Research on A Sweetness Measuring Instrument

Jian Huang*  
XiJing University, Xi'an 710123, China  
*Corresponding author e-mail: huangjian@xijing.edu.cn

Abstract. A sugar water sweetness measuring device is proposed, which uses STM32 single chip microcomputer as processor. Fdc2214 sensor is used to detect the concentration of sugar water. The capacitance change caused by the concentration change of sugar water is converted into 28 bit binary number, which is transmitted to STM32 through IIC interface. The corresponding relationship between the concentration of sugar water and the measured value is obtained through analysis and processing. The system displays system information through a 1.44-inch TFT LCD. The alarm threshold value is set by pressing the key. When the sugar level exceeds the standard, the alarm will be given by the buzzer. This design has the characteristics of high detection accuracy and low cost, and has high practicability.

Keywords: Sweetness Detection, Fdc2214, STM32, Capacitance Sensing

1. System Block Diagram  
The system architecture is shown in Figure 1:

![System Architecture Diagram](image-url)

**Figure 1.** system architecture  
The sensor collects the concentration value, transmits it to the controller for numerical processing, displays it on the display, and the alarm circuit plays a warning role.
Sugar concentration monitoring equipment needs to monitor the concentration of the solution at all times, so a special liquid concentration monitoring sensor is needed, and the sensor must have a high accuracy, the equipment must have a main controller to achieve the function, the main controller receives the collection signal of the sensor and processes it, because the information obtained by the sensor is not necessarily the concentration value of the liquid directly, because this controller should have certain data processing capacity.\cite{1-3}

Fdc2214 is a common liquid level monitoring sensor, fdc2214 is a capacitive sensor, which changes the monitored liquid level, concentration and medium into the change of the voltage at both ends of the sensor. Therefore, fdc2214 can be used as the concentration sensor of the solution, and STM32 series single-chip microcomputer can be used in the control part to meet the control requirements. At the same time, LCD display can be used to realize the concentration detection. Add buzzer circuit to realize concentration and limit alarm.

2. Design

2.1 STM32 Circuit Design

![Figure 2. minimum system circuit of single chip microcomputer](image_url)

Power supply circuit: as the whole power supply core of the minimum system of single chip microcomputer, the power supply circuit of STM32 single chip microcomputer can generally choose to supply power from the VCC pin of single chip microcomputer and its own USB power supply interface. All 5V pins on the whole 51 single chip microcomputer are connected together, and the corresponding negative pin of power supply is also connected together, so the power supply of single chip microcomputer is generally connected. A break doesn't have to be a break. It should be noted that the driving voltage capacity of the power supply pin of the single chip microcomputer is limited to...
about 3.3v-5.5v, and the voltage higher than 5.5V may cause the single chip microcomputer to fail to work normally or even burn down. In addition, if the driving voltage of the single chip microcomputer must be above 3.3V, the driving capacity of the single chip microcomputer pin will be insufficient, and the single chip microcomputer cannot work normally.

Clock circuit: the clock circuit of STM32 single chip microcomputer generally consists of two starting capacitors and an external crystal oscillator. The single chip microcomputer is the core of the whole express cabinet system, and the clock circuit is the core of the single chip microcomputer. The operation of all the circuits on the single chip microcomputer depends on it, but the working frequency of the clock circuit on the single chip microcomputer is far higher than the working frequency of the automobile engine. Generally speaking, the working frequency of a single second using the 8MHz crystal oscillator clock circuit can reach 8000, More than 000 times. In our practical use, we use more 8m crystal oscillator.

2.2 Display Circuit Design
TFT LCD is used in this design, and two data lines are used for serial communication. IIC bus protocol is adopted for serial mode, and only two lines are needed for data transmission. Although the transmission efficiency is not high in parallel, it is only used for display in our system, so the serial connection mode is comprehensively considered to save MCU resources. The connection mode is shown in Figure 3.

![Figure 3. LCD circuit](image)

2.3 The Basic Principle of Sugar Water Concentration Measurement
Figure 4. working circuit of fdc2214 sensor

As the change factors of capacitance are plate spacing, media change between plates and area change of plates, as long as the liquid level of the capacitance sensor and the container remain unchanged, the change of capacitance is the change of solution concentration, and the change of voltage is caused by the change of solution concentration. Therefore, the concentration of the collected solution is realized, as shown in the circuit diagram. The chip has four groups of input signals, IN0, in1, 01 channel as a group, similar to two plates for capacitance, the collected signals are transformed by new dispatch, and the information is exchanged with the single-chip microcomputer through IIC communication at the output end, the single-chip microcomputer gets the voltage change value generated by the capacitance change, and the concentration change of the collected solution of the sensor is obtained through the internal data processing.

The capacitance can be calculated by the following formula:

$$C = \left( \frac{\varepsilon_0 \varepsilon_r A}{d} \right) \times N$$  \hspace{1cm} (1)

Where, $\varepsilon_0$ is a constant and the value is 8.854 PF/m, A is the area of an electrode (unit: m$^2$), D is the distance between plates (unit: m), $\varepsilon_r$ is the dielectric constant relative to air $^{[4-5]}$, C is the calculated capacitance (unit: F). It can be seen from formula (1) that the capacitance is directly proportional to the relative permittivity $\varepsilon_r$, the area A of the plate, and inversely proportional to the distance d between the plates. 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$^{[6-7]}$.

Figure 2 shows the schematic diagram of fdc2214 channel 0 detecting variable capacitance Cx. In the figure, CX and l and C form an oscillating circuit. The oscillation frequency FS is calculated by formula (2).
Figure 5. circuit diagram of channel 0 detection

\[ f_s = \frac{1}{2\pi \sqrt{l(c + c_s)}} \]  \hspace{1cm} (2)

Formula (3) gives the calculation method of reference frequency when fdc2214 is measured.

\[ f_r = \frac{f_{clk}}{CH0 \_ sel} \]  \hspace{1cm} (3)

In formula (3), FR is the reference frequency, fclk is the input frequency of fdc2214, which is 40MHz. CH0 \_ sel is the frequency division coefficient. The frequency division of fclk 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.

\[ DATA_0 = \frac{f_s}{f_r} \times 2^{28} \]  \hspace{1cm} (4)

It can be seen from the above formula that when CX changes, the oscillation frequency FS will change\[8-10\]. After calculation, a 28 bit binary number Data0 can be output.

3. Test

After connecting the hardware and software, a set of test data is obtained as follows.

| 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                        |

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.

4. Conclusion
This chapter mainly completes the final debugging of the system, which is divided into two parts: one is hardware debugging, the other is software debugging. First, debug the hardware circuit to ensure the perfection of the hardware circuit, and then carry out software debugging. When debugging the hardware, pay special attention to whether there is a short circuit in each part of the circuit, and then the connection between each part to ensure that there is no problem, software debugging. Through the program to control whether the hardware circuit works according to the effect of demand, the system finally runs in the whole, so as to realize the function and complete the whole design.

References
[1] Zhang Hao, Chen Minghui, Li Zhenyang, Wang Cheng, Zheng Gang. Optical low coherence interference method for measuring glucose concentration [J]. Optical technology, 2018, 44 (3): 287-290
[2] Chen Donghe, Liang Xiaochong. Measurement of glucose concentration by microwave spectrometer [J]. Experimental technology and management, 2018, 35 (12): 75-77
[3] Zhang Shuren, Xu ya, Xie Dailiang, Xu Zhipeng, Liu Tiejun, Wang Yuebing. Study on the measurement of suspended matter concentration in ultrasonic water based on ant colony algorithm [J]. Journal of sensing technology, 2019,32 (8): 1163-1168
[4] Yang Xuan, Su Mingxu, Cai Xiaoshu, Wu Jian. Study on density measurement of ethanol solution by ultrasonic multiple echo reflection method [J]. Journal of sensing technology, 2011,24 (7): 937-940
[5] Wu Lijie, Jiang Zhidi, Wu Zhenqian. High precision measurement method of ultrasonic liquid concentration based on curved surface fitting [J]. Journal of sensing technology, 2018,31 (8): 1169-1175
[6] Wan Haoping, Yang Nan, Fan Yi. Measurement method and system research of concentration field in large area water area [J]. Water conservancy and hydropower technology, 2017,48 (3): 71-76
[7] Hu Di, Tang Kaihao, Tang Chenhui, Wang Xiaoxin. Principle and application of two-phase flow parameter detection based on capacitance sensor [J]. JOURNAL OF NORTHWEST UNIVERSITY (NATURAL SCIENCE EDITION), 2019,49 (4): 681-690.
[8] Zhou Hao, Wu Jianbo, Yang Yu, et al. Measurement of gas-solid two-phase flow field at the exit of swirl burner by optical wave method [J]. Journal of Zhejiang University (Engineering Edition), 2012, 46 (12): 2189-2193
[9] Wang Liming, Shen Yidi, Cao Bin, Mei Hongwei, Zhao Chenlong. Measurement method and device of equivalent concentration of soluble salt in atmospheric environment [J]. High voltage technology, 2019,45 (12): 3777-3784
[10] Zhang Yeming; Li Zhiguo; Wang Geng; Li Zhongkai; Liu Xu; Wang Kunpeng. Design and application of mechanical rotating pulse water depth and level measuring device [J]. Sensors and Microsystems, 2015,34 (10): 72-75