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Design and Implementation of Transparent Liquid Concentration Measurement Based on ARM

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Abstract: At present, there have been many research results in liquid concentration detection, but China is still relatively backward in optical detection technology, and it is of great significance to research and develop new liquid detection systems. Under the same solute, due to the different concentration of the liquid, its absorption degree of fixed incident light will also be different, the use of photoelectric sensor to detect the change of light intensity, you can obtain the absorbance of the liquid, and then calculate the liquid concentration. Based on the above theory, this paper designs a liquid concentration measurement system based on the main control module of STM32F103RCT6 chip based on ARM Cortex-M3 core. The system consists of an STM32F103RCT6 chip, a TSL2591 photoelectric sensor, a laser emitter, and an OLED display. When the liquid concentration in the container changes, it will cause the light intensity change detected by TSL2591, and according to the change of the obtained data, the data will be fitted with the change of the configured liquid concentration, and finally a curve corresponding to the liquid concentration and the data change is obtained. The value measured by the TSL2591 is substituted into the curve to obtain the concentration value of the liquid and displayed on the OLED display. Through tests, it has been proved that the device can determine the concentration of liquids more accurately. The system has the advantages of simple structure, high sensitivity and fast response time, and can accurately measure the concentration of liquid.

Keywords: ARM Cortex-M3 core;TSL2591 light sensor;OLED screen

1. INTRODUCTION

In recent years, the rapid development of liquid detection technology, involving almost all aspects of the production process, in many production fields, not only requires the simple operation of measuring instruments, but also requires high accuracy of liquid measurement, such as in the production of drugs, the need for accurate configuration of the proportion of various medicinal materials and the concentration of various drugs in order to make successful drugs. Especially in recent years, the outbreak of the epidemic, the country's demand for drugs is increasing day by day, at this time, the detection of drug concentration is particularly important, so detection technology is one of the directions of people's research.

There are various methods for measuring liquid concentration, and after years of development, the detection technology has also developed relatively maturely, and the methods that have been applied and popularized include capacitance method, supergenerated grating method, grazing incidence method, etc.[1]. The design of this project is based on a novel optical method, which mainly uses photoelectric sensors to measure the concentration of liquids. The detection of liquid concentration by using the photoelectric sensor method has the characteristics of fast, simple, no contamination of the liquid to be measured, and easy signal conversion to achieve automatic control.

2. GENERRAL DESIGN

In order to complete this test task, the STM32F103RCT6 chip based on the ARM Cortex-M3 core is selected as the main control module of the measurement device, and the TSL2591 photoelectric sensor is also selected as the main test element, and the light intensity digital signal converted by the TSL2591 photoelectric sensor is received by the IIC communication principle of the STM32F103RCT6 chip. The data is displayed on the OLED screen via the IIC[2]data bus, i.e. the liquid concentration.

2.1 Experimental Principle

Lambert-Beale law: is the basic law of light absorption, which describes the relationship between the intensity of light absorption by a substance at a certain wavelength and the concentration of light-absorbing substances and the thickness of their liquid layer[3]. The relationship is shown in equation (1).

$$A=Kbc \quad (1)$$

Where K is the molar absorbance coefficient of the solute, b is the range of light passing through the solute, and c is the concentration of the liquid. From the basic idea of Beer's law, it can be seen that absorbance is directly proportional to the concentration of the liquid, that is, the greater the concentration of the liquid, the greater the absorbance. The absorbance is the intensity of the incident light before the light passes through the liquid and the transmitted light intensity after the light passes through the liquid, as shown in equation (2) (I_0 is the light intensity of the control group, I_1 is the light intensity of the liquid to be measured).

$$A=lg\frac{I_0}{I_1} \quad (2)$$

The basic principle of this experiment is that under the same solute, the concentration of the liquid will be different, and the degree of absorption of light will also be different. Therefore, the relationship between the light intensity of different concentrations of liquids and the light intensity of the same beam of light through different concentrations of liquids is studied, and the concentration of liquids can be accurately measured by using this relationship.

2.2 Modle Choice

2.2.1 Main Control Module

In this design, a STM32F103RCT6 microcontroller was selected as the main control module, and the chip is based on the ARM Cortex-M3 core, which can perform complex data

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processing. The main frequency of the clock is relatively high, the maximum speed of the CPU can reach 72MHz, and at the same time, the chip integrates 12-bit precision ADC, USART serial port and other complex circuits[4].

2.2.2 Sensor Module

Sensor, also known as transducer, is a device that converts information into electronic information signals, usually composed of sensitive originals and conversion originals, which can convert the obtained information into electronic information signals in accordance with certain specifications and rules, so that the obtained information can meet the requirements of information transmission, storage, display, recording and management. In this paper, TSL2591 photoelectric sensors are mainly used for liquid detection. The photoelectric sensor module is TSL2591[5], which is an extremely sensitive optical-to-digital converter that converts light intensity into a digital signal and outputs it directly through the IIC interface.

2.2.3 Display Module

The display module uses a 0.96-inch (4-pin) OLED[6] display. The module has the characteristics of small size, high resolution, self-illumination, and a variety of interface methods.

2.2.4 Key Detection Module

The key detection module adopts an external interrupt mode, the STM32 microcontroller receives the digital signal sent by the photoelectric sensor, presses the button, and the STM32 microcontroller sends the signal to the screen, that is, the screen displays the concentration of the liquid to be measured.

2.3 Device Design

Figure 1 shows the basic module of the device, which consists of an STM32 main controller, a photoelectric sensor module, a laser emitter, a display module, and a button module. The laser emitter irradiates the liquid, and the photoelectric sensor module converts the light intensity signal into a digital signal and transmits it to the STM32 main controller.

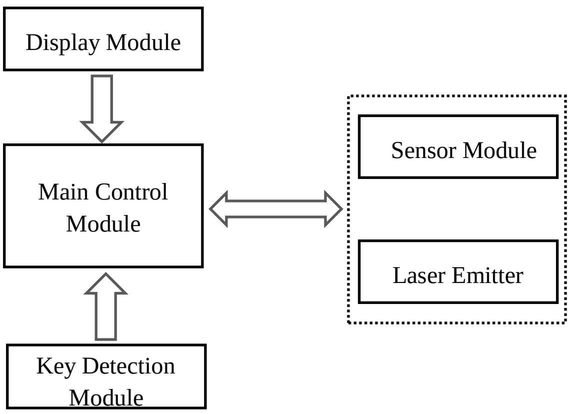

Figure. 1 The basic module of the device

The actual drawing of the device is shown in Figure 2.

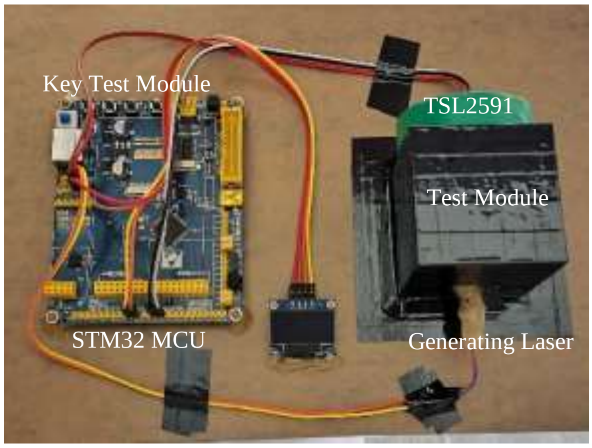

Figure. 2 Device diagram

3. DESIGN OF EXPERIMENTS

3.1 Liquid Selection

Two reagents were prepared for this design: saline and sugar water.

It is understood that the absorbance of salt water does not exceed 0.650, which is not suitable as a detection object, and the absorbance of sugar water is much greater than that of salt water, so the liquid selected for measurement in this design is sugar water, sugar water is easy to obtain, and the operation of configuring different concentrations is relatively simple, the larger the concentration of sugar water, the greater the density of the liquid, and the change of light intensity through sugar water also becomes larger, and the absorbance changes greatly, which is convenient for observation and analysis in the experiment. experiment.

3.2 Experimental Procedure

According to the principle of concentration detection, the experimental process design was completed.

(1) Configure 6%-14% sugar water liquid with a gradient concentration of 1% (due to the fixation of the experimental device, the actual operation is to add sugar to the low-concentration liquid to increase the concentration);

(2) Measure the intensity of the incident light emitted by the laser emitter through the clear water, wait for the device to be stabilized, read multiple sets of data, and take the average value as the control group of this experiment;

(3) Replace different concentrations of sugar water liquid into a square container in turn, read the data of each concentration of liquid for multiple times, take the average value, and find the transmitted light intensity after the light passes through different liquid concentrations;

(4) According to the transmitted light intensity and incident light intensity of the corresponding concentration, the absorbance of the corresponding concentration is calculated, and the specific mapping relationship between the liquid concentration and absorbance is fitted by MATLAB[7];

(5) The curve equation obtained by fitting the curve is written into the program through the STM32Cube, and then the program is burned into the single-chip microcomputer;

(6) Configure different concentrations of sugar water liquid, and test the error of the device to measure the concentration of liquid.

3.3 Fitting Phase

Before starting the test, the relationship between the absorbance of the liquid and the concentration of the liquid needs to be fitted to obtain its specific mapping. In the process of testing the data, it is necessary to ensure that the experimental environment remains unchanged, and the flow chart of the main program in the fitting stage is shown in Figure 3.

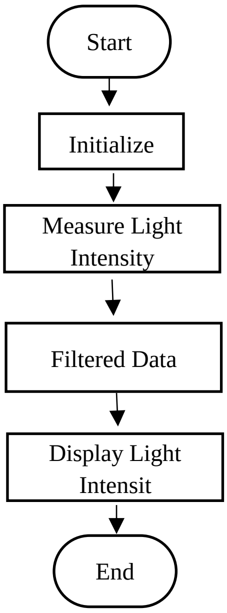

Figure. 3 Fitting phase process

After the experiment starts, the system is initialized, the photoelectric sensor measures 30 times, and the filtering after sorting, that is, the first five maximum values and the last five minimum values are removed, and then the remaining 20 items are averaged, and the light intensity is displayed on the OLED screen and the serial port of the PC side.

3.4 Testing Phase

After determining the relationship between light intensity and liquid concentration, the accuracy of the fitting curve needs to be checked. The main procedures in the pilot phase are shown in Figure 4. After the experiment starts, the system is initialized, and the interrupt detection button is checked, and if there is no button pressed, the key is continued to be detected in a loop; If pressed, the photoelectric sensor will measure, and after 30 measurements, the maximum value will be averaged with the fitting stage program, and then the corresponding liquid concentration will be displayed through the OLED screen according to the fitting curve.

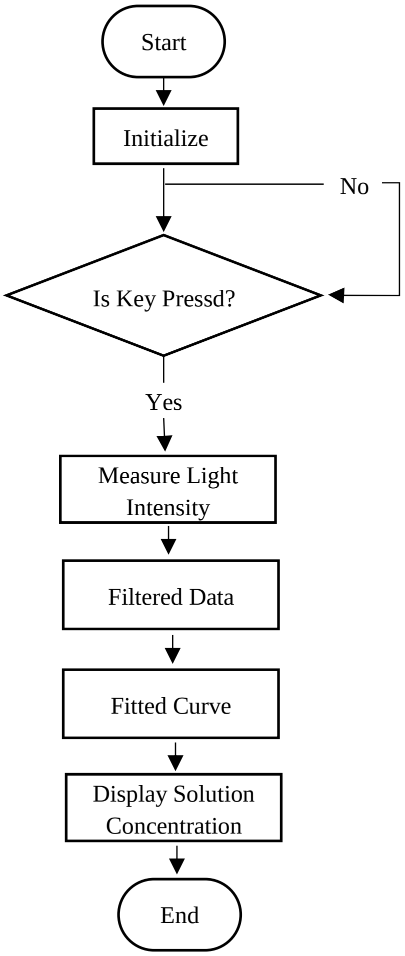

Figure. 4 Test phase process

4. EXPERIMENTAL RESULT

4.1 Metrical Data

During the test, 70g of water was added to the device, and then 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, and 14% sugar liquid were respectively configured to pass through the light intensity of the water as the incident light, and the light intensity of the liquid with sugar added to the sugar was used as the transmitted light, and the absorbance (as shown in Table 1) was calculated according to equation (3). The measurement data are shown in Table 1.

$$Absorbancy = lg\frac{\text{Average Light Intensity of Clean Water}}{\text{Average Light Intensity of Solution}} \qquad (3)$$

Table. 1 Measurement data

Mass Fraction(Unit: %)	Average Value	lg
0	17865.40	0
6	12148.22	0.16750
7	11078.80	0.20752
8	10284.96	0.23981
9	9208.79	0.28781
10	8637.99	0.31560
11	7733.97	0.36361
12	6943.24	0.41045
13	5984.29	0.47500
14	5357.75	0.52303

4.2 Data Fitting Curve

According to the program design, the collected values are unified and analyzed, and then the data are fitted to obtain a formula for extrapolating the liquid concentration from the collected data. Different data were selected for mathematical analysis, and the equations were established, and the following optimal fitting function formula (4) was obtained by MATLAB.

$$y=0.126*x*x*x-0.328*x+0.403*x+0.000735 \qquad (4)$$

The fitting curve is shown in Figure 5.

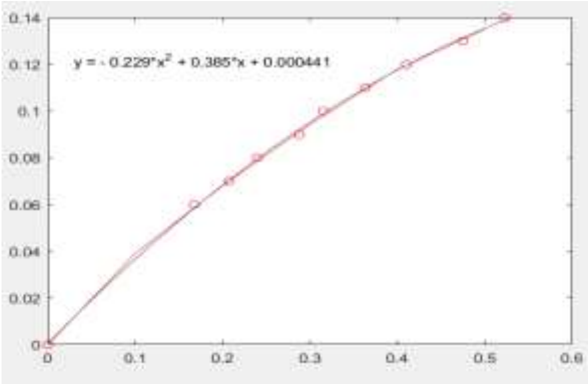

Figure. 5 Quadratic functions fit curves

As can be seen from the quadratic function, the slope of the curve decreases gradually, and it can be analyzed that when the concentration of the liquid gradually increases, it tends to a saturation value, so the change in absorbance gradually decreases.

5. INTERPRETATION OF RESULT

As shown in Table 2, the quadratic function is used as the fitting curve, and the maximum error is 0.2279% and the minimum error is 0.0115%, which is more accurate.

As can be seen from the experimental data, the test concentration data fluctuated up and down from the standard concentration data, and the fluctuation range was expected, but this fluctuation could not be avoided.

There are many reasons for errors, such as human errors, tool errors, device errors, environmental errors, etc. For example, in the configuration of liquid, the liquid will contain many impurities, which will lead to deviations in the experimental results, and a series of problems such as inaccurate mass measurement will occur in the process of solute configuration. In addition, ambient light can also have an impact on the installation.

Table. 2 Test values and errors

Mass Fraction (Unit: %)	Test Concentration (Unit: %)	Error (Unit: %)
0	0	0
6	5.8504	0.1496
7	7.0474	0.0474
8	7.9598	0.0402
9	9.2279	0.2279
10	9.9138	0.0862
11	11.0154	0.0154
12	11.9885	0.0115
13	13.1648	0.1648
14	13.9162	0.0838

6. CONCLUSION

In order to complete this test task, the STM32F103RCT6 chip based on the ARM Cortex-M3 core is selected as the main control module of the measurement device, and the TSL2591 photoelectric sensor is also selected as the main test element, and the light intensity digital signal converted by the TSL2591 photoelectric sensor is received by the IIC communication principle of the STM32F103RCT6 chip. The data is displayed on the OLED screen via the IIC data bus, i.e. the liquid concentration. In this experiment, a simple device was fabricated based on the principle that there are differences in absorbance of liquids at different concentrations. After excluding several influencing factors, the light intensity of the transmitted clear water was used as the incident light control group, and the light intensity of different concentrations of the liquid in each group was compared as the transmitted light experimental group, so that the absorbance of different concentrations of liquid was obtained. The mathematical relationship between absorbance and liquid concentration was established by using the curve fitting method of MATLAB, and the experimental results were verified by using this relation. Through the test, it is proved that the device can determine the concentration of the liquid more accurately.

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