Design of formaldehyde concentration detection system for smart home based on STM32 controller

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Abstract. It is a well-known thing that formaldehyde can seriously endanger human health. During decoration, some decoration materials, including furniture, will contain a large amount of formaldehyde, and some wall paint will also emit a lot of formaldehyde. Therefore, how to judge that the harmful gas in a house exceeds the standard has become a headache. In response to this problem, this article has designed an intelligent formaldehyde detection system, which can accurately detect the concentration of harmful gases in the room and then alarm. The operation is simple. The system consists of STM32F103C8T6 microcontroller circuit, LCD1602 liquid crystal display circuit, and formaldehyde detection sensor circuit. The voltage value and formaldehyde concentration value before formaldehyde conversion can be displayed in real time as the formaldehyde concentration changes. If the concentration of formaldehyde in the air is higher than the body's tolerance range, the buzzer will sound a "beep" alarm, otherwise it will not sound.

1. Introduction
Science and technology have promoted economic development, especially since the beginning of the 21st century. People's lives are not as poor as before, and the requirements for living environment are gradually increasing. Coupled with China's large population base, many land developers have begun to build high-rise buildings. These buildings are relatively closed, and air circulation has become difficult. Instead, the density has increased significantly. Although living in a high-rise building has given people a great sense of accomplishment, the risks associated with this sense of accomplishment have also quietly arrived.

Formaldehyde is a harmful indoor gas. Floors and paints used to decorate homes can volatilize a large amount of formaldehyde. High formaldehyde concentrations can cause people who have been in them to edema, paralyze, and even cause major carcinogenic consequences. Formaldehyde is far more threatening to the fetus than adults, and it is easy to cause the fetus to suffer from congenital diseases and severely cause deformities in newborns.

As early as the 1980s, there was a formaldehyde measurement device using piezoelectric sensors. It was very advanced at the time, but its fatal flaw of detecting instability in environments with high moisture content directly limited its popularity. Since people know the dangers of formaldehyde, research on it has not stopped until the emergence of single-chip microcomputers, and the
formaldehyde detection system has been qualitatively improved, and it is moving towards multi-faceted development[1]. Leading foreign companies include ESC in the United States and ppm in the United Kingdom. Their measuring instruments are also slightly different compared to domestic ones. Because China's control technology is still immature, domestic measuring instruments are not as long as foreign products. It is also more complicated than foreign products.

The formaldehyde detection instruments on the market are relatively expensive and are not suitable for daily use by ordinary households. However, the problem of the harm of formaldehyde to the human body needs to be solved urgently. Therefore, this article designed a household formaldehyde concentration detection system. Accurate detection of formaldehyde concentration is relatively inexpensive.

2. System design ideas and overall structure

2.1. System design ideas

This design first establishes the consumables required for the research, analyzes the functions, divides the hardware and software design into two major modules, designs the overall hardware structure, and then performs the software design process, writes the program, adjusts the subroutines, combines the software and hardware to debug and test the Precision. The overall design idea is shown in figure 1. The design consists of STM32F103C8T6 microcontroller core board circuit, LCD1602 liquid crystal display circuit and formaldehyde detection sensor circuit.

When the system is powered on through the USB cable, a voltage of 5v is passed, which exceeds the operating voltage of the microcontroller, and it must go through a step-down chip to step down to 3.3v to power the microcontroller. The formaldehyde sensor needs to be connected to two voltage-dividing resistors in order to connect to the microcontroller, which prevents the voltage from being too high.

The microcontroller receives the analog value of the formaldehyde sensor A/D conversion in real time and converts it into a formaldehyde concentration value, compares it with the internal preset threshold of 2ppm, and controls the buzzer to respond. At the same time, the LCD liquid crystal display is driven to display the formaldehyde concentration value.

![Figure 1. Overall design ideas.](image)

2.2. The overall structure of the system

The total power supply is connected to the smallest system board of the single-chip microcomputer through a step-down circuit to provide the power supply voltage for the entire system circuit. The concentration of formaldehyde in the air is collected by the formaldehyde sensor and transmitted to the single-chip microcomputer. The signal is converted in the single-chip microcomputer and compared with the internal signal. After that, the data is displayed on the LCD1602 liquid crystal display. If the formaldehyde concentration is higher than the threshold, the buzzer will alarm; if it is lower than the threshold, the buzzer will not alarm. The overall block diagram of the system is shown in Figure 2.
3. Hardware design

3.1. STM32 microcontroller
The STM32 series is produced by STMicroelectronics. STM32 microcontrollers are widely used. The controller has powerful performance, rich and reasonable peripheral equipment, supports powerful software and comprehensive technical documentation, and is low in price. So it is widely used in various control systems[2].

The control chip used in this article is the STM32F103ZET6 microcontroller of the STM32 series, as shown in figure 2. The sensor is connected to the I/O port of STM32F103ZET6 to collect parameters such as temperature, humidity and light intensity, which are analyzed and processed by STM32F103ZET6 and controlled. TM32F103ZET6 is a commonly used enhanced series of microcontrollers. The core is an ARM 32-bit Cortex-M3 CPU with built-in high-speed memory. It can work in the temperature range of -40 °C ~ +105 °C, and the power consumption is relatively low. It is very suitable for the research design of this subject[3-5].

3.2. LCD1602 LCD
This article uses LCD liquid crystal display to display data. LCD liquid crystal display is cheaper than dot matrix digital tube display. The most important thing is that it can display more digits, more than LED digital tubes, and the display scheme is simple, the power consumption is relatively low; the external influence is also small, and the service life is long. [6].

3.3. Audible alarm module
The alarm circuit uses a buzzer as the alarm device. The buzzer does not need a speaker drive circuit like a voice integrated chip. The alarm device is an alarm circuit composed of a buzzer. This circuit is relatively simple, easier to accept than a voice integrated chip, more reliable in performance, and particularly cheap in cost[7, 8].

3.4. MS1100 formaldehyde sensor module
The MS1100 formaldehyde sensor is widely used to measure some VOC gases. Its anti-interference ability has been greatly improved compared to previous piezoelectric sensors, and it can accurately detect organic volatile components such as formaldehyde and benzene in the air. Its application is very extensive, and it can be seen in various small appliances, ventilation equipment, air filters and other equipment. Its main parameters and module parameters are as follows:
- Power supply 5V; working temperature -10 °C ~ 50 °C; working humidity 5 ~ 90% RH; non-condensing; storage temperature -20 °C ~ 80 °C; response time is less than 10 seconds; minimum oxygen concentration is about 18%. Oxygen concentration also affects its accuracy.
- VCC is connected to 5V; GND is grounded; AOUT is an analog voltage output; DOUT is a TTL level output[9].

4. Circuit connection

4.1. Display circuit

![Figure 2. Block diagram of the overall system.](image-url)
LCD1602 is lightweight and easy to carry. It is the most common display device in the design of single-chip microcomputers. It can be connected directly with a single pin without the need for an external drive circuit. The content and clarity of the display are far superior to those of digital tube displays. Lower. The display capacity of LCD1602 is 16 characters×2 lines, and the working voltage is 5±0.5v. [10]. 

The LCD1602 uses a 14-pin interface with 11 instructions. The read and write operations of the 1602 LCD module are controlled by instruction programming. Its circuit diagram is shown in figure 3.

![Figure 3. LCD1602 display circuit.](image)

4.2. Alarm circuit
The core component of the alarm circuit of the formaldehyde concentration detection system is an active buzzer, that is, an electronic buzzer. Its power supply mode is DC voltage, driven by a transistor, and the working voltage is 5 volts. Once the single-chip microcomputer receives the data, it compares the human body with an acceptable range of 2ppm, and then transmits the instruction to the buzzer to control the buzzer to respond and realize the alarm. R1 in the figure is a current limiting resistor, which prevents the buzzer from burning out and has a protective effect. The alarm circuit is shown in figure 4.

![Figure 4. Buzzer alarm circuit.](image)

4.3. Formaldehyde detection circuit
The connection of MS1100 formaldehyde sensor in the circuit is shown in figure 5.

![Figure 5. MS1100 formaldehyde detection circuit.](image)

4.4. Overall circuit structure
The microcontroller, formaldehyde concentration detection module, display module, and liquid crystal display are connected in kind according to the method shown in Figure 6. At the same time, the
drawing software Altium Designer is used to draw the circuit wiring diagram of the formaldehyde concentration detection system. The overall circuit schematic is shown in 7.

![Diagram of a formaldehyde concentration detection system](image1)

**Figure 6.** Physical connection diagram.

**Figure 7.** Schematic of the overall circuit.

5. **Program development environment**

The formaldehyde concentration detection system uses Keil uVision5 as the development environment. It is convenient to compile, connect and debug the system. Keil uVision5 not only provides a complete Windows development interface and supports C / C++ language development, but also has a high C language editing efficiency, enabling developers to use C language for R & D very conveniently.

Keil has a wealth of library functions that can be called directly, which essentially reduces the working time, reduces the workload, and supports multiple operating systems; Keil can start from the first editing of the development process, compile, link and debug, and even Simulation can be achieved; Keil uVision5 is more powerful than Keil uVision4 IDE. Cortex-M core MCU development support has been enhanced, and the development form and development interface direction have also changed accordingly[11].

6. **PL2303 serial program programming**

This article uses the PL2303 serial programming module to program. The PL2303 serial programming module uses a USB interface and is suitable for various operating systems such as win7 and win10. There are two power supply methods for programming microcontroller chips. One is to use the target system itself. Built-in power supply, the other is to use USB for power supply, when using USB to ensure that the target board current is less than 500mA.

PL2303 has five pins, of which RXD and TXD are directly connected to the corresponding pins on the microcontroller, GND is grounded, + 5V is 5v output, and 3V3 is 3.3v output. If the circuit board has an external 5v power supply, it is not connected. + 5V. Similarly, if the circuit board has an external 3.3v power supply, 3V3 may not be connected. The specific wiring between the PL2303 serial programming module and the microcontroller is shown in figure 8.

![Diagram of PL2303 serial programming module and microcontroller connection](image2)

**Figure 8.** PL2303 serial programming module and microcontroller connection.
7. Program flowchart
The soft design of this system mainly uses Keil uVision5 to write software and debug programs. The specific program design flowchart is shown in figure 9.

8. Data test
For the human body, in the formaldehyde environment at a concentration of 2ppm, it can cause a slight tingling sensation in the eyes and throat, which can be tolerated for a short time, usually no more than eight hours. 1ppm will detect odor, but it will not be unbearable, and the degree of harm to the human body is within an acceptable range.

The MS1100 formaldehyde sensor is suitable for testing 0.1 to 30 ppm of VOC gas, and the signal output terminal correspondingly outputs an analog signal (0.5 to 4.5 Volt). Table 1 Correspondence between output voltage and VOC gas concentration (typical value 30 ° C, 55% RH).

Table 1. Correspondence between output voltage and gas concentration.

| Formaldehyde gas concentration(ppm) | 0   | 0.1 | 0.3 | 0.5 | 0.7 | 1   | 2   | 3   |
|------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| The output voltage(V)              | 0.5 | 1.4 | 1.75| 2.1 | 2.35| 2.5 | 3.9 | 4.5 |

This system can change the value with the change of formaldehyde concentration in the air, and can reflect the formaldehyde concentration in the air in real time. Because the formaldehyde concentration in the normal study life is less than 2ppm, I use a lighter gas to simulate the formaldehyde concentration. Normal conditions The measured formaldehyde concentration is shown in figure 10 below. As the lighter gas is released, the voltage value increases and the formaldehyde concentration value also increases accordingly.

9. In conclusion
The system is designed reasonably, the data test is accurate, authentic, reliable, and highly accurate, which meets the needs of people's lives and enhances the sense of life security.
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