Study on the Sugar Water Concentration Measuring Instrument

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Abstract. A new type of sugar water concentration meter was studied. When the concentration of sugar water changes, the capacitance will change. A test device is built to insert a metal sheet into the sugar water. When the concentration of sugar water changes, the parasitic capacitance on the metal sheet changes. The change is measured by a microprocessor, and the functional relationship between the capacitance and the concentration of sugar water is determined through experiments. The test results show that the method can detect the concentration of sugar water quickly with an accuracy of 0.1%.

Keywords: Sugar Water Concentration, Capacitance Sensing, Electrolyte

Sugar water concentration detection is widely used in food processing, medical and health care. The commonly used measuring methods are Pycnometer method, balance method, etc.

The above methods are based on ultrasonic or optical characteristics, and their reliability and accuracy need to be further verified [1-3]. With the purpose of improve the measurement accuracy, a new method of sugar water concentration measurement based on the non-contact capacitance sensing technology, a new digital capacitance sensor fdc2214 is used to test the variation of sugar water level and concentration. When the liquid concentration changes, the parasitic capacitance on the CCL will change. Fdc2214 can detect the capacitance value and convert it to a binary number of up to 28 bits, output it to the microprocessor with IIC interface, and analyze the data to get the sugar water concentration.

1. System Block Diagram
The design flow of sugar water concentration detection system is shown in Figure 1. In the figure, the high-performance microprocessor stm32h743iit6 is used as the main control unit for data acquisition and processing [4-6].

The thin copper strip is used as the sensor probe, which is connected with the detection channel of fdc2214 to sense the change of parasitic capacitance value on the copper strip caused by the change of sugar water concentration, and convert it into 28-bit number, then send it to the stm32h743iit6 with IIC interface. The data processed by the software is transmitted to the computer through the usart or spi to the LCD screen. Power supply is 3.3V.
2. Design
The capacitance can be calculated by formula (1):

\[ C = \left( \frac{\varepsilon_0 \varepsilon_r A}{d} \right) \times N \]  \tag{1}

Where, \( \varepsilon_0 \) is a constant and the value is 8.854 PF/m. \( A \) is the area of an electrode (unit: m²), \( D \) is the distance (unit: m), \( R \) is the dielectric constant relative to air, \( C \) is the calculated capacitance (unit: F). It can be seen from formula (1) that when the medium changes (for example, the concentration of sugar water changes), it will cause the change of \( \varepsilon R \) and the change of capacitance \( C \) [7-10].

Figure 2 shows the schematic diagram of fdc2214 channel 0 detecting variable capacitance \( C_x \). In the figure, \( C_X \) and \( I \) and \( C \) is calculated by formula (2).

\[ f_s = \frac{1}{2\pi \sqrt{1/(C + C_x)}} \]  \tag{2}

Formula (3) gives the calculation method of reference frequency when fdc2214 is measured.
$$f_r = \frac{f_{clk}}{ch0 \_sel}$$

(3)

In formula (3), $f_{clk}$ is the clock, which is 40MHz. $ch0 \_ sel$ is the frequency division coefficient. The frequency division of $f_{clk}$ is realized by setting the internal register 0x14 of fdc2214 by software. During the test, it is set to dichotomy, and FR is 20MHz after calculation.

Formula (4) gives the calculation method of 28 bit binary number.

$$DATA_0 = \frac{f_s}{f_r} \times 2^{28}$$

(4)

It can be seen from the above formula that when CX changes, the oscillation frequency FS will change. After calculation, a 28 bit binary number Data0 can be output.

3. Software Design

3.1. Software Flow

After the system is built according to the above principles, the collected data can be processed by software. The following first initializes the serial port, IIC interface and timer. After completion, the measured values of channel 0, 1 and 2 of fdc2214 can be read in sequence through IIC interface every 50ms, and the values of channel 0 and channel 2 are fixed. The value of channel 1 will change with the change of liquid concentration. In order to ensure the accuracy and reliability of data collection, channel 1 should be collected many times, and the interference should be removed by software filtering algorithm to get the accurate value. All data can be sent to computer through serial port, analyzed and processed under Matlab, and displayed on LCD screen [11-16].

The whole software design is written in C language, and the compiling environment is MDK 5.2.

3.2. Software Filtering Algorithm

In order to reduce the error and improve the measurement accuracy, it is necessary to collect and filter the capacitance sensing value many times. First of all, a certain sugar water concentration should be measured 100 times repeatedly, then the measured data should be sorted from small to large, 20 maximum and 20 minimum data is deleted, and the remaining 60 data should be used to calculate the average value as the final value, so as to effectively remove the interference and reliability of the measurement.

4. Test

The test device is mainly composed of fdc2214 module, stm32h743iit6 module and 4.3-inch TFT display module. Write the program and download it to stm32h743iit6 chip for testing after it is compiled in mdk5.23 development environment.

During the test, each time different concentrations of sugar water are configured, poured into a glass container, and then read the data of capacitance sensing fdc2214. Get the data as shown in Table 1.

It can be seen from the table that with the increase of sugar water concentration, the capacitance sensing value gradually decreases, showing a certain regularity. In order to get the relationship between the accurate sugar water concentration and the capacitance sensing value, these data are analyzed in MATLAB to get the curve as shown in Figure 7. In the figure, the x-axis is the capacitance measurement value, and the y-axis is the corresponding sugar water concentration, in
percentage.

| Capacitance sensing value | Sugar water concentration (%) |
|---------------------------|------------------------------|
| 22289                     | 0.80                         |
| 22278                     | 1.19                         |
| 22271                     | 1.54                         |
| 22264                     | 1.82                         |
| 22257                     | 2.08                         |
| 22251                     | 2.35                         |
| 22245                     | 2.55                         |
| 22239                     | 2.72                         |
| 22233                     | 2.95                         |
| 22227                     | 3.12                         |
| 22225                     | 3.22                         |
| 22222                     | 3.35                         |

5. Conclusion
In this paper, the principle and method of measuring the concentration of sugar water by capacitance sensing are analyzed, and the measuring device is designed. It is verified that there is a certain functional relationship between the concentration of sugar water and the measured value of capacitance sensing, which proves that this method can be used to measure the concentration of sugar water. The whole system has the advantages of higher measurement accuracy, stronger anti-interference ability, low cost and easy to realize.

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