

Design of STM32 Air Quality Detection System

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Abstract

With the acceleration of industrialization and the expansion of urbanization, environmental pollution issues have become increasingly severe, especially air pollution, which has become a global public health issue. Long-term exposure to high concentrations of fine particulate matter (such as MQ-2) and other pollutants can have a severe impact on human health, including respiratory and cardiovascular diseases. Therefore, monitoring environmental quality has become particularly important. Moreover, with the improvement of people's living standards and health awareness, more and more people are beginning to pay attention to the quality of the environment they are in. Whether it is at home, in the office, or outdoor activities, a tool that can monitor environmental quality in real-time is needed to help make healthier lifestyle decisions. Based on the above aspects, this system is designed for environmental monitoring.

Keywords

Temperature and Humidity; MQ-2; Atmospheric Pressure; OLED.

1. Introduction

With the increasing attention to the safety of living and working environments, the demand for environmental monitoring systems has gradually increased. Especially in places such as residential homes, office spaces, schools, and hospitals, attention to air quality is particularly important. Poor indoor environmental quality has been proven to cause various health problems, such as respiratory diseases, allergic reactions, and cardiovascular diseases. At the same time, governments and regulatory bodies continue to introduce new environmental protection regulations, requiring the reduction of harmful gas emissions and the improvement of safety standards in public areas.

There are already various environmental monitoring systems on the market, which are widely used in homes, offices, schools, hospitals, and other places. These systems usually have functions such as monitoring temperature, humidity, and air quality, and with the advancement of technology, more and more products are beginning to integrate wireless communication technology for remote monitoring and management.

2. System Design Plan

2.1. Design Ideas

The air quality monitoring system designed this time mainly consists of five parts: DHT11 temperature and humidity sensor, MQ-2 gas sensor, MQ-7 carbon monoxide sensor, buzzer, and an OLED display. The STM32F103C6T6 microcontroller is used as the main control core of the system. The system structure is shown in Figure 1-1. Initialize all hardware components, including DHT11 temperature and humidity sensor, MQ-2 gas sensor, MQ-7 sensor, OLED display, and buzzer. First, set up the microcontroller to prepare for data collection and

processing. Then, the microcontroller periodically reads the DHT11 temperature and humidity data, MQ-2 gas data, and MQ-7 carbon monoxide concentration data. Then process and convert the collected data. And display the current temperature, humidity, smoke, and carbon monoxide concentration through the OLED display. If the external data exceeds the threshold, activate the buzzer to sound an alarm.

2.2. System Composition

When designing the STM32-based air quality monitoring system, we carefully divided it into two core parts: hardware design and software design, which work together to create an efficient and intelligent monitoring solution.

Firstly, the hardware design part of this system aims to build a portable environmental monitoring system through carefully selected sensors and components. The system integrates DHT11 temperature and humidity sensors, MQ-2 gas sensors, MQ-7 carbon monoxide sensors, OLED displays, and buzzers, which can monitor temperature, humidity, smoke, and carbon monoxide concentration in the environment in real-time and sound an alarm when necessary. By selecting high-performance microcontrollers and designing a reasonable power management system, the stability and portability of the system are ensured. In addition, the system also has expandability and can add wireless communication functions as needed.

Then, we entered the core stage of software design. With the help of KEIL, a powerful integrated development environment, we carried out the writing of the system program. KEIL not only integrates a wealth of compilation and debugging tools but also provides efficient simulation debugging functions, helping us to quickly promote the development and testing process of the program.

During the programming stage, we chose C language, a high-level programming language with a clear structure and easy to maintain, and built multiple functional modules according to the needs of the system, covering data collection, data processing, display control, and alarm triggering. By adopting a modular design concept, we ensured the clarity and flexibility of the program, laying a solid foundation for future functional expansion and maintenance.

After rigorous testing and debugging, we successfully wrote the compiled hex file into the STM32F103C6T6 microcontroller, achieving comprehensive control of the environmental monitoring system. So far, an environmental monitoring system that integrates temperature and humidity detection, smoke detection, carbon monoxide detection, and high-concentration alarms has emerged, providing users with a safer and smarter air quality monitoring system product.

3. System Hardware Part Design

3.1. Microcontroller Minimum System

The STM32F103C6T6 is a 32-bit microcontroller based on the ARM Cortex-M3 core, belonging to the STM32F103 series, also known as one of the "Blue Pill" series. This series of microcontrollers is popular for its high performance, low power consumption, and rich peripheral resources.

High performance: Adopts a high-performance ARM Cortex-M3 core, with a main frequency of up to 72 MHz, providing high-speed processing capabilities.
Storage resources: Equipped with 64 KB flash memory and 20 KB SRAM, providing enough space for program storage and data processing.
Rich peripherals: Integrates a series of peripherals, including multiple timers, ADC (analog-to-digital converter), DAC (digital-to-analog converter), USART/UART (serial communication interface), SPI (Serial Peripheral Interface), I2C (Inter-Integrated Circuit bus), etc., to meet various application needs.
Low power consumption: Supports various low-power modes, such as sleep mode, stop mode, and standby mode, suitable for battery-powered

applications. Safety features: Has various protective mechanisms, such as watchdog timers and power monitors, to ensure stable system operation. Packaging form: Adopts LQFP-48 packaging, which is convenient for PCB layout and soldering. Rich development resources: Has a wide range of development tool support, including IDEs (Integrated Development Environment), evaluation boards, reference designs, etc., facilitating rapid development.

In summary, STM32F103C6T6, with its excellent performance, rich peripheral resources, and low power consumption characteristics, has become an ideal choice for many embedded applications. The microcontroller's minimum system is shown in Figure 1.

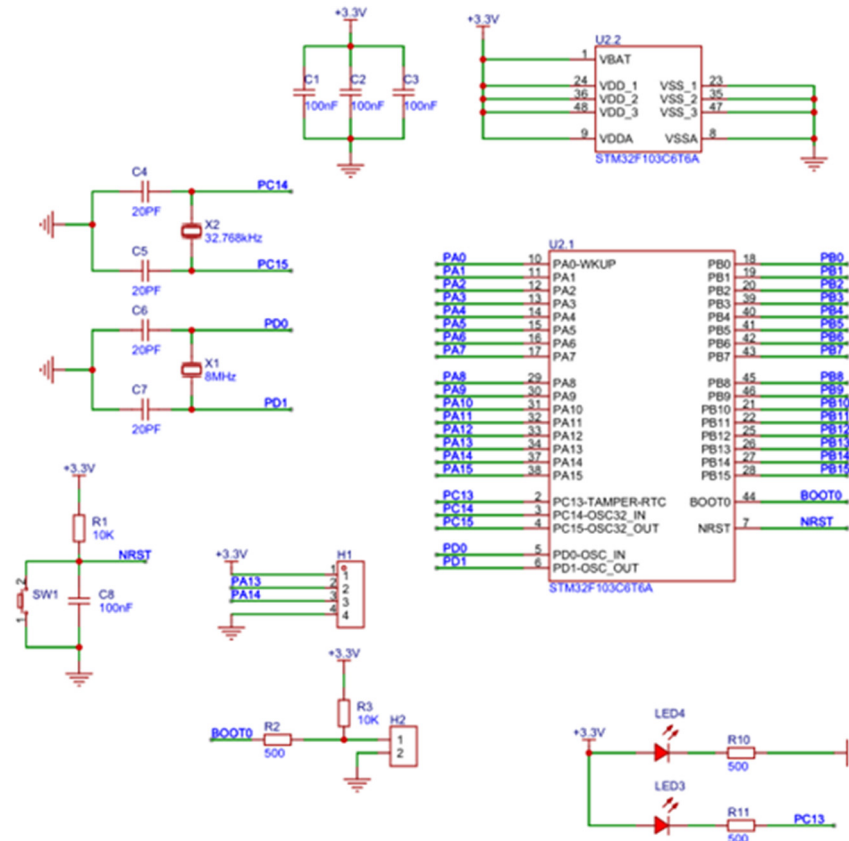


Figure 1. Microcontroller Minimum System Diagram

3.2. Power Circuit

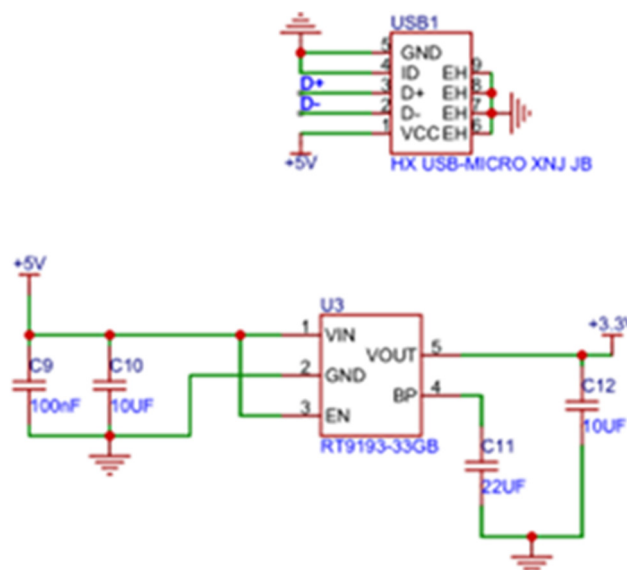


Figure 2. Power Module Schematic

The power part of the air quality monitoring system designed based on the STM32F103C6T6 microcontroller uses a regulator to convert the input voltage into the required output voltage. In this system, the regulator reduces the 5V input voltage to 3.3V to provide a stable +3.3-volt voltage. In addition, there are multiple capacitors in the circuit, such as C9, C10, etc. These capacitors are mainly used for filtering and decoupling purposes, helping to eliminate power supply noise and ensure stable voltage supply to the load.

In general, the main function of this circuit is to receive the 5-volt voltage from the USB interface and use the regulator to adjust it to 3.3 volts to power downstream devices. The power module schematic is shown in Figure 2.

3.3. Button Circuit

This system is equipped with four buttons to control the various functions of the system. These buttons are the interface switch button, option switch button, plus button, and minus button. The specific operation process is as follows:

When K1 is pressed, the system enters the alarm setting interface. Then, users can use the K2 button to switch between temperature, humidity, carbon monoxide concentration, and smoke concentration to select the alarm parameter that needs to be set. Users can use the K3 button to increase the alarm threshold of the selected parameter. Users can use the K4 button to reduce the alarm threshold of the selected parameter. In this way, users can conveniently set the alarm thresholds for various parameters to meet personalized needs. The button control schematic is shown in Figure 3.

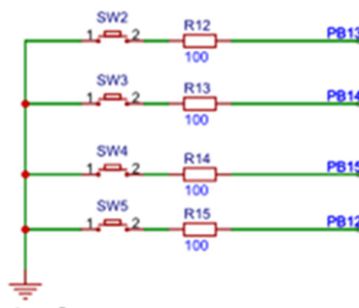


Figure 3. Button Control Circuit

3.4. Temperature and Humidity Detection Circuit

This system is equipped with a DHT11 temperature and humidity detection module to detect the air. DHT11 is a low-cost digital temperature and humidity sensor, widely used in various environmental monitoring applications. It has a temperature and humidity-sensitive element and a dedicated signal processing circuit inside. It can measure the relative humidity and temperature of the surrounding air and output this data through a digital interface. The temperature and humidity detection circuit schematic is shown in Figure 4.

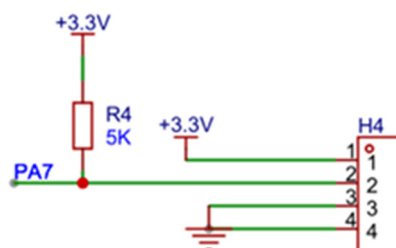


Figure 4. Temperature and Humidity Detection Circuit Schematic

3.5. Smoke Detection Circuit

This system uses the MQ-2 sensor to detect the concentration of smoke in the air. The MQ-2 sensor is a gas-sensitive element based on tin dioxide semiconductor materials, mainly used to

detect the presence and concentration of various gases. When there is smoke in the environment, the MQ-2 sensor can respond quickly and output corresponding signals for triggering alarms or other safety measures. In addition to smoke, the MQ-2 sensor can also detect leaks of liquefied gas, hydrogen, and other flammable gases, which is very important for preventing fires and explosions. The smoke detection circuit is shown in Figure 5.

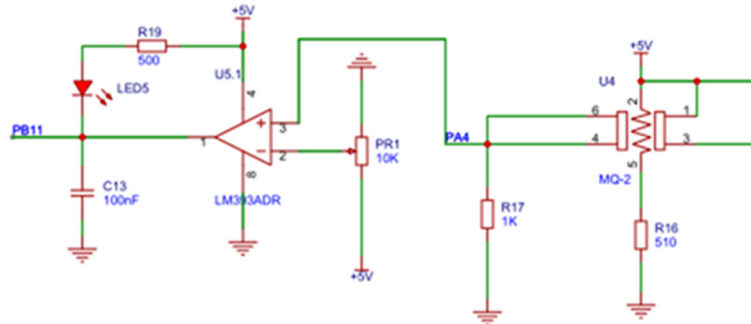


Figure 5. Smoke Detection Circuit

3.6. Carbon Monoxide Detection Circuit

This system uses the MQ-7 sensor to detect the concentration of carbon monoxide in the air. The MQ-7 is a gas-sensitive sensor specifically used to detect the concentration of carbon monoxide (CO) in the air. It is based on metal oxide semiconductor (MOS) technology, and its core component is a specific type of semiconductor material, usually tin dioxide. When the concentration of carbon monoxide in the air exceeds the set threshold, the MQ-7 sensor can respond quickly and output corresponding signals to trigger alarms to remind users to leave in time. The carbon monoxide detection circuit is shown in Figure 6.

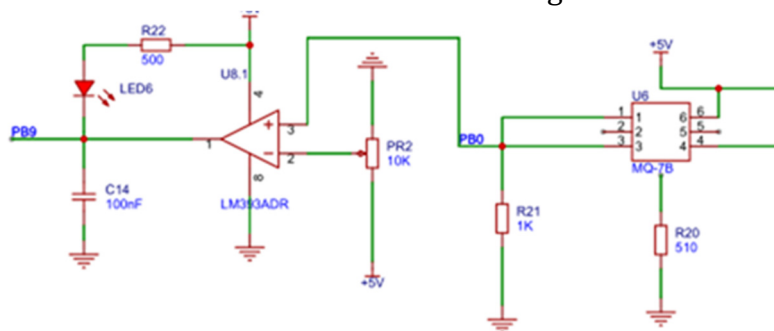


Figure 6. Carbon Monoxide Detection Circuit

3.7. Alarm Circuit

In the air quality monitoring system designed this time, an alarm circuit is equipped to issue an alarm when the air quality parameters detected (such as temperature, humidity, carbon monoxide concentration, or smoke concentration) exceed the preset thresholds. The system uses an electromagnetic buzzer, which works based on the electromagnetic effect. The electromagnetic buzzer contains a coil and an iron vibration piece inside. The buzzer alarm circuit is shown in Figure 7.



Figure 7. Buzzer Alarm Circuit

4. Conclusion

As an intelligent environmental monitoring solution that integrates temperature and humidity detection, harmful gas monitoring (smoke and carbon monoxide), and alarm functions, this system fully demonstrates the wide application potential and value of IoT technology in daily life. By integrating the DHT11 temperature and humidity detection module, MQ-2 smoke sensor module, MQ-7 carbon monoxide detection module, buzzer, and OLED display, the system achieves comprehensive monitoring and real-time feedback of air quality, effectively enhancing the safety of living or working environments.

(1) Comprehensive functions and real-time monitoring: The system can simultaneously detect temperature, humidity, smoke concentration, and carbon monoxide concentration in the air, which are crucial parameters for assessing environmental quality. With high-precision sensors, the system can capture environmental changes in real-time, providing users with accurate data support.

(2) User-friendly human-machine interaction: The introduction of the OLED display makes the monitoring data visually accessible, allowing users to easily obtain environmental information without professional equipment. At the same time, the design of button input allows users to customize alarm thresholds, enhancing the system's flexibility and personalized setting capabilities.

(3) Timely and effective safety alarms: When the smoke concentration detected exceeds the preset threshold, the buzzer immediately sounds an alarm, quickly alerting surrounding personnel to pay attention and take corresponding measures, effectively reducing the risk of safety accidents such as fires.

(4) Low cost and easy deployment: The system is small in size and low in cost, suitable for rapid deployment in various scenarios, whether it is homes, offices, or public places, it can play an important role. This feature makes the system highly acceptable and promotable in the market. It is believed that with the continuous development of artificial intelligence technology in the future, machine learning algorithms can be introduced into the system to enable the system to automatically learn and optimize alarm threshold settings, improving the accuracy and efficiency of monitoring. At the same time, remote monitoring and data analysis can be achieved through IoT technology to further enhance the system's intelligent level.

In addition to the existing temperature and humidity, smoke, and carbon monoxide detection, more environmental parameter monitoring functions can be considered in the future, such as PM2.5, formaldehyde, and other harmful gas detections, as well as comprehensive air quality evaluation, to meet a wider range of application needs. While maintaining the basic functions of the system, the user interface design can be further optimized in the future to enhance the system's ease of use and aesthetics. At the same time, functions such as voice prompts and remote control via mobile APP can be added to make the system more user-friendly and closer to user needs.

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