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Design of Nitrite Concentration Detector Based on Embedded Technology

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Sodium nitrite has been widely used as food additives in food processing for a long time. With the improvement of people's living standards and the frequent occurrence of sodium nitrite food safety accidents, the safety of sodium nitrite residues in food has attracted much attention. Therefore, the design of a simple, accurate and reliable sodium nitrite detector can greatly avoid the occurrence of food poisoning events. In order to solve the problems caused by sodium nitrite, we design and realize a nitrite concentration detection system based on spectrophotometry. By detecting the concentration of sodium nitrite, we can better judge the harm degree of sodium nitrite in food. Firstly, the principle of Spectrophotometric Determination of sodium nitrite is introduced. Then, according to the advantages of embedded technology in instrument control, we use embedded controller STM32 to design the hardware circuit and software program of the system. Finally, the curve equation is obtained by the standard solution experimental data, which can be used to measure the concentration of sodium nitrite in samples. The experimental results show that the system does not exceed 5% error in measuring the concentration of nitrite in sample solution, which meets the requirements of the national food arrangement detector. The design has the advantages of simple operation, low power consumption, high accuracy, and reliability, and it has good application value.

1. Introduction

Sodium nitrite (NaNO2) is a white to pale yellow granular crystal or powder. The main characteristics of NaN02 are odorless, hygroscopic, toxic, and slightly soluble in alcohol and ether. Its aqueous solution is alkaline, and the PH value is about 9.Sodium nitrite is an industrial salt. It is a white opaque crystal. Because of its shape is very similar to salt, commonly known as nitrite. Nitrite as a food preservative and hair color agent, can improve the color and taste of food (Wu, 2007). Sodium nitrite has the dual functions of hair color and antiseptic, which is one of the food additives allowed to be used in the country (Panalaks et al., 2010; Zhai, 2002). Sodium nitrite is widely used in food industry as a food additive, and also exists in pickled products. In meat processing, sodium nitrite is used to improve its appearance, flavor, texture and storage resistance, so that the products show good color. At the same time, nitrite has a certain effect on inhibition of microorganisms. Combined with salt, it can increase the antibacterial activity and inhibit the Clostridium botulinum. However, nitrite is one of the substances that cause acute poisoning in food additives. Some studies showed that nitrate and nitrite will cause abnormal and cancer (Guo, 2009; Guo, 2010; Prasad, et al., 2002; Gary et al., 2012).

Sodium nitrite widely exists in people's daily life, and all exist in people's daily diet in the form of small amount. Therefore, the determination method of nitrite content in various foods is mainly based on instrumental analysis. With the continuous development and progress of new methods and technologies of analytical chemistry, the detection methods of sodium nitrite in food are more diverse, and new detection methods are emerging. At present, there are three kinds of methods to detect nitrite content in food. The first method is electrochemical analysis. This method is low cost, easy to operate, and can be used for rapid qualitative detection, and the sensitivity is low, and nitrite is easy to decompose and volatilize under acidic conditions, which is easy to cause missed detection (Miao, 2013).The second method is spectrophotometry. The most widely used spectrophotometric method is diazo coupling spectrophotometry. The method is mature and accurate, but the sensitivity is general. The reagents commonly used are carcinogenic and easily cause

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secondary pollution. When the nitrite content in the sample is high, the purple azo compounds are difficult to generate, which will cause false negative. Although the fluorescence method can improve the sensitivity of detection, but the interference factor is large, and the conditions are not easy to control, thus reducing the reproducibility of the detection (Berlin et al., 2011; Liao, 2013). However, this method is easy to operate and can be used to detect the concentration of sodium nitrite solution combined with embedded technology (Zhang, 2012; Liu et al., 2014). The third method is chromatographic analysis. The method has the advantages of high accuracy, low detection limit and wide linear range. It is suitable for trace or even traces analysis of nitrite in various biological matrices. However, the pretreatment is relatively complicated, and the pretreatment of gas chromatography needs derivatization, which increases the risk of artificial operation error (Chen et al., 2008).

2. Principle of Spectrophotometric Determination of sodium nitrite

Usually, the content of sodium nitrite is measured by measuring the content of NO2-. In recent years, there are many methods for the determination of N02- at home and abroad. Spectrophotometry, electrochemical analysis, chemiluminescence analysis and chromatography are commonly used. At present, the standard method for determination of nitrite at home and abroad is diazo coupling colorimetric method. In dilute phosphoric acid medium, N02- and amino benzamide (or sulfanilic acid) reaction of heavy ammonia salt, and then N-(1-naphthyl) ethylenediamine (or alpha naphthalene ammonia) coupling to produce red dye. Finally, the content of N02- is determined by spectrophotometry.

The harmful substances in food can react with specific reagents to produce color reaction. The maximum absorption wavelength is selected according to different color reactions. The absorbance is measured by spectrophotometry, and the concentration of the substance can be obtained according to Lambert Bill law. Lambert Bill law can be described as that when a bunch of parallel monochromatic light passes through an absorption pool containing a uniform light absorbing substance, a part of the light is absorbed by the solution and a part passes through the solution, and the formula is as follows:

$$A=\log(1/T)=KCL \quad (1)$$

$$T=I/I_0 \quad (2)$$

Among them, I_0: Incident light intensity; I: Transmitted light intensity; A: Absorbance; K: Molar absorption coefficient; C: Solution concentration; C: Thickness of liquid layer; T: Transmission ratio

It can be deduced from the above formula that when the molar absorption coefficient K and the liquid layer thickness L are unchanged, the absorbance A is proportional to the solution concentration C.

3. System design

The design of nitrite concentration detection system is composed of four parts, which are monochromatic light source selection, data acquisition, data processing and data display. We choose STM32 as embedded processor, and the structure of the system is shown in Figure 1. First, the stepper motor is selected to select the maximum absorption wavelength of the material to detect, that is, the sensitive wavelength of the material. Then, the signals collected by the optical frequency converter are sent to the STM32 single chip microcomputer for processing, and the absorbance and concentration of the material are calculated automatically. Finally, the data is displayed on the LCD screen.

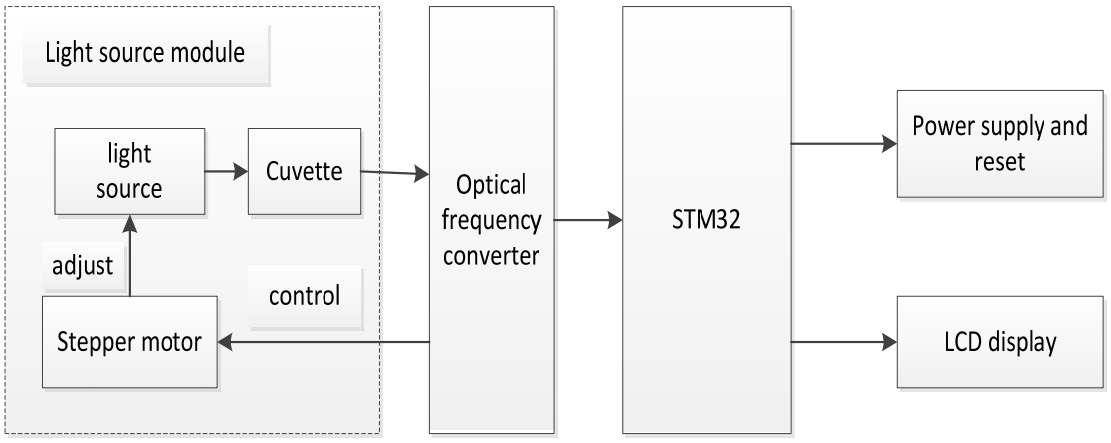

Figure 1: Block diagram of system design.

3.1 Hardware circuit design

3.1.1 Design of power supply module

There are two kinds of power supply in the system design, they are 12V and 5V. Among them, the 12V is the stepping motor driving voltage and the FET voltage. The 5V provides voltage for single chip microcomputer, TSL230 optical frequency converter and LCD. The power supply has great influence on the operation performance of the system, requiring stable and reliable power supply, small ripple, and providing stable voltage and enough current. The power circuit is composed of three terminal voltage regulators LM7805 and LM7812, and the multilevel capacitor filter is used to make the output voltage constant 5V and 12V. The power circuit is shown in Figure 2.

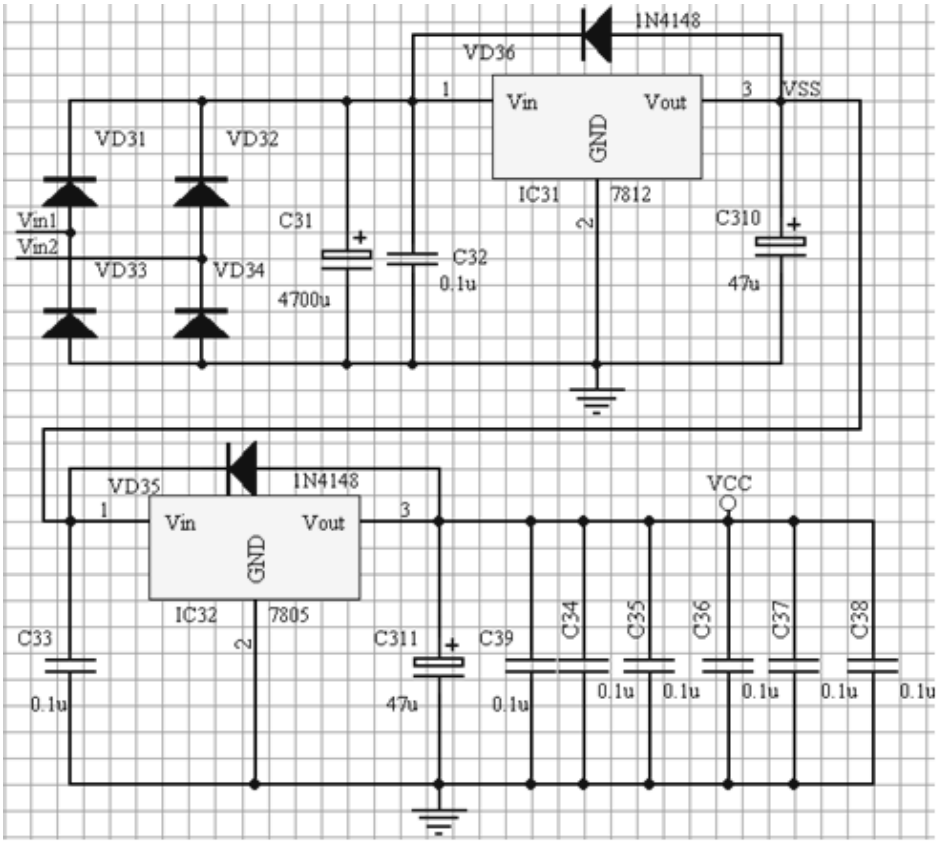

Figure 2: Power supply circuit.

3.1.2 Design of data acquisition module

The system requires a wavelength range of about 580nm. In this system, an integrated digital optical frequency converter TSL230 with a photosensitive wavelength of 300-1000nm is selected as the optical receiving sensor, as shown in figure 3. The device can directly convert the light intensity to the frequency with high resolution and is not affected by the peripheral devices. The input and output signal level is TTL compatible, the output frequency signal can be directly collected by microcontroller without amplification and A/D conversion. Since the output of TSL230 is frequency signal, the acquisition of data can be equivalent to the measurement of frequency signal. Since the frequency of the TSL230 output signal is proportional to the received light intensity, the measured frequency can be used as the equivalent light intensity.

3.1.3 Display module design

The system requires output and display measurement results, including absorbance of solution and concentration of sodium nitrite, requiring liquid crystals to display letters and numbers. LCD12864 resolution reached 128*64, for 16*16 fonts can display 4 lines, 8 columns of Chinese characters, has been able to meet the requirements of most of the equipment display. LCD12864 in the market is mainly divided into two types, one is with Chinese font by using the ST7920 controller, but its price is slightly higher. Another is the dot matrix mode without font by using KS0108 controller, and its price is more affordable. In this paper, we choose to use the LCD without font, the model is SO-LCM12864, and the display circuit is shown in Figure 4.

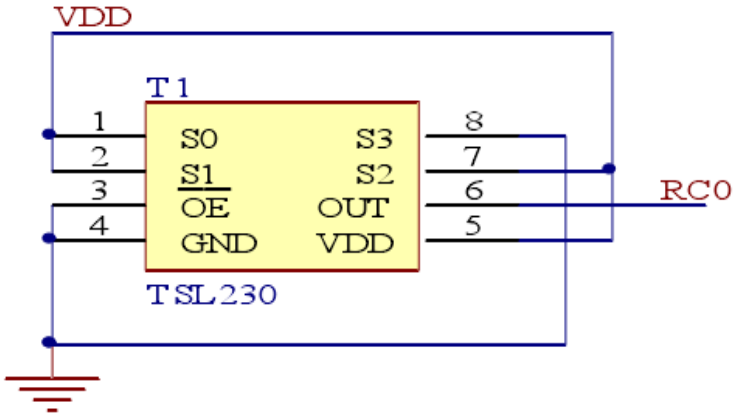

Figure 3: Acquisition circuit design.

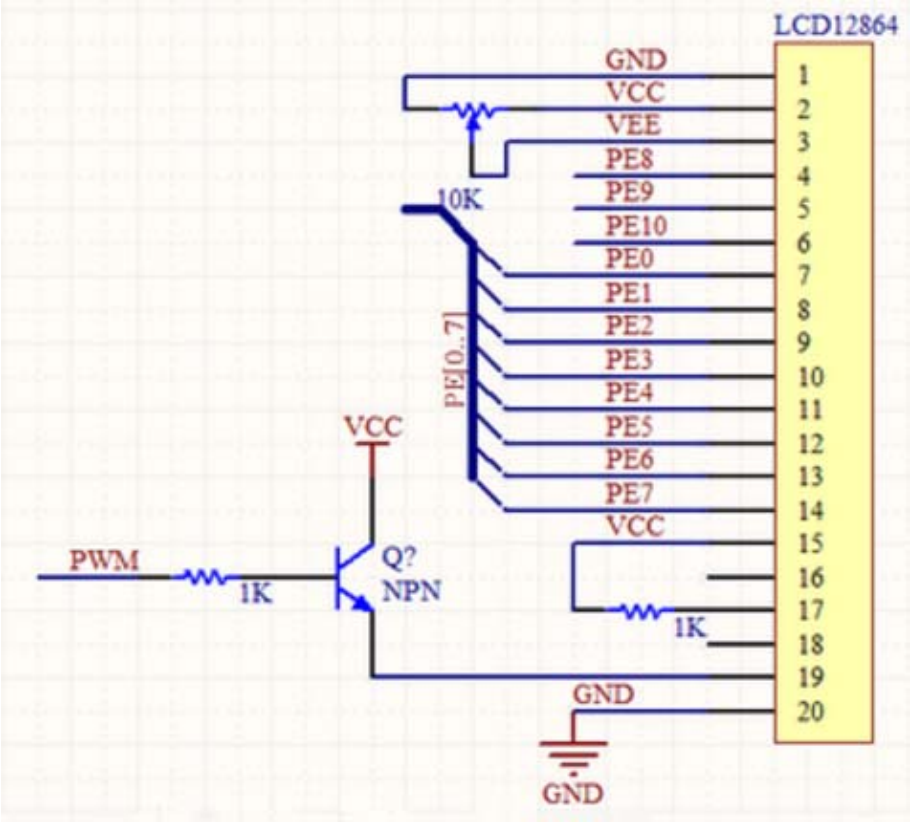

Figure 4: Display circuit.

3.2 Software programming

The system software program is written in C language, which is easy to transplant. The system software flow chart is shown in Figure 5. The whole software design mainly includes the main program and two subroutine modules. Through the embedded processor programming to achieve two functions, that is to control the stepper motor rotation and data acquisition. The data acquisition is the acquisition of transmitted light frequency after the TSL230 optical frequency converter, and the data is sent to the embedded processor processing. This involves the timing, counting and interrupt functions of single chip microcomputer. In order to solve the color reaction of the solution, the stepper motor is selected to control the light source of the proper wavelength by the program. Then, in the setting time (200ms), the number of pulses transmitted by the optical

frequency converter TSL230 is counted, and the transmission ratio, absorbance and concentration are calculated within the microcontroller after reaching the specified time. Finally, the results are shown on LCD12864.

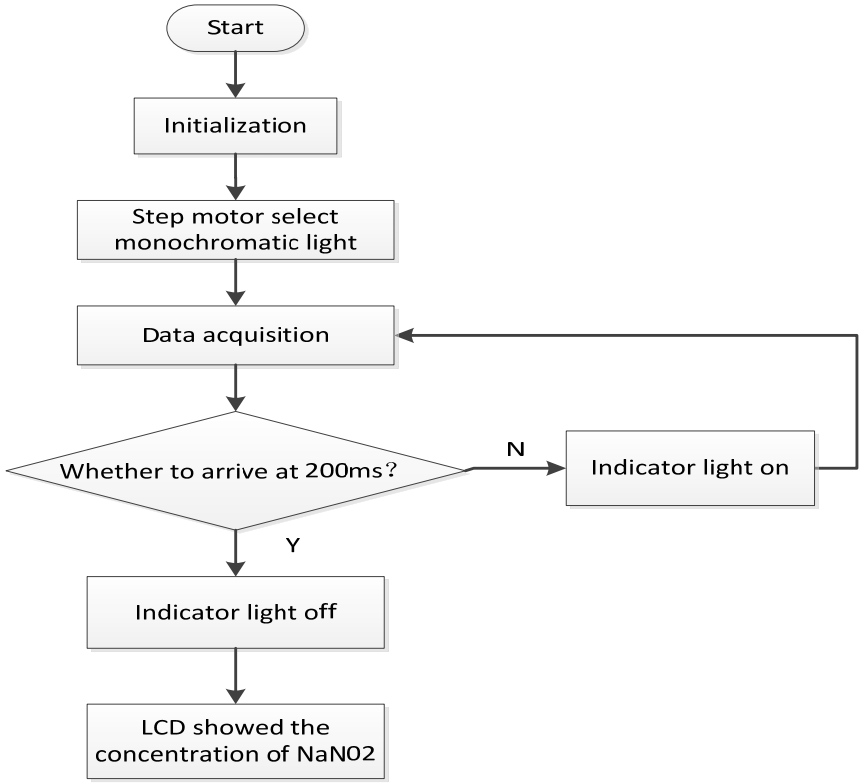

Figure 5: Flow chart of system software.

4. Experiment and result analysis

The designed nitrite concentration detection system based on embedded technology is used to detect the standard solution and sample solution to test its accuracy and reliability. After the reaction between sodium nitrite and para amino sulfonic acid, the chromogenic agent, ethylene diamine hydrochloride, is added, and then the purple dye is formed. The maximum absorption wavelength of purple red dye is 538nm at 25 degrees centigrade, and the concentration of sodium nitrite can be determined by measuring the absorbance at this point. The standard curve method is used to measure the concentration of the sample, that is, the concentration factor R of the concentration and absorbance is obtained by the standard curve, and then the concentration of the solution is calculated according to the relationship between the concentration and absorbance of $C=RA$. Table 1 is the experimental data of sodium nitrite standard curve.

Table 1: Experimental data of standard curve.

Number	1	2	3	4	5
Concentration (ug/ml)	0	0.1	0.2	0.3	0.4
Absorbance (A)	0	0.0265	0.0476	0.0845	0.1043

According to the corresponding relationship between concentration and absorbance in Table 1, the linear regression equation can be obtained as follows: $y=3.1217x+0.0043$. The 3.7217 obtained is the ratio coefficient R, and the value of R is stored in the system as the standard proportion of the concentration of sodium nitrite in the sample after detection.

In the experiment of measuring the concentration of sodium nitrite in sample solution, the absorbance of different solutions is measured continuously for 3 times under the same experimental conditions. The concentration of sodium nitrite in the solution can be calculated by the linear regression equation of the

standard curve of sodium nitrite. The measurement results of sodium nitrite concentration in sample solution are shown in Table 2.

Table 2: Measurement results of sodium nitrite concentration in sample solution.

Actual concentration of sample (ug/ml)	Measurement order	Measurement Result (ug/ml)	Average relative error(%)
0.16	1	0.173	1.57
	2	0.176	
	3	0.178	
0.34	1	0.364	2.1
	2	0.361	
	3	0.359	
0.68	1	0.661	3.2
	2	0.728	
	3	0.710	

From the results of Table 2, the system can be used to measure the concentration of sodium nitrite. The average relative error of measurement is no more than 5%, which meets the national requirements for food safety testing instruments (less than 10%).

5. Conclusion

The nitrite concentration detector based on embedded technology has the advantages of simple operation, small volume and high precision. The system has been used to detect the concentration of sodium nitrite in food. Firstly, the integrated digital optical frequency converter TSL230 is used as the optical receiving sensor to collect the data. Then, the digital signal sent by TSL230 is sent to STM32 embedded processor for processing. Finally, the concentration of sodium nitrite and other related parameters are shown by LCD12864. The hardware circuit and software program of sodium nitrite detector are designed and implemented, and the concentration of sodium nitrite is measured by standard curve method. The experimental results show that the system does not exceed 5% error in measuring the concentration of nitrite in sample solution, which meets the requirements of the national food safety detector.

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