1	1	1	1	1	1	1	1
sum	10	10	10	10	10	10	10	10	10	10
correct number	10	10	9	10	10	9	10	9	10	10
Wrong number	0	0	1	0	0	1	0	1	0	0
Accuracy %	100%	100%	90%	100%	100%	90%	100%	90%	100%	100%

Under the same conditions, more than 30 pieces of A4 paper were tested respectively, and the value of ten times of data in the test process, the results show that there will be a certain error in the case of a large number of errors, but the error range is relatively small, the accuracy reached more than 90%.

3.3. Error Analysis

(1) The plate is not completely parallel with a small *Angle;* improper operation of the paper placement operation will affect the positive area between the two plates.

(2) the paper thickness is not absolutely consistent and there is error, resulting in calculation error.

(3) There is air between the two plates and the paper, which affects the dielectric constant and the plate spacing.

(4) In addition to the steady-state error caused by the system's own structural parameters and external effects, the nonlinear factors existing in the system, such as zero drift, will cause additional steady-state error.

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(5) improper extraction of paper caused by error, extraction of paper friction in the polar plate surface will produce electric charge.

4. Conclusion

This paper analyzes the design steps of paper counting device using STC12LE5A60S2 microcontroller and capacitance sensor chip FDC2214, analyzes its working principle and design circuit diagram, programming to achieve paper calibration and measurement. The interference and error in the testing process are analyzed and solutions are proposed. Fuzzy algorithm and Kalman filter principle are used to process and correct the experimental data in the later stage. After the measurement is completed, a prompt sound is issued and displayed on the display screen, realizing precise measurement and human-computer interaction under a simple device.

Acknowledgments

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