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Design and Implementation of Intelligent Air Purification and Disinfection Control System

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ABSTRACT
With the development of industrialization and urbanization, air pollution has become increasingly severe, and air quality issues have emerged as a pivotal concern in the post-pandemic era. As people's awareness of environmental hygiene and respiratory disease prevention grows, air disinfection equipment is being increasingly utilized in various settings such as hospitals, workshops, food enterprises, laboratories, households, shopping malls, service halls, and public venues. This article provides a detailed introduction to the design of an intelligent air purification and disinfection control system. The system is developed with a focus on intelligence, automation, and autonomy in air purification and disinfection. It offers advantages such as high efficiency, high safety, intelligence, and ease of management. It effectively reduces infection risks and public health operational costs, ensuring public health safety in the post-pandemic era.

KEYWORDS
Air purification; Intelligent disinfection; Remote control; Autonomous operation

1 Current status and demand of air purification and disinfection devices

The domestic disinfection machine industry started relatively late, but after years of development, it has now begun to take shape with a continuously expanding market scale and a rising output value year by year. At the same time, the number of enterprises producing air disinfection machines is increasing, and the market is flooded with a mix of good and bad products. There is a lack of guarantee in product technology and quality, and there is a scarcity of leading brands in the industry. In the fiercely competitive market environment and the continuous challenges posed by technological innovation, Chinese air disinfection machine enterprises should focus on strengthening technological research and development, and actively expand their market share to enhance their competitive strength.

This project is based on practical considerations, developing an intelligent air purification and disinfection control system that combines various technologies such as embedded technology, communication technology, and intelligent control technology. The system possesses notable characteristics such as a user-friendly human-computer interaction interface, convenient operation, controllable cost, efficient operation, and outstanding intelligence level. The intelligent air purification and disinfection control system can greatly enhance the efficiency of air purification and disinfection, and can autonomously, automatically, and intelligently complete environmental disinfection tasks efficiently. Therefore, the development of the intelligent air purification and disinfection control system plays a crucial role in the growth of China's national economy.

2 System design scheme

2.1 System structure diagram

The intelligent air purification and disinfection robot control system detects multiple environmental information such as temperature and humidity in the air in real-time, displays it in real-time, and operates fully automatically and independently. This device can adapt to diverse operation scenarios, covering multiple working modes such as manual control, full-process automated operation, and remote command control. It allows for the appointment of disinfection time, duration, method, wind speed, etc., and can control multiple functions such as plasma and negative ions to improve air quality. It has the advantages of stability and reliability, saving manpower and material resources, ease of management, and high efficiency [1].

2.2 Overall system scheme

The system adopts an integrated design architecture, primarily consisting of three core components: hardware modules, software modules, and an upper computer module. The hardware part is composed of environmental information acquisition circuits and control circuits, including air quality sensors, temperature and humidity sensors, etc. The main control part processes and analyzes the data collected from environmental information, controls the actions of

the actuator according to preset rules, and achieves the function of air purification and disinfection. The software part consists of an embedded logic control program and a human-computer interaction module. For ease of operation and simple control, the device adopts a 7-inch capacitive touch screen to display environmental information and device working status information in real time. The upper computer part implements remote monitoring and management functions. Users can view the system operating status in real time through terminal devices such as computers or mobile phones and perform remote operations, mainly recording detailed information about the device's operating conditions, including the device's working location, working time, working mode, device fault records, and analysis of device user habits. The overall design structure of the system is shown in Figure 1.

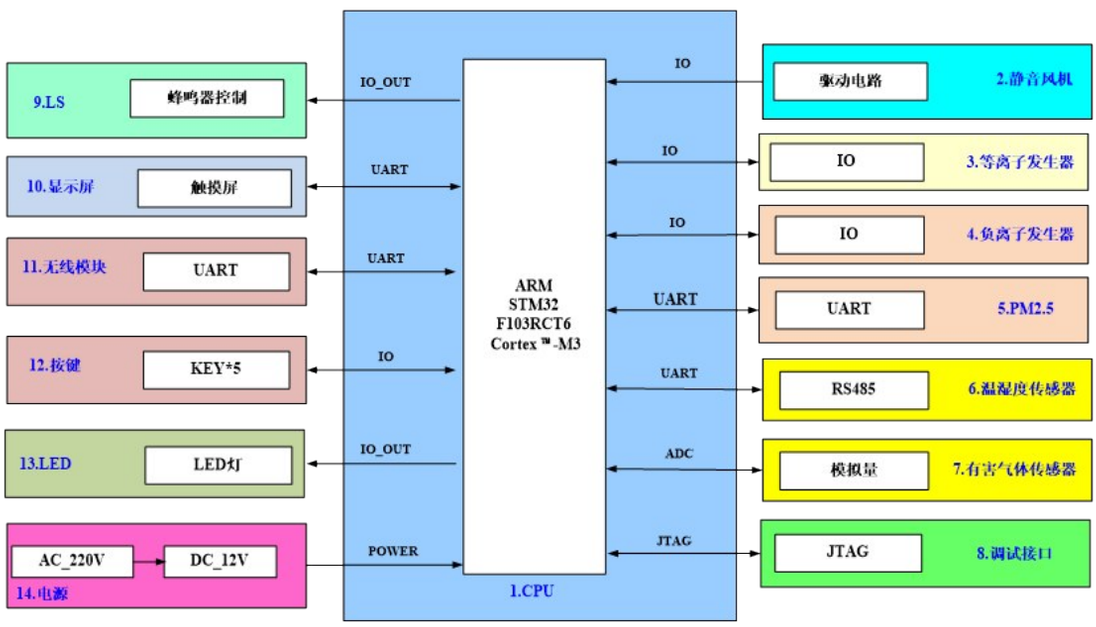

Figure 1 Overall Design System Structure Diagram

3 Main hardware circuits of the system

The hardware architecture of this device comprises multiple key modules, such as the system's main control minimal system, power management circuit, temperature sensing component, humidity monitoring unit, real-time clock, fan speed regulation and start-stop control, infrared remote control signal reception, screen display control, buzzer prompt, sound and light alarm device, plasma and negative ion generator regulation, and wireless communication function module, which work together to achieve air quality monitoring, purification, and intelligent control of the device.

3.1 Main control circuit design

(1) Selection of main control chip: STM32F030C8T6 is selected as the main control chip, which is a mainstream ARM Cortex-M0 value-for-money series MCU equipped with 64 KB Flash memory and a 48 MHz CPU, high-speed embedded memory, featuring high performance and low power consumption. It integrates rich peripheral resources, extensive enhanced peripherals and I/O ports, multiple general-purpose timers, serial communication interfaces (USART), SPI interfaces, I2C interfaces, etc., capable of meeting the system's requirements for data processing and multi-device communication.

(2) Minimum system design: The minimum operating environment for the main control chip encompasses several key units, including power management, clock signal generation, reset control, and debug interface. The power circuit utilizes a 3.3V regulated power supply to ensure stable operation of the chip. The clock circuit employs an 8MHz external high-speed crystal oscillator and a 32.768kHz low-speed crystal oscillator to provide precise clock signals for the system. The reset circuit combines button reset and power-on reset to ensure timely resetting of the system in abnormal situations. The debug interface circuit utilizes a SWD interface for convenient program download and debugging. The minimum system circuit diagram of the main control microcontroller of the system is shown in Figure 2.

3.2 Air purification and disinfection circuit

The air purification and disinfection circuit is the executive part of the system, which purifies and disinfects the

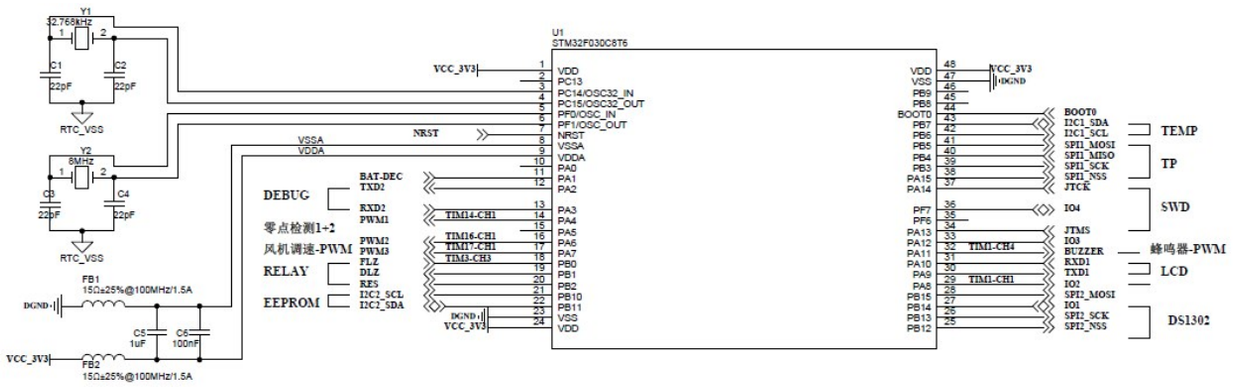

Figure 2 Minimum system circuit of the main control microcontroller

ambient air according to the instructions of the intelligent control unit. This system employs various air purification and disinfection technologies, including filtration, adsorption, and ultraviolet sterilization [1]. Among them, the air filter can remove particulate matter and microorganisms from the air; the activated carbon adsorbent can adsorb harmful gases in the air; and the ultraviolet sterilizer can kill bacteria and viruses in the air. These devices work together to ensure effective purification of the air in the workshop.

The drive circuit of the air purification equipment primarily consists of a silent fan and a filter. The silent fan is driven by a DC brushless motor, whose speed is controlled by a PWM (Pulse Width Modulation) signal to adjust the air flow rate. The drive circuit utilizes a domestically produced dedicated motor drive chip, FU6861Q from Fengxuan Technology. This chip integrates an 8051 core and a "dual-core" motor drive MCU with a motor control engine[2]. The dual cores work together to achieve various high-performance motor controls, easily enabling efficient FOC (Field-Oriented Control) motor drive. It can provide a large drive current to meet the operational requirements of the fan, achieving silent purification, high efficiency, and energy saving, as shown in Figure 3.

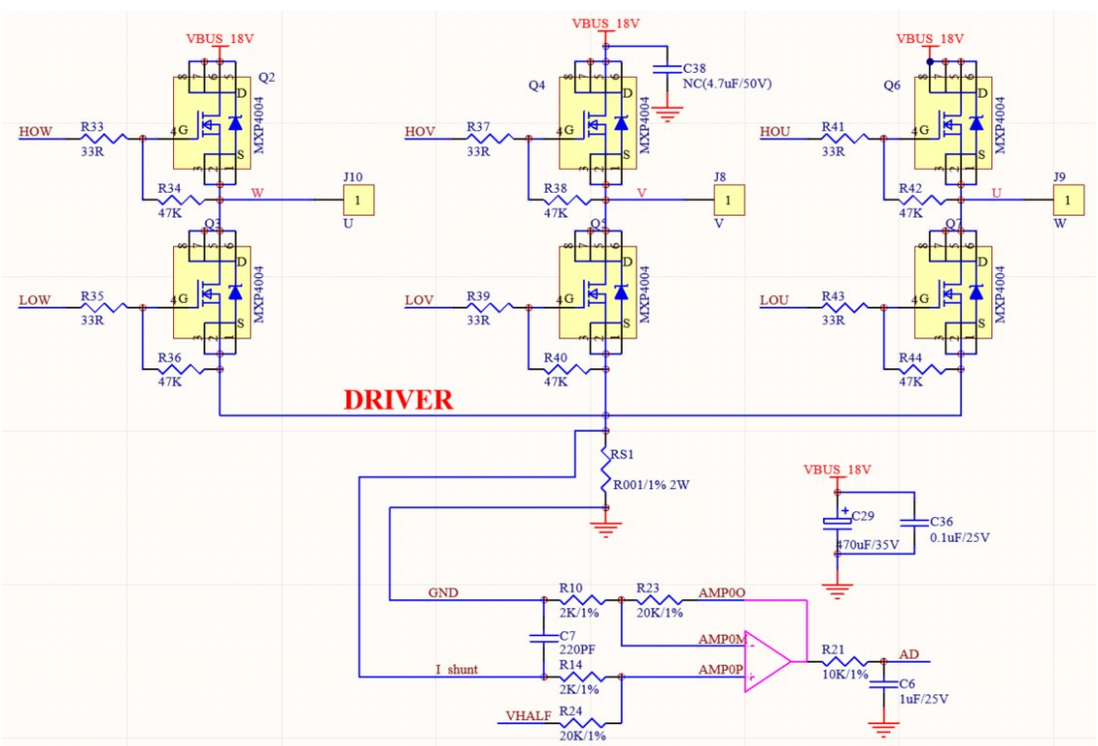

Figure 3 BLDC motor control circuit

3.3 Intelligent control circuit

The intelligent control unit module is the core part of the system. It intelligently controls the air purification and disinfection equipment using advanced control algorithms based on sensor data. This system employs a fuzzy logic-based control algorithm, which can automatically adjust the operating state of the air purification and disinfection equipment according to the air quality parameters in the workshop, achieving automated operation and energy saving.

Furthermore, the system utilizes an adaptive learning algorithm to continuously improve the control strategy based on past data and current real-time information, enhancing the accuracy and reliability of control, as shown in Figure 4.

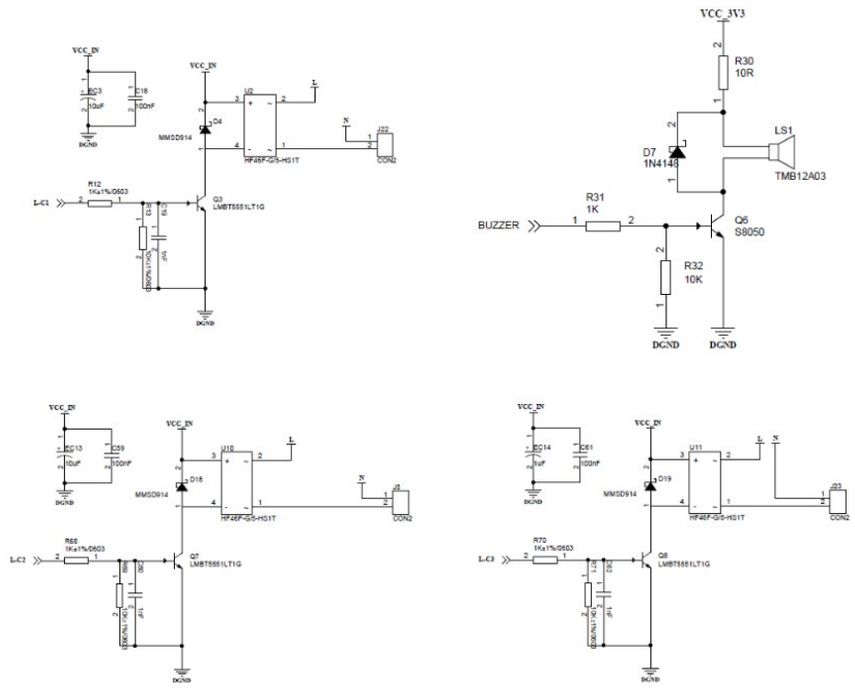

Figure 4 Control circuit

4 Human-computer interaction design

The human-computer interaction module provides monitoring and data analysis functions, facilitating remote management and maintenance of the system by administrators. This device features real-time supervision, past information retrieval, alarm notifications, and other functions. In addition, it is equipped with deep data analysis and parsing capabilities to assist administrators in making decisions. The main control circuit communicates with the touch screen using an RS485 bus, employing a two-wire half-duplex mode and differential signal logic, paired with shielded twisted-pair cables, providing excellent anti-interference performance and ensuring stable system operation [3]. The main interface of the touch screen is shown in Figure 5.

Figure 5 Touch screen interface diagram

5 System performance verification

To verify the performance and effectiveness of this system, we conducted practical tests in the workshops of local enterprises. The test results showed that this system can monitor the air quality parameters in the workshop in real-time

and automatically adjust the operating state of the air purification and disinfection equipment according to changes in air quality. During the test period, the air quality in the workshop was significantly improved, with a substantial decrease in harmful gas concentration and microbial counts. At the same time, this system also has good energy-saving effects, which can significantly reduce the energy consumption costs of enterprises. As shown in Figure 6.

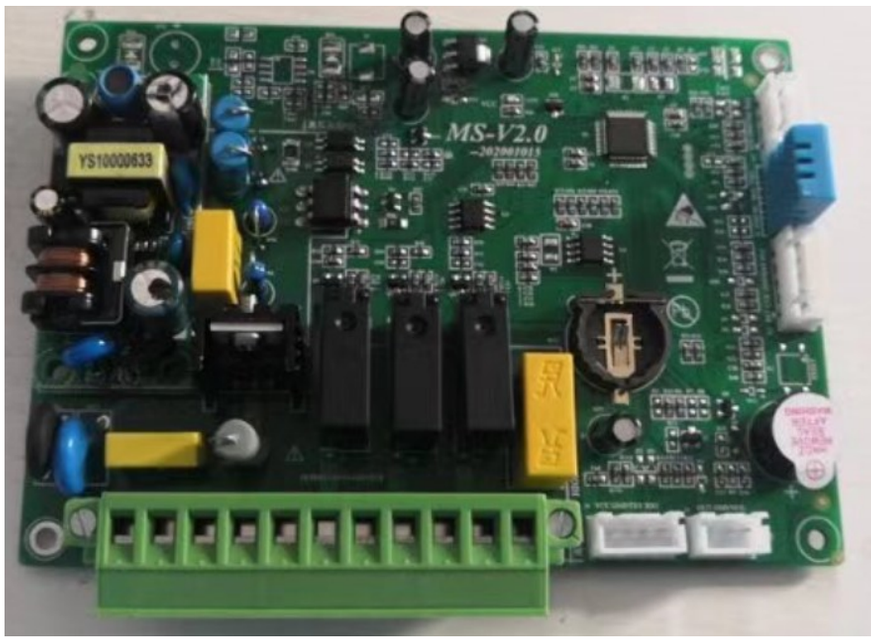

Figure 6 Main control board card

6 Conclusion

This article designs and implements an intelligent air purification and disinfection control system. The system utilizes advanced sensing technology, intelligent control algorithms, and efficient air purification and disinfection equipment, enabling real-time monitoring and purification of the air within the workshop. It effectively removes harmful gases and microorganisms, providing a healthy and safe production environment for rubber and plastic enterprises. Experimental results show that the system has good performance and effectiveness, significantly improving the environmental protection level of enterprises and the health level of employees.

Looking ahead, we will continuously improve and enhance the various functions and performance indicators of this system, striving to enhance its reliability and operational stability. At the same time, we will also explore more air purification and disinfection technologies to meet the needs of different industries and scenarios. We believe that, driven by continuous technological advancements, the intelligent air purification and disinfection control system will be widely applied in more fields, providing better protection for people's health and quality of life.

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