Design and Research on the N02 Gas Monitoring System Based on MCU

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The harm of nitrogen dioxide is not limited to the great impact on the atmosphere, environmental safety and even harms human, animal, and plant life. Damage to devices and buildings can cause industrial accidents, huge property losses, and even cause casualties. Nitrogen dioxide (NO2) has attracted much attention as a toxic gas with high content, many sources, and greater hazards in the air. In recent years, with the development of industry and the emission of a large amount of automobile exhaust, the emission of nitrogen dioxide has been increasing every year. The air emission in the potential nitrogen dioxide emission area should be treated in time, and the emission must be carried out at a concentration that meets the standard. Only by detecting the concentration of nitrogen dioxide in the emission site at all times can the gas be effectively treated. The inspection system has been designed, it is still inadequate in many aspects. For example, the system takes a bit long time to warm up, and the solder joints are prone to poor contact. In future research, there can be two main research directions: 1. Improve the writing ability of C language to improve the stability of the detection system. 2. Find and synthesize more stable gas-sensitive materials to improve the sensitivity of the signal acquisition system and the accuracy of detection. Although the system has worked accurately and met the requirements, there is still a long way to go for future research, and more in-depth research on the product is needed.

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1. INTRODUCTION

1.1 Common Hazards of Nitrogen Dioxide

Nitrogen dioxide (NO2) has caused great harm to the environment and human health. The impact on the environment is mainly the impact on the competition and composition changes between wetlands and terrestrial plant species. A large amount of nitrogen dioxide will not only reduce atmospheric visibility, acidification, and eutrophication of surface water, also increase the impact on the water surface. The toxin content is harmful to fish and other aquatic organisms.

NO2 is a toxic gas with a pungent odor. It is chemically stable at room temperature and easily dissolves in water to generate acidic liquid. A high concentration of nitrogen dioxide is one of the main reasons for acid rain, and also in the formation of ozone. Inhalation of high concentrations of nitrogen dioxide in the human body will cause acute irritation to the human respiratory tract, and can also cause vision and smell disorders. Long-term inhalation of low concentrations of nitrogen dioxide can cause chronic bronchitis and other poisoning symptoms.

According to recent studies, Photochemical smog can cause green plants to lose their green color, causing leaf damage, leaf fall, and fruit fall, until the yield is reduced and the harvest is eliminated. In addition, it will cause an increased incidence of livestock, corrosion of metal products, aging of rubber products, and damage to various utensils, materials, and buildings.

1.2 Primary Sources of NO2

The sources of nitrogen dioxide are divided into natural sources and man-made emission sources. Among them, anthropogenic emissions are the main source. Anthropogenic emissions are further divided into fixed emission sources and mobile emission sources. Natural sources are mainly produced by lightning, nature, and soil nitrification, but the amount is relatively small, not same as the main source of dinitrogen oxide in the air, and can be ignored.

Stationary sources are mainly produced by combustion processes such as industrial boilers, industrial kilns, heating boilers, and large catering stoves. The bottom line is the large-scale use of coal, especially during the winter heating period that emits the most nitrogen dioxide. The mobile source is the exhaust emissions of motor vehicles on the streets and alleys. The emissions are relatively stable throughout the year without major fluctuations.

1.3 Research Methods of NO2 Detection

There are many methods for detecting nitrogen dioxide in the atmosphere, which are mainly divided into non-optical methods and optical methods. Non-optical methods include electrochemical methods, meteorological chromatography, mass spectrometry, etc. Optical methods use the interaction between light and pollutant molecules. The mechanism of action is detected, such as infrared absorption method, laser photogeneration method, Raman spectroscopy, etc. Here are a few more advanced methods in current research.

The detection of trace nitrogen dioxide gas based on LED light source jointly researched by the Chinese Academy of Sciences, the School of Physics of Jilin University, and the School of Science of Changchun University of Science and Technology. There are many designs of nitrogen dioxide-sensitive devices based on nanomaterials in modern research. Using the different reaction characteristics of metal oxides to different gases, the gas sensitivity of a certain material to nitrogen dioxide is tested through experiments. Then the metal oxides are used to prepare nanomaterials, and the prepared nanomaterials are used to manufacture gas sensors to achieve the two Nitrogen oxide detection.

This article uses metal oxides to prepare a gas sensor sensitive to nitrogen dioxide. Then uses a programming language to combine the single-chip microcomputer and the sensor to make its recognition intelligent.

1.4 The Purpose and Significance of this Study

1.4.1 Research purpose

Nitrogen dioxide is an important part of the air and also an important part of the ozone. However, excessive nitrogen dioxide not only causes great damage to the human brain, heart, and lung functions, also great damage to animals and plants. Therefore, it is necessary to

strengthen the detection of nitrogen dioxide in daily life.

When the air conditioner is turned on for a long time, a large amount of nitrogen dioxide will be produced. If the nitrogen dioxide cannot be emitted in a closed space, it is very necessary to measure the concentration of nitrogen dioxide at this time. For example, when driving on a highway for a long time, there is no way to drive with the window open all the time, and the nitrogen dioxide produced by the air conditioner cannot be discharged in time, which will cause unnecessary harm to the driver and passengers. Sometimes it can also cause the driver to be slow to respond to emergencies, leading to traffic accidents and causing heavy property losses and casualties. In addition, a large amount of nitrogen dioxide is also produced in places such as coal-burning boiler rooms, which is the main source of nitrogen dioxide pollution in the air. Excessive nitrogen dioxide emissions in the boiler room can cause irreversible losses to the air and staff.

The above two situations are only two typical situations of nitrogen dioxide gas hazards. There are still many nitrogen dioxide production situations in daily production and life, which are continuously affecting and harming the environment. Therefore, the detection device of nitrogen dioxide can be installed in key places where the NO2 gas produces and take necessary steps if gas emissions reach harmful levels.

1.4.2 Research significance

Combining the new C51 single-chip technology with the gas sensor makes the detection of the target gas more convenient and concise. By reading the literature, choosing the appropriate metal oxide as the target material, using the preparation technology of nanomaterials in the laboratory to prepare the nanomaterials sensitive to nitrogen dioxide, and using the sensor preparation technology to prepare the nanomaterials sensitive to nitrogen dioxide sensor and then independently designed the correct circuit and programming language. Then conducted continuous debugging, and finish testing. Finally designed a simple single-chip-based nitrogen dioxide detection system to increase the practicality of nanomaterials.

After the detection system of a single sensor is completed, another gas sensor added to identify interference. Use the gas-sensitive material test

system in the laboratory to test the sensitive data of the gas-sensitive material to the two gases, and use the data processing software to respectively fit the working characteristic curves of the two materials. Then compile them into the database of the single-chip microcomputer. The test process is performed by comparing the measured data with the database in the single-chip microcomputer, which can easily identify the gas type and gas concentration to be tested, and so on. With the hardware upgrade and sufficient data, the system can recognize the number and concentration of gas types. So, the value will become more and more accurate. The system shows the basic working principle of the current popular electronic nose. The device uses bionic technology, which imitates the working method of the human nose. Through learning and training, the system can accurately identify various gases and detect the concentration. In theory, as long as the hardware keeps up and the database is large enough, there can be an unlimited number of gas types identified.

2 SCHEME DESIGN

2.1 Design Topic

This design combines the gas sensor manufactured in our laboratory with the single-chip microcomputer to show the practical value of the sensor. This method can be used to detect the concentration of harmful gases in automobiles, alarm for exceeding the standard, and can also be applied to other places where nitrogen dioxide is often produced. In order to increase the broader practical value of the development of the system, on the basis of detecting nitrogen dioxide, an alcohol sensor and an ammonia sensor are also added for development.

2.2 Design Summary

First, select the hardware that meets the requirements, such as sensors, microcontrollers, display screens, and so on. For the detection of the target gas, a self-made gas sensor is used. Due to time reasons, commercial sensors are used for the detection of the other two gases.

After the control, display, signal acquisition, and other components are selected, the microcontroller is developed and studied, then the workflow is determined, and the program is compiled & the circuit diagram of the single sensor is designed. Then weld the designed

circuit diagram, and conduct power-on debugging after checking. Based on the success of a single sensor, two and three commercial sensors are designed and developed.

While studying and developing the single-chip microcomputer, the preparation of materials and the manufacture of sensors must also be carried out. After the successful development of the three sensors, the self-made sensors will be tested. Then the performance parameters of all sensors are tested and compiled into the program for the final development and testing of the detection system.

3. COMPARISONS AND SELECTION OF PLANS

3.1 Selection and Preparation of Nitrogen Dioxide Sensor Materials

3.1.1 Selection of nitrogen dioxide sensor materials

In the current research, the nano-structured resistive metal oxide semiconductor has a large surface area and simple sensing principle, so it is very suitable for the detection of nitrogen dioxide. Theoretically speaking, due to the adsorption of oxidizing gas, all metal oxide semiconductors will show a change in resistance. When selecting materials for testing nitrogen dioxide, it is required to choose materials that are more sensitive to nitrogen dioxide. In our test system, in addition to detecting the main body's nitrogen dioxide, it is also necessary to test interference gases such as alcohol gas and ammonia gas. This manual only details nitrogen dioxide-sensitive materials.

3.1.2 Introduction of tungsten trioxide nanomaterials

WO3 is an N-type metal oxide semiconductor material and a promising detection material for nitrogen dioxide gas. Gas sensors have a wide range of applications together with tungsten trioxide [1]. The nanostructure of tungsten trioxide is synthesized by various methods such as chemical vapor precipitation method, spray dehydrogenation method, sol-gel method, and so on. Among the different synthetic routes, the hydrothermal method has the advantages of low cost, low operating temperature, simple process control, and friendly process environment, and is considered to be a good technology for preparing

nanomaterials. In addition, this method does not require additional annealing to achieve a better crystallization temperature and can be used to synthesize free-dimensional nanostructures with various morphologies through a hydrothermal approach at a lower temperature.

In modern research, the two-step hydrothermal method is often used to prepare gas sensors based on tungsten trioxide. In the first step, a hydrothermal method is used to synthesize tungsten trioxide. In the second step, a variety of chemical methods such as the dripping method and spraying method are used to precipitate the synthetic powder on the glass substrate. In order to reduce costs and avoid multi-step and post-processing complications, a team has now proposed a one-step synthesis process.

Because WO3 nanosheets have a large effective surface area and a special surface morphology, they have broad application prospects. In the air, oxygen is chemically adsorbed on the surface of two-dimensional WO3 nanosheets and reacts with excessive electrons to form oxygen species (O2-, O-) [2,3]. Then a space charge layer is formed on the surface of the two-dimensional WO3 nanosheet, which reduces the carrier concentration. When the surface of the two-dimensional WO3 nanosheet is exposed to NO2 gas, the surface adsorbs oxygen and reacts with the gas, reducing the electron concentration near the surface of the two-dimensional WO3 nanosheet, thereby increasing the resistance. The two-dimensional nano-WO3 nano-sheet topography sensor has potential application prospects in high-sensitivity and high-selectivity gas sensing [2;4].

3.1.3 Introduction of tin dioxide nanomaterials

Tin dioxide is an N-type wide bandgap semiconductor oxide. The simultaneous appearance of transparency and conductivity of tin dioxide is a unique feature of group IV elements in the periodic table. Its excellent optical transparency is suitable for optical passive components in many devices [5]. The research of tin dioxide stems from its wide application in solar cells, such as catalytic support materials, solid-state chemical sensors, and so on [2]. The key to understanding all aspects of tin dioxide is its surface properties, and ultimately its properties depend on the bivalence of tin. The bivalence is beneficial to transform the surface composition from a

stoichiometric surface with Sn4+ surface cations to a reduced surface with Sn2+ surface cations, which depends on the oxidation potential of the system [6].

3.1.4 The choice of copper oxide nanomaterials

Semiconductor gas sensors will show resistance changes when exposed to toxic and dangerous gases. So far, research has focused on improving the gas sensing performance of n-type semiconductors such as SnO2 and ZnO. Correspondingly, there are few studies on CuO gas sensors with P-type semiconductor materials. Research on the gas sensing properties of CuO nano powders, nanobelts and nanorods, many physical and chemical methods for preparing Cu2O or CuO nanostructures have been explored, including the polyol method, hydrothermal reaction, anodic oxidation, electrospinning and thermal oxidation. The CuO prepared by thermal oxidation has higher crystallinity and a longer aspect ratio than those prepared by the solution method [7]. Therefore in this study, CuO was grown by the thermal oxidation of copper foil. As the CO and NO2 sensing characteristics of Cu were studied, interesting results regarding NO2 sensing were found. That is, the sensor resistance increases at high NO2 concentration (30-100ppm), but decreases as the NO2 concentration decreases to ≤ 5ppm.

The results of this research provide a new idea for preparing a new type of gas sensor, which can be used to control the air quality in the cabin [8]. The sensor will have the same resistance change when exposed to carbon monoxide and low concentrations of nitrogen dioxide.

By comparing the feasibility and economics of the preparation of various materials, copper oxide is finally selected as the final gas-sensitive material. The nano-sized copper oxide is produced in the laboratory. Finally proceed on the production and detection of dioxide Nitrogen gas sensor.

3.1.5 Synthesis of copper oxide

The preparation process of CuO is mainly divided into two steps. First, dissolve 170 mg of CuO·5H2O in 20 ml of deionized water. After it is completely dissolved, add 2 ml of NH3·H2O dropwise while stirring. At room temperature, magnetically stir at 500 r/min for 1 h, then transfer the light blue emulsion into a vacuum reactor and keep it in an oven at 120±1°C for 6 hours. After centrifugation, washing with deionized water 3 times, and then washing with absolute ethanol 2 times, the precipitate was collected, and the dried precipitate was annealed at 270°C for 48 h. Put the light green powder obtained by vacuum drying into a muffle furnace, raise it from room temperature to 350°C at a rate of 10°C/min, and keep it for 30 minutes before taking it out. The result will come out as CuO.

3.1.6 Preparation of nanomaterials

There are several methods for preparing nanomaterials. The main method is electrospinning, which is an electrospinning manufacturing technology [9]. In recent years, due to its versatility and application potential in different fields, it has caused more and more attention. Notable applications include tissue engineering, biosensors, filtration, wound dressings, drug delivery, and enzyme immobilization.

The main application in our laboratory's experiments is electrospinning technology, which has been very advanced in the production of modern nanomaterials. Its characteristics are low output and suitable for small-scale production, just to meet our application needs. After the preparation process of nanomaterials is completed by electrospinning technology, the prepared nanomaterials should be smeared on the base of the sensor device to complete the manufacture of the sensor. Then the manufactured device is placed in the detection box and injected with different concentrations of dioxide Nitrogen measures its sensitivity. Finally solders it on the detection circuit for final testing and regulation.

3.2 Selection of Control System

Single-chip microcomputer which is known as "computer on circuit board", combines CPU, memory, and other IO interfaces with large-scale integrated circuit technology. It has developed from the first 4 to 32 bits present [10]. The single-chip microcomputer is now widely used in design and research, and the technology is also very advance. 51-core single-chips occupies the vast majority of single-chip production, which makes the development and application of single-chips more convenient [11]. It's just that different types of single-chip microcomputers have different application directions, and the functions of

individual pins are slightly different. In the early stage of system design, we must integrate and analyze our existing resources to select the most suitable hardware device to make our design more simplification, lower costs and increase safety performance.

3.2.1 STC12C5A16AD type single chip

The STC12C5A16AD single-chip microcomputer is a new generation of high-performance single-chip microcomputer produced by Hongjing Company, and its pins are shown in the figure:

The STC12C5A16AD single-chip microcomputer is an 8051 single-chip microcomputer contains the central processing unit, program memory, data memory, and timer of all sensors, input, and output serial ports, etc. [12]. There are also some unique functions, such as the built-in A/D conversion function. Compared with the traditional 51-core single-chip microcomputer, this type of single-chip microcomputer has very simple and unique functions. For example, the internal A/D conversion function is a lot easier to

program that requires this process [13]. The storage space of the traditional 51 single-chip microcomputer has also been expanded, and the STC12C5A16AD single-chip microcomputer has added functions such as a second function reset pin and an external power-down detection circuit. It is a type of single-chip microcomputer that is widely used in design and programming.

The STC12C5A16AD microcontroller is a commonly used 40-pin microcontroller, and its main pins and functions are as follows:

1. A/D conversion interface (P0.0-P0.7): The digital-to-analog conversion function is a special function of this series of single-chip microcomputers, which is different from the general input and output interface of the traditional C51 single-chip microcomputer. With eight conversion channels, 10-bit ADC, its conversion speed can reach 250,000 times per second [12].
2. The STC12C5A16AD microcontroller has four 16-bit timers. While compatible with the T0/T of the traditional C51 timer, the 2-way PCA can also implement two timers.
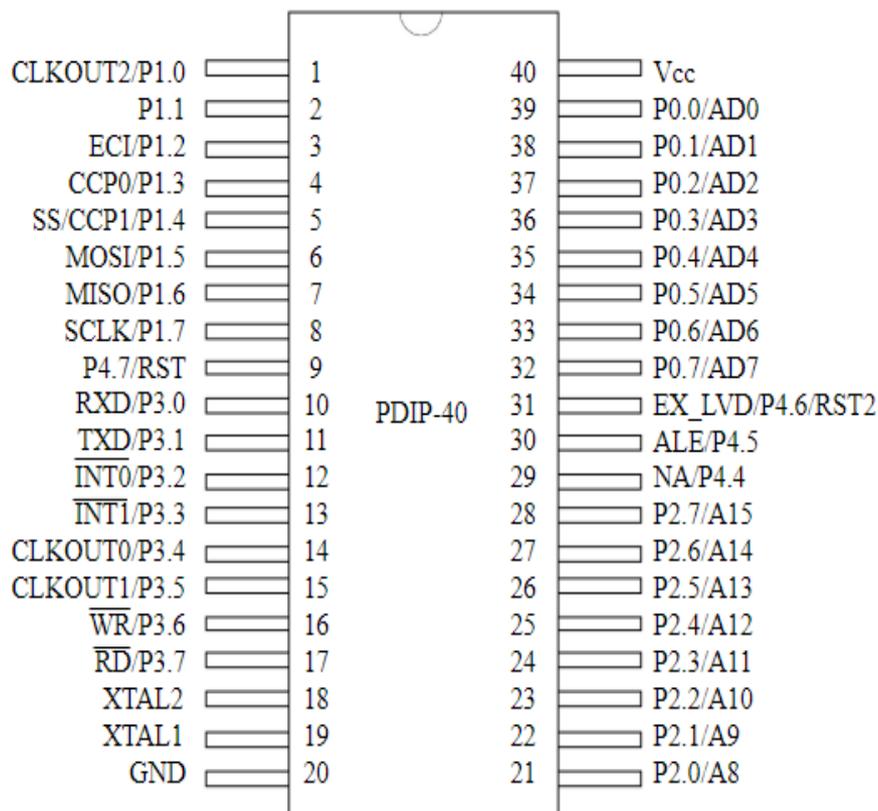

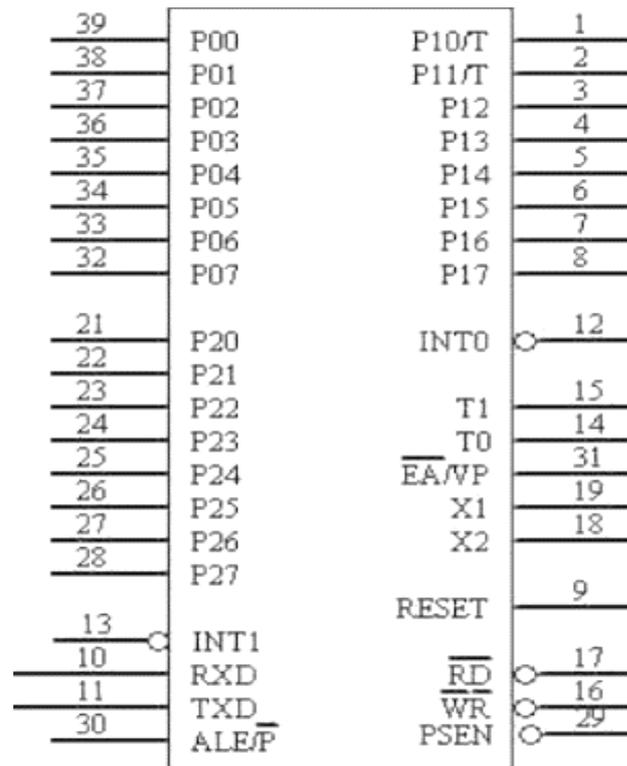**Fig. 1. STC12C5A16AD type single chip**

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39 ── P00          P10/T ── 1
38 ── P01          P11/T ── 2
37 ── P02          P12   ── 3
36 ── P03          P13   ── 4
35 ── P04          P14   ── 5
34 ── P05          P15   ── 6
33 ── P06          P16   ── 7
32 ── P07          P17   ── 8

21 ── P20          INT0  ── 12
22 ── P21
23 ── P22          T1    ── 15
24 ── P23          T0    ── 14
25 ── P24         EA/VP  ── 31
26 ── P25          X1    ── 19
27 ── P26          X2    ── 18
28 ── P27

                   RESET ── 9
13 ── INT1
10 ── RXD          RD    ── 17
11 ── TXD          WR    ── 16
30 ── ALE/P        PSEN  ── 29
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Fig. 2. STC89C52RC MCU

3.2.2 STC89C52RC MCU

The STC89C52RC single-chip microcomputer is also a new generation of high-speed, low-power, and super anti-jamming single-chip microcomputer produced by Hongjing Company [12]. The instruction code is fully compatible with the traditional 8051 single-chip microcomputer. The main functions of its pins are as follows:

While the STC89C52RC single-chip microcomputer has also strengthened the core of the traditional C51 single-chip microcomputer, it has also expanded its program storage memory and data storage memory. Its instruction code is fully compatible with 51 single-chip microcomputer, so there are enough resources to learn and develop the single-chip microcomputer.

The biggest advantage of the STC89C52RC single-chip microcomputer is that it has 32 universal input/output interfaces [12]. For developers, it can reduce the process of learning special pin functions separately [14].

The STC89C52RC single-chip microcomputer has not made any large-scale changes compared with the traditional 51 series single-chip microcomputer, except for some enhancements in its functions. The main functions are described below:

1. It has the same three 16-bit timers/counters as the C51 series single-chip microcomputers, namely timers/counters T0, T1, T2 (14 pins, 15 pins, 1 pin).
2. Pin 40 is VCC, which is connected with power supply voltage. The working voltage of the 5V single-chip microcomputer is 5.5V-3.3V (commonly used), and the working voltage of the 3V single-chip microcomputer is 3.8V-2.0V; the 20 pin is VSS pin, which is grounded.
3. P3.0 is P3.0-P3.7, and the corresponding pins are 10-17 pins. Not only can be used as input/output ports but there are also some multiplexing functions. The specific functions are P3.0 (RXD) as a serial input port, P3.1 (TXD) as serial output port, and P3.2/P3.3 as External interrupt 0/1, P3.4/3.5 is the external input of timer 0/1, P3.6 is the external data memory write strobe, and P3.7 is the external data memory read strobe.

3.2.3 Determine the model

STC12C5A16AD microcontroller and STC89C52RC microcontroller, as two

132

representative microcontroller models, have functions that can meet my design requirements. Next, we will consider the existing resources and the difficulty of development as follows.

The laboratory has the development system of Puzhong company's single-chip A7 model, with zero-based development tutorials and language writing tutorials. The development board mainly corresponds to the development of traditional C51. At the beginning of the project, it played a very important role in guiding and getting started. Among the single-chip learning materials collected, most of the traditional C51 series single-chip microcomputers are used as teaching cases. At the same time, based on our design principles and functional requirements, as well as the ease of development and economical principles, finally we chose the STC89C52RC microcontroller as our design control system.

3.2.4 STC89C52RC MCU physical picture

Fig. 3. STC89C52RC MCU physical picture

3.3 Selection of Display System

In this detection system, the most important hardware design except the control system is the display system. The types of display screens most commonly used in production and life are common displays, which are divided into CTR displays, LCDs, and LED displays [15]. By comparing the advantages and disadvantages of various displays, the LCD1602A liquid crystal display was finally selected. The display is an industrial character LCD, which can simultaneously display 16×02 or 32 characters (16 columns and 2 rows). In daily life calculators, multimeters, etc. have been widely used. In the man-machine communication interface of the single-chip microcomputer, the general output methods are as follows: luminous tube, LED digital tube, liquid crystal display. Light-emitting tubes and LED digital tubes are more commonly used, and the software and hardware are relatively simple.

3.3.1 Advantages of LCD1602A

Because every point of the display keeps that color and brightness after receiving the signal. Therefore, the display has the high image quality and does not flicker. Relatively speaking, the power consumption of the liquid crystal display is mainly consumed on its internal electrodes and driving IC, so the power consumption is much less than other displays [16, 17].

3.3.2 Physical image of the display

Fig. 4. Physical image of the display

3.3.3 Display circuit

This project uses a 10k resistor and 1k resistor partial pressure to adjust the grayscale, and the grayscale is moderate. The liquid crystal display circuit is as follows:

3.4 Selection of Signal Acquisition System

In the design of a nitrogen dioxide detection system based on a single-chip microcomputer, a sensor is needed to collect the signal. The sensor receives the gas and changes the corresponding physical properties, and transmits it to the single-chip microcomputer for data processing. Finally, the size of the concentration is displayed. In addition to the test target gas nitrogen dioxide, two interfering gases will be added to make the function of the detection system more diversified. The detection device of nitrogen dioxide adopts the device made of gas-sensitive materials prepared by ourselves in the laboratory, which has been introduced in detail in the selection of materials. For the detection of interfering gases, we use commercial sensors to collect signals. This section only describes the selection of commercial sensors.
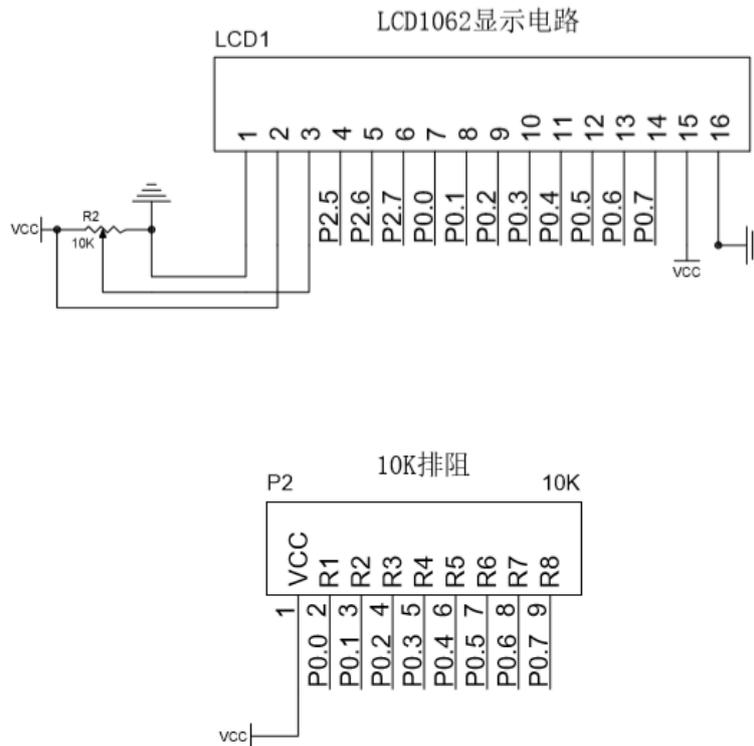
LCD1062显示电路

10K排阻

Fig. 5. Display circuit

3.4.1 Selection of sensor type

Common sensor types are divided into resistive sensors and electrochemical sensors. Electrochemical sensors mainly use the chemical properties of materials to detect target gases [18]. Resistive sensors use the physical properties of materials, such as resistivity and other properties for detection. This design mainly collects the voltage signal of the signal acquisition system and converts it into a digital signal. Moreover, the cost of chemical sensors is higher than that of resistive sensors. Considering the stability and economy, the signal acquisition system of interfering gas adopts resistive sensors.

According to the actual situation of the laboratory, ammonia, and gas alcohol were selected as the interference gases for this design. The alcohol sensor is MQ-3, and the ammonia sensor is MQ-137. The following briefly introduces the basic performance parameters of the sensor.

Introduction to MQ-3 sensor: The MQ-3 alcohol sensor has stable performance, but it needs to be heated for about five minutes before

it can be tested [16]. The main parameters of this type of sensor are shown in Table 2.4.1.

Introduction to MQ-137 sensor: The gas-sensitive material used in the MQ-137 sensor is tin dioxide with low resistivity in the air [11]. The resistivity increases as the concentration of ammonia increases. It has high sensitivity and is ideal for the detection of organic amines. The sensor can detect a variety of ammonia-containing gases. Its main parameters are shown in Table 2.4.2.

3.5 Selection of Other Hardware

Because the selected STC89C52RC type single-chip microcomputer has no A/D replacement program inside, it is necessary to select an additional conversion module for A/D conversion. Only one sensor was used in the early development, so an 8-pin, dual-signal receiving channel ADC0832 type A/D conversion chip was selected.

The conversion principle of ADC0832 is relatively simple, only need to use the programming language to control the high and low frequency of the pin to control the on-off and channel selection

of the chip [19,3]. This chip belongs to the relatively elementary development hardware in the MCU development process, so a large number of learning materials can be searched for development and research. The development of single or two sensors in the early stage can be fulfilled with one ADC0832 chip [20]. In the development of more than two sensors, since one sensor has only two signal conversion channels, it is necessary to use more pin conversion chips, or add ADC0832 The number of chips to meet the needs of development and testing [21]. The physical diagram of ADC0832 is shown in Fig. 6 below:

Table 1. MQ-3 sensor

Product number	MQ-3
Product type	Semiconductor gas sensor
Standard package	Bakelite (Black Bakelite)
Detection gas	Gas alcohol
Detection concentration	5-500ppm alcohol
Loop voltage (VC)	≤24V
Heating voltage (VH)	5.0V±0.2V AC or DC
Load resistance (RL)	Adjustable
Heating resistance (RH)	30±3 ohm (at room temperature)
Heating power consumption (PH)	≤900mW
Surface resistance of sensitive body (Rs)	2,000 ohms to 20,000 ohms (in 0.4mg/L alcohol)
Temperature humidity	20±2℃；65%±5%RH
Standard test circuit	V_C：5.0V±0.1V
	V_H：5.0V±0.1V
Preheat time	No less than 48 hours

Table 2. MQ-137 sensor

Product number	MQ-137
Product type	Semiconductor gas sensor
Standard package	Bakelite, metal cover
Detection gas	Ammonia
Detection concentration	5-500ppm ammonia
Loop voltage (VC)	≤24V
Heating voltage (VH)	5.0V±0.2V AC or DC
Load resistance (RL)	Adjustable
Heating resistance (RH)	29±3 ohm (at room temperature)
Heating power consumption (PH)	≤900mW
Surface resistance of sensitive body (Rs)	2,000 ohms to 20,000 ohms (in 0.4mg/L alcohol)
Temperature humidity	20±2℃；65%±5%RH
Standard test circuit	V_C：5.0V±0.1V
	V_H：5.0V±0.1V
Preheat time	No less than 48 hours

Fig. 6. Hardware

In addition to the main hardware mentioned above, the others are simple components, such as self-locking switches, buttons, etc. See Appendix 1 for details.

3.6 Non-technical Analysis

In addition to the comparison and selection of the various systems mentioned above, non-technical analysis of the selected schemes, such as safety, economy, environmental protection, etc., are also important factors that affect the comprehensive evaluation of the system design.

3.6.1 Security analysis

Many similar experiments have been done in the laboratory for the preparation of copper oxide nanomaterials, and the required materials are stable, non-corrosive, highly toxic, and other dangerous properties. Moreover, the experimental procedure is simple, and the operation of the experimental instrument is clear and simple. The voltage used in the design system is 5V, and there is no danger of electric shock. The entire design process is simple to operate and safe.

3.6.2 Economic analysis

The materials such as copper sulfate pentahydrate and ammonia water required for the experiment are the basic materials of the laboratory, and the required content is very small, so the cost can be ignored. The production technology of the single-chip microcomputer is now very advanced. The unit price of the universal board is about 7 yuan, and the unit price of the STC89C52RC type single-chip microcomputer and LCD1602A liquid crystal display is about 5 yuan. The unit prices of small devices such as key switches and ADC0832 chips are also very cheap. In the signal acquisition system, the unit price of an alcohol sensor is about 5 yuan, and the unit price of ammonia is 55 yuan. The unit price of a commercial nitrogen dioxide sensor is more expensive, where the cost of our own nitrogen dioxide sensor is low. The sensor effectively reduces our design cost. In general, the design cost of the entire detection system is controlled within one hundred yuan, and the economic performance is good.

3.6.3 Environmental protection analysis

The experimental materials for the preparation of copper oxide are common experimental materials. The waste materials after the experiment will be recycled and processed in a centralized manner, and the impact on the environment is basically negligible. The other components are purchased finished products. After the completion of the design, the finished product designed for this subject can be used to detect polluted gases. It can also be left in the laboratory for other research and use. It has a long life and is environmentally friendly.

4. DESIGNS OF PROGRAM AND CIRCUIT

After the basic devices such as hardware and sensors are prepared, on the basis of learning the MCU development board, start the program compilation and circuit diagram design of the MCU. It requires sufficient C language foundation and electrical circuit knowledge, as well as a full grasp of the working principles and development principles of the single-chip microcomputer, sensor, display, ADC0832 chip, and other devices used.

4.1 Design of the Program

For the compilation of the program, not only the programming language that can make the single-chip computer work is written in software, but also the sensitivity characteristic curve of the sensor and the flow of the detection system have a clear understanding. Only by clarifying the workflow, we can determine which functions the microcontroller needs to implement. Only in this way can the programming language be compiled accurately.

4.1.1 Flow chart design

Before the program is compiled, it is necessary to have a full grasp of the workflow of the detection system. The main workflow of the system is to detect and identify the signal, and then perform A/D conversion on the detected signal. For a multi-sensor detection system, it is necessary to screen and compare the signal sources detected by different detection ports, and finally, display the output on the display system. The specific workflow is as follows.

4.1.2 Compiling the program

There are assembly language and C language for the development of single-chip microcomputer. Since assembly language is more complex and its versatility is not as good as C language, C language is used as the

development language of single-chip microcomputer this time. The applied writing software is Keil 5, and the application of this software is relatively wide [22]. The compilation process should be divided into different modules, which is convenient for calling and later modification when compiling the main function. After the program is compiled, the software can be used to compile and run, and it can also be used for simulation work. After the compilation is successful, save it as a HEX file type, and put the compiled program file into the single-chip microcomputer through the USB to TTL download line, and then you can run the test system. The programming of the program can

also be arranged after the welding with the circuit is completed [23].

4.2 Design of Circuit Diagram

The design of the circuit diagram should follow the principles of electrical engineering and the use of various components. The use of each pin of the single-chip microcomputer and the display screen is not the same, so it is necessary to know the function of the single-chip pins clearly. The specific introduction of the single-chip microcomputer has already been introduced in the hardware selection, this part will not be introduced in detail.
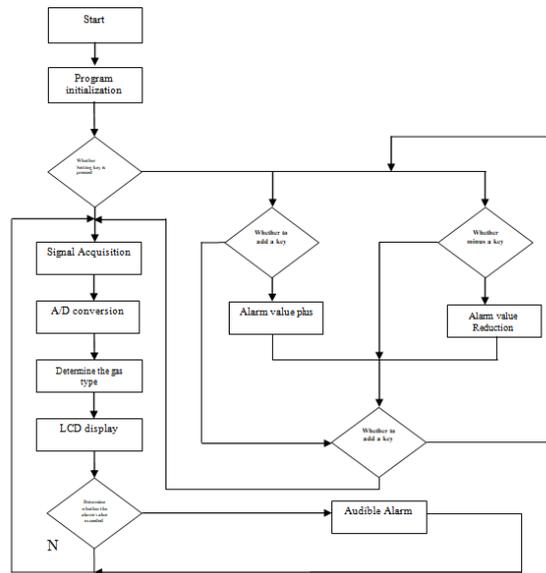

Fig. 7. Flow chart design

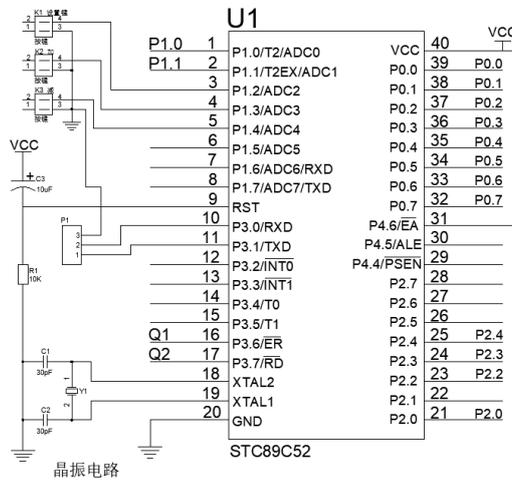### 4.2.1 Circuit diagram of the control system

Fig. 8. Circuit diagram of the control system
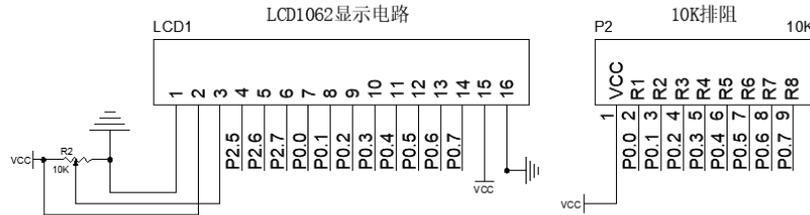
4.2.2 The circuit diagram of the display system

Fig. 9. The circuit diagram of the display system

4.2.3 Circuit diagram of signal acquisition system
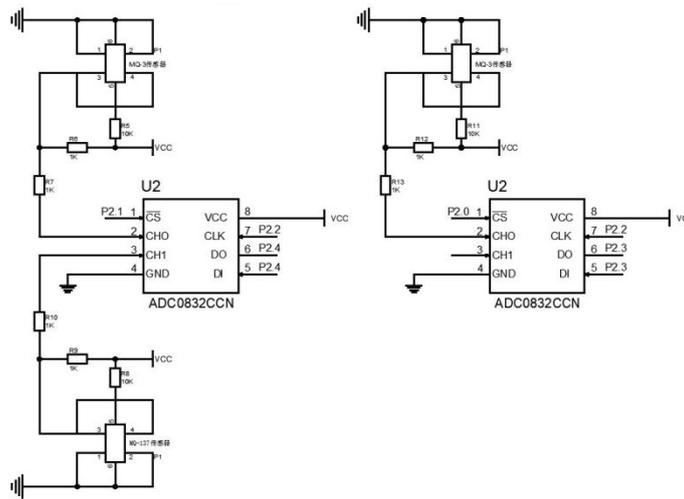

Fig. 10. Circuit diagram of the signal acquisition system

5. WELDING AND TRIAL RUN

5.1 Welding of the circuit

The welding of the circuit is also divided into two parts. The circuit diagram of a single sensor is welded in the early stage. Welding is mainly divided into three parts: the control system, the display system, and the information acquisition system. First weld each system individually, and then weld each system together. Finally, the welding of the test system is improved on a single welding board, and the other two signal acquisition systems are added for welding.

5.2 Debugging of the detection system

After we put the compiled program into the welded test system, press the switch, observe whether each system is working and whether the working state is normal. Detect and repair the abnormal part, find the cause of the abnormal work. Then propose a modification method, and finally implement it. The main reasons for the lack of electricity are, poor contact of the soldered pins, false soldering, wrong soldering, or too much solder to solder the two pins together. Then the signal acquisition system is energized for a long time, and the sensor is aging, so the sensor test is relatively stable. Finally, the debugging shows whether the system is working normally and whether the displayed data is normal. If it is not normal, the data in the program and the gas sensitivity characteristics of the materials must be revised. Finally, the tested gas is used for experimental operation. Knowing that each system is working normally and the indicator light and buzzer can alarm normally, which proves that the test system design is successful.

5.3 How to use the test system

First, power on the inspection system after welding and debugging. When plugging in the power port, be careful not to use too much force to avoid damage to the ambassador interface. Then connect the other end of the power cord to the USB port of the computer or to the mobile power or 5v power supply. Then press the self-locking switch. At this time, can be seen that the background light of the display is lit, and two rows of data are displayed on the display. The first row displays the test data, and the second row displays the alarm setting value. After pressing the switch, wait a few minutes for the display to stabilize. In this process, the sensor is heating, and the gas test can be performed after the preheating is completed. Because the sensor test needs to be heated, it is not recommended to touch the sensor during the test, so as not to affect the test accuracy. There are three buttons in the test system. After pressing the first button, can debug the alarm value. From left to right, it is still the debug switch key, numeric value plus key, and numeric value minus key. After pressing the debug switch key, can debug the value. Press the plus or minus key to increase or decrease the value by one.

After the power is turned on, when the display does not display or the displayed hours are wrong, check the entire circuit system, mainly check two aspects:

1. Check whether there is any problem with the welding pins, power pins, grounding pins, etc. The pins of the display screen have a great influence on its performance, and a wrong pin connection may cause the display screen to not work.
 2. Check whether the single-chip microcomputer is working normally and whether there is a high-temperature phenomenon. If a high-temperature phenomenon occurs, turn off the power immediately and remove the single-chip microcomputer. Re-check whether the soldering of the crystal oscillator is correct. The above situation occurs because the crystal oscillator is installed incorrectly, which causes the temperature of the single-chip microcomputer to rise sharply. Failure to deal with it in time may burn out the components.

6. RESULTS AND DISCUSSION

After the accurate and error-free operation of the sensor demonstration experiment is completed,

the results of this experiment are consistent with the progress of the system flow design plan designed this time. It shows that the design of this program is very accurate from device selection to program writing and implementation. There have also been some mistakes in circuit connection, such as connecting the power supply directly to the circuit after failing the button, which caused the switch to be short-circuited, and preliminary attempts compilation errors when writing programs. Therefore, repeated checks must be done in the experiment to ensure the normal progress of follow-up work. In the process of programming, there are many different ways of writing the program to achieve the same control purpose. In the later debugging process, you must have sufficient patience and knowledge, and need to continuously correct the gas sensitivity function and modify the program until the final success of the test system.

7. CONCLUSION

In the design of a nitrogen dioxide detection system based on a single-chip microcomputer, the two most important aspects of knowledge are the development of a single-chip microcomputer and the preparation of nanomaterial sensors. The single-chip microcomputer uses the most commonly used STC89C52RC type single-chip microcomputer, combines the single-chip microcomputer and ADC0832 to realize A/D conversion, and uses LCD1602A liquid crystal display as the display system. The alcohol sensor, the ammonia sensor, and the nitrogen dioxide sensor are combined to realize an array of sensors. Circuit design and device location design need to be repeatedly considered and modified to make the system's circuit more in line with the circuit's welding guidelines. The main application direction of the system is the detection of nitrogen dioxide. Despite having some limitations, this device is a cost-effective, lightweight, safe, user-friendly, portable, and simple system device for detecting harmful N02 gas. Later, more gas detection designs can be carried out under the premise of hardware upgrades.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for

any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table 3. List of components

Serial Number	Component	Model	Mark	Quantity
1	Universal board	9×15	/	1
2	40-pin IC seat	/	/	2
3	52 single chip microcomputer	STC89C52	/	1
4	8-foot seat	/	/	1
5	AD0832 chip	ADC0832	/	2
6	LCD1602 liquid crystal	LCD1602	LCD1	1
7	Pin	16p	/	1
8	Single row nut socket	16p	/	1
9	Button	/	/	3
10	MQ-3 sensor	MQ-3	/	1
11	MQ-137sensor	MQ-137	/	1
12	103adjustable potentiometer	/	/	1
13	Resistance	1k	/	7
14	Resistance	10k	/	4
15	Capacitance	20uf	/	1
16	Resistance	220Ω	/	2
17	Resistance	10Ω	/	1
18	103 exclusion	103	/	1
19	8550 transistor	8550	/	1
20	Active buzzer	/	/	1
21	Capacitance	30pf	/	2
22	LED lights	yellow	/	1
23	Crystal oscillator	11.0592M	/	1
24	LED lights	red	/	1
25	Self-locking switch	/	/	1
26	Wire	/	/	Several
27	USB power cord	/	/	1

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