A new type of RMB counting device

Jian Huang
Xijing University, Xi’an, China

Corresponding author and e-mail: Jian Huang, 565200245@qq.com

Abstract. In order to measure the quantity of paper with high speed and accuracy, a new measuring technology based on the principle of capacitance sensing is proposed and a measuring device is made. Put two metal plates of the same size at a certain distance with a piece of A4 paper in the middle. When the thickness of the paper changes, the capacitance on the metal plate will change. Use the capacitance sensor fdc2214 to sense the change. After modeling and analysis, determine the functional relationship between the thickness of the paper and the measured value, and calculate the paper quantity. The test results show that the device can count the number of paper accurately and quickly.

1. Introduction
In industrial production, it is necessary to count the number of banknotes accurately. People have done a lot of research on this. Recently, there are many new measurement methods, among which literature [1] proposed a stack banknote counting algorithm combining minimum curvature method and peak detection. The paper money counting method based on machine vision imaging is proposed in reference [2]. In reference [3], a robust image counting algorithm combining global periodic constraints and local pattern correlation measures is proposed. The above method is based on image processing technology, with high algorithm complexity, low recognition rate, complex equipment and high production cost.

In order to overcome and avoid these shortcomings, this paper proposes a new paper money detection method based on non-contact capacitance sensing technology. Put a copper plate of the same area up and down, with a certain distance between them, and put a certain number of A4 notes in the middle. When the type and quantity of banknotes change, it will cause the change of capacitance capacity of two copper clad plates. The sensor will perceive this weak change and convert it into high-precision digital output. After data processing, the number of banknotes can be obtained.

2. System
In order to measure the number of banknotes, the design scheme shown in Figure 1 is adopted.
The high performance microprocessor stm32h743iit6 is used as the main control in Figure 1. The two electrode plates act as sensors to sense the change of the number of banknotes, and convert it into the corresponding capacitance value and send it to fdc2214. After processing, it turns into a 28 bit binary number, which is sent to stm32h743iit6 through IIC interface for processing. After a successful data acquisition, the buzzer will sound once. And send the measurement results to the monitor or computer.

3. Measuring principle

3.1. Capacitance calculation

The capacitance can be calculated by the following formula:

$$C = \frac{\varepsilon A}{d} \times 8.85 \times 10^{-12}$$

(1)

Where a is the area of a capacitor plate, in M2, D is the distance between plates, in M, C is the capacitance, in F, and $\varepsilon$ is the dielectric constant relative to air [4-6]. It can be seen from formula (1) that the capacitance is directly proportional to the dielectric constant $\varepsilon$, the area a of the plate, and inversely proportional to the distance d between the plates.

The relative permittivity of common dielectrics is shown in Table 1.

Table 1. Table of $\varepsilon$ values of different media constants.

| No | medium   | $\varepsilon$ |
|----|----------|---------------|
| 1  | atmosphere | 1.0           |
| 2  | teflon    | 2.0           |
| 3  | paper     | 2.5           |
| 4  | oil       | 4.0           |
| 5  | mica      | 5.0           |
| 6  | Glass     | 7.5           |
| 7  | alumina   | 10            |
| 8  | ceramics  | 1200          |

For the paper money detection device, the area a of the plate is fixed. When the paper money is put in, it will cause the change of the medium and distance, which will lead to the change of the capacitance capacity [7-8].

3.2. Detection principle of capacitance

Fdc2214 detects the variable capacitance CS. Fdc2214 has four channels, namely channels 0, 1, 2 and 3. The detection principle of each channel is the same. Channel 0 and channel 3 can be used to connect the two plates of banknote detection respectively. CS in the figure represents the capacitance generated on one of the plates.

Taking channel 0 as an example, it can be seen from the figure that after the variable capacitance CS and C are connected in series, they form an oscillation circuit with the inductance L. The oscillation frequency can be calculated by formula (2)Fs.
\[ f_s = \frac{1}{2\pi \sqrt{L(c + c_v)}} \]  
\[ (2) \]

In formula (2), \( L \) is the inductance, the value is 18uH, \( C \) is the capacitance, the value is 33pF, \( C_v \) is the variable capacitance. \( FS \) is the calculated oscillation frequency.

Fdc2214 is externally connected with 40MHz active crystal oscillator. In the test, the working frequency of fdc2214 channel data acquisition shall be set, and the formula (3) shall be used for calculation.

\[ f_{ref} = \frac{f_{clk}}{CH_x \cdot FREF \cdot DIVIDER} \]  
\[ (3) \]

Formula (3) \( f_{ref} \) is the data acquisition frequency of each channel, \( f_{clk} \) is the input frequency of fdc2214, and the value is 40MHz. \( CH_x \) - \( Fref \) - \( DIVIDER \) is the frequency division coefficient, and the frequency division is selected. After frequency division, the frequency of \( f_{ref} \) is 20MHz.

After obtaining the \( f_{ref} \), we can use formula (4) to calculate the converted 28 bit binary number.

\[ DATA = \frac{f_s}{f_{ref}} \times 2^{28} \]  
\[ (4) \]

Formula (4) is the calculation formula for converting the changing frequency to binary number [9-10]. \( Fref \) is 20MHz after calculation by formula (3), \( FS \) is the vibration frequency after calculation by formula (2), and data is the corresponding 28 bit binary number after conversion. In this way, the weak change of the external parasitic capacitance can be transformed into a binary output of up to 28 bits, which can be output to the microprocessor for processing with the IIC interface.

Stm32h743iit6 uses standard IIC interface to read 28 bit binary of fdc2214, mainly including SDA data line and SCL clock line. Data reading and writing follow standard IIC interface protocol [11-12].

3.3. Software design
The software flow chart is as follows.
Figure 2. Software flow chart.

First, initialize the serial port, IIC, timer, etc. The timer is initialized to read the values of fdc2214 channels 0 and 3 once in 10ms, and the baud rate of serial port initialization is 115200. Then, fdc2214 should be self calibrated, because fdc2214 is a high sensitivity sensor, if the measurement environment changes, it will have an impact on the measurement value, so the current air environment should be measured first and the system calibration should be carried out.

Then, the IIC interface can be used to read the values of fdc2214 channels 0 and 3. In order to ensure the reliability, it is necessary to carry out multiple measurements and remove the interference with the mean filtering algorithm. Increase the number of banknotes, get a set of data, determine its mathematical model (this part is given in the test part), calculate the number of banknotes, complete a measurement, send the results to the computer or the display through the serial port, and the buzzer alarms once.

IIC reading and writing sequence is as follows.

Figure 3. IIC write sequence diagram.
4. Test
After the completion of hardware and software design. It mainly includes fdc2214 module, stm32h743 development board, 4.3-inch RGB LCD screen and two 30cm * 20cm single-sided copper clad panels, with a certain distance between the upper and lower alignment, and A4 paper money can be placed in the middle.

During the test, try to keep the test device as fixed as possible, carry out self calibration, and then put A4 paper between the two copper plates. Starting from 1, gradually increase the number, get a group of data, send it to the computer through the serial port, and analyze it under Matlab.

After several tests, a set of data is obtained as shown in Table 1.

Table 2. Comparison between measured value and real value of paper.

| Measured value | actual value |
|----------------|-------------|
| 1              | 1           |
| 5              | 5           |
| 10             | 10          |
| 20             | 21          |
| 50             | 51          |
| 100            | 99          |
| 150            | 150         |
| 200            | 201         |
| 250            | 248         |
| 300            | 301         |
| 350            | 351         |
| 400            | 401         |
| 450            | 449         |
| 500            | 501         |
| 550            | 548         |
| 1000           | 998         |
It can be seen from table 2 that there is no error between the measured value and the real value, indicating that the method can accurately measure the quantity of A4 paper.

5. Conclusions
In this paper, a new paper money measurement method is proposed. Based on the capacitance sensing technology, the corresponding measuring device is made. The functional relationship between the number of paper money and the measured value is determined through experiments and data analysis, which proves that the method can accurately measure the number of A4 paper money. At the same time, other types of banknotes can also be counted by using the above method and measurement process. The whole design and research has the advantages of simple hardware circuit, strong anti-interference ability, high recognition rate, high precision, fast speed and low cost.

References
[1] Qiu Hualin, Xiao Changyan, Jiang Shilong. Paper money counting algorithm based on minimum curvature method and peak detection [J], Journal of electronic measurement and instruments, 2017,31 (9): 1475-1480.
[2] Yang Shuo, Peng Shuang, Xiao Changyan. Fast linear growth algorithm for image analysis and counting of laminated banknotes [J], computer application and software, 2015,32 (9): 188-191.
[3] Dai Rong, Xiao Changyan. Detection of the number of laminated banknotes based on image frequency domain analysis and correlation measurement [J], Chinese Journal of image graphics,2016,21(12):1644-1651.
[4] Zhang Mingyang, Chen Zhenyue, Wang Xia. Algorithm design of banknote counting based on image texture [J]. Optical technology, 2013,39 (2). 151-156.
[5] Yuan weiqi, Qiu Kai, Tang Yonghua. Banknote counting machine paper money crown size chart Image acquisition system [J]. Instrument technology and sensors, 2013,9:32-35.
[6] Dong Jintong, Liu Jia. Analysis of infrared characteristics of low cost banknotes Methods [J]. Instrument technology and sensors, 2013,12:151-153.
[7] Yuan weiqi, Wei Yiting, Yu Yang. Image collection of banknote in cash counting machine Development [J]. Instrument technology and sensor, 2013,11:22-25.
[8] Hou Li Li, Kong Xiang Xi, men Xin, Yang Heng. The effect of ultrasonic excitation on the drying uniformity of banknotes [J]. China paper, 2019,38 (12): 35-41.
[9] Bao Binghao, Jiang Feng, Zhao Zhan, song Xuefeng. A new type of weak magnetic field sensor based on the giant magneto impedance effect of amorphous belt [J], Journal of sensing technology .2006,19(6):2380-2383.
[10] Liang Haiyi, Wang jisen, Li Wen, sun Lingyuan. Design and analysis of counting algorithm based on texture image [J], Journal of metrology, 2017,38 (4): 416-419.
[11] Ao Yinhui, Jiang Jin. Paper counting based on texture segmentation [J]. Packaging engineering, 2015,36 (19): 135-138.
[12] Huang Jian, Huang Jiaqi, Chen Nanyu, Zhang Shanwen, LV Lintao. Development of a new linear position sensor [J]. Instrument technology and sensor, 2019,1:42-44.