Research on multi-functional intelligent ventilator based on UC/OS-Ⅲ operating system for gas concentration detection

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Abstract. In order to change the traditional gas concentration inspection and exhaust device, the system through the gas concentration to control the rotation of the fan, to achieve real-time gas concentration monitoring, alarm control and GPS global positioning. In this study, STM32F4ZGT6 with ARM Coretex-M4 as the core controller is combined with embedded system design, and MDK is used to develop software programming. Through the ADC MQ-9 carbon monoxide sensor detection module and infrared NDIR carbon dioxide sensor detection module of the output of the analog conversion to digital quantity acquisition and processing, when the gas concentration exceeds the pre-set threshold, triggering a buzzer alarm, timer and the energy conservation and exhaust fan work, implementation is beyond the rapid circulation of the gas and gas concentration inside and outside the display of the time. Through bluetooth and mobile phone connection, real-time check of gas concentration, using the upper computer to control the operation mode of exhaust fan and change the gas concentration threshold. Modular programming is adopted in this study to improve the maintainability and facilitate debugging and modification in the later stage of the study. Through practical verification, the system can realize the detection of carbon monoxide and carbon dioxide concentration, real-time alarm monitoring, GPS positioning and change exhaust fan working mode and other functions, with real time, practicality and reliability.

1. Introduction

In China, in the north and some rural families will be in charcoal, coal heating, when the combustion is insufficient, will produce a lot of colorless and tasteless carbon monoxide, inhaled through the respiratory tract to form carbon oxygen hemoglobin, resulting in tissue asphyxia and death. According to the investigation, the number of people dying from carbon monoxide poisoning in China is increasing every year. This shows the importance of gas concentration detection device. Gas monitoring is developed with the development of fossil energy. Britain invented the first gas detector in the world, and Japan invented the optical interference gas detector based on the principle of optical interference[1]. In recent years, great achievements have been made in gas monitoring in China, making a big step towards intelligent development. The core control of this system is shown in Figure 1. The hardware part and software part complement each other. The system compared with single function detection device on the market, realize the multifunction gas monitoring, able to control energy-saving exhaust fan works, realize the control of indoor gas concentration, the resolution and precision of gas concentration have greatly ascend, also can communicate with PC, the convenient
user use, high integration, high maneuverability. The system can effectively reduce the occurrence of carbon monoxide poisoning and improve indoor air.

![Diagram](image.png)

Figure 1. Core control of this system

### 2. The hardware design

The hardware mainly includes STM32F407ZGT6, MQ-9 carbon monoxide sensor[2], NDIR carbon dioxide detection, HC-05 Bluetooth module, energy-saving ventilator and TFT LCD screen. The modules are related to each other and work independently of each other. MQ-9 output 0-5V analog voltage (the higher the voltage value represents the higher the concentration) and NDIR CO\(_2\) detection output PWM signal is sent to STM32F407ZGT6 core processor for AD sampling, in STM32F407ZGT6 installed HC-05 Bluetooth module to communicate with the host computer, real-time display on the client; External GPS global system positioning module, ultra-high-speed positioning, precise locking user position; When the concentration of indoor gas exceeds the threshold, the built-in buzzer is triggered to alarm[3]. At the same time, the electromagnetic coupling is driven by the transmitter and the exhaust device is opened to trigger the operation of the energy-saving ventilation fan to realize the circulation of indoor gas. The system has automatic sleep function. If the instrument does not measure, it will enter sleep mode automatically after 5 minutes to reduce power consumption and achieve the purpose of energy saving.

#### 2.1. Core Processors

STM32F407ZGT6 microcontroller is based on Arm Cortex-M4 kernel, with 168MHZ/105DMIPS processing speed, advanced architecture, ultra-high performance, low cost, low power consumption. The system is programmed on UC/OS-III embedded operating system. RTOS ensures the real-time performance of the system, multi-task management and preemptive scheduling based on task priority. It not only realizes the maximum utilization of CPU resources, but also provides convenient conditions for modular programming. Figure 2 shows the task status of UC/OS-III.
2.2. MQ-9 Carbon monoxide sensor detection

The device adopts DC 5V power supply, with two signal outputs: one signal is TTL level output signal, the effective level of DO signal is low level; The other signal is DA analog output, the output voltage range is 0-5V, the gas concentration is proportional to the voltage. When the output is effective, The TTL signal triggers the relay to close and the built-in buzzer alarm, and changes the working mode of the energy-saving exhaust fan at the same time. MQ-9 carbon monoxide sensor detector adopts double-sided PCB design, small size, high integration, long service life and very reliable stability. Its schematic diagram is shown in Figure 3.

2.3. NDIR Carbon dioxide sensor detection

NDIR is non-dispersive infrared technology[4]. After infrared radiation is absorbed by gas, gas concentration is proportional to spectral intensity, and indoor gas concentration can be measured by
the change of spectral light intensity. The device uses 5V voltage power supply, power supply current must be greater than 150mA, otherwise it will bring large error or sensor failure. Measuring range between 0-500ppm, by measuring the output PWM forward pulse width can be measured carbon dioxide concentration value. The operating temperature of the device is between -10℃ and 60℃. In order to optimize the performance of the system, a temperature compensation device is added, and a zero adjusting knob is provided. The temperature compensation range is 0℃~50℃. The actual test shows that[5], the measurement error is about 5%, which is characterized by high sensitivity and precision. The actual test data is shown in Table 1.

| group | Standard values | experimental value | error |
|-------|-----------------|--------------------|-------|
| A     | 50              | 48                 | 4%    |
| B     | 100             | 99                 | 0.01% |
| C     | 300             | 297                | 0.01% |
| D     | 450             | 440                | 2.2%  |

2.4. Energy saving exhaust fan
Energy-saving exhaust fans[6] use air convection to form a suction force indoors and absorb fresh air from the outdoors, so as to achieve the purpose of ventilation. The system adopts simultaneous ventilation mode, using two fans and a small chamber, small fans will blow air into the air chamber, low noise, high sensitivity, used for centralized air detection. The motor is driven by electromagnetic coupling, and the strong electric circuit switch is controlled by weak current. The system is more stable, safe and reliable, and the motor rotation speed can be adjusted by multiple gears. When indoor carbon monoxide and carbon dioxide concentrations reach a preset value, the motor starts automatically; when the concentration is lower than a certain value, the motor stops to achieve energy saving[7]. Moreover, the speed of the ventilator fan accelerates with the increase of detected gas concentration. Added the timer function. When the detected gas reaches the threshold, the timer starts to work. When the user misoperates or someone deliberately makes the motor turn, the timer can still work, which can effectively understand the time when the gas exceeds the concentration and help solve some murder cases.

2.5. HC-05 Bluetooth and GPS global positioning
The data collected on STM32F407ZGT6 and the processed information are transmitted through Bluetooth and displayed on the upper computer. Bluetooth technology is a low-cost short-range wireless connection, which can simplify the communication between mobile communication terminals. Because of its low cost, flexibility, security, convenience and fast, it is widely used in various intelligent fields.

GPS positioning technology is to obtain position information after error processing of the signal received by GPS receiver, and then connect it to the equipment for transformation and calculation. In this device, GPS positioning technology can help medical staff or police personnel find the user's location quickly and accurately, which effectively reduces the occurrence of carbon monoxide poisoning.

3. The software design
The ADC sampled data is sent to the CPU for processing[8]. Once the threshold is exceeded, the internal buzzer alarm is triggered. On the one hand, the current gas concentration value and energy-saving fan speed are displayed on the TFT LCD. On the other hand, through real-time communication with the upper computer, the data value is displayed on the app side, and the interface is simple and clear. It realizes better human-computer interaction and is convenient for users to operate. The system flow chart is shown in Figure 4.
3.1. The ADC sampling
In order to save CPU resources occupied by ADC sampling [9], the device uses DMA controller. DMA data transmission does not need to go through the CPU, but opens up a direct data transmission path, which greatly improves the operation efficiency of the CPU. In STM32F407ZGT6, set the trigger mode of ADC sampling to timer trigger. The advantage is that the sampling frequency can be changed at will, which is conducive to the integrity of data.

3.2. Upper computer display
It is written in the “Flutter” framework and is committed to low delay input and high frame rate. Users can log in to the app for management, set the gas concentration alarm threshold, control the wind speed of energy-saving exhaust fan, and view the terminal location in real time. The server is developed using “Spring Boot” and “mybatis-plus” back-end framework + MySQL database. “EMQ X Enterprise” enterprise-class Internet of Things MQTT messaging platform is used to communicate with hardware.

4. Main innovations
The special structural design of the ventilation fan is conducive to more concentrated air and remarkable ventilation effect. The combination of two small fans and small air chamber effectively reduces the noise and improves the user's sense of product experience.

With electromagnetic coupling drive, the reliability and stability of the system have been greatly improved. The motor has automatic sleep function, which is consistent with the concept of “low carbon and environmental protection”.

With Bluetooth host computer control function, the mobile phone can remotely control the energy-saving exhaust fan. The application of embedded operating system ensures the real-time and accuracy of system task scheduling.

5. Conclusions
This project actively promotes "green, energy saving" development, and aims to change the traditional gas concentration detection instruments through MQ-9 carbon monoxide sensor detection and NDIR
carbon dioxide sensor detection. By changing the working mode of the energy-saving exhaust fan to balance the indoor gas concentration, the remote communication and host computer display are realized efficiently and quickly. Hardware module and software module complement each other, and build a stable, reliable and high-precision system with strong practicability.

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References
[1] Yu Jian.(2016)Design of portable multi-gas concentration detector.D.Zhengzhou university.
[2] Huang Guokai, Zhang Junfu, Lv Haiyu, Yu Haixia.(2020)Detection system of kitchen carcinogenic gas and oil temperature based on SCM.J.Internet of Things technology.,10:30-31.
[3] Zhang Zhiang, Zhang Woyang.(2018)Design and implementation of carbon monoxide alarm system based on single chip microcomputer.J.Era of agricultural machinery.,45:226-227.
[4] Zhang Zhaoxiang, Pan Fei, Zhu Juxiang. (2021)Weak signal conditioning design of methane sensor based on NDIR.J.Automation and instrumentation.,36:85-88.
[5] Yu Yilong.(2018)CO concentration on-line detector based on AVR microcontroller and its design.J.Era of agricultural machinery.,45:237-238.
[6] Ding Yi.(2018)Design of automatic exhaust fan electrical control system.J.The southern farm machinery.,49:77-78.
[7] Wang Jun, Liu Jianrong.(2010)Simple and practical machine room exhaust fan automatic operation and stop device.J.audio-visual.,24.
[8] Guo Zhongjie, Liu Shen, Su Changxu, Cao Xitao, Li Chen, Han Xiao.(2021)A high precision clock duty cycle correction method for ADC sampling.J.Electronic devices.,44:1036-1040.
[9] Li Yang.(2021)The application strategy of low carbon concept in residential interior design.J.Green building materials.,09:61-62.