Research and design of an intelligent ventilation system

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Abstract. A kind of intelligent ventilation system is studied in this paper, which includes host system and slave system. The design scheme and schematic diagram of the hardware circuit are given. A variety of sensors are integrated, which can measure temperature, humidity, formaldehyde, PM2.5 dust, smoke and other parameters. According to the measured data, the host sends out control commands such as “open window,” “purify air” and “draught fan speed”, and realizes intelligent ventilation. The system has dust prevention, damp proofing and other work mode. The power drive circuit designed by SCR designs to realize no spark control. Host monitors multiple slave stations using ZigBee wireless networks, through the WIFI broadband access network and realize the application of “Internet +”. Therefore, users can view and monitor the home environment status through the mobile phone APP software. The system can be used in the newly decorated houses without ventilation, and can also be used in various mines, subway stations, working room of chemical plant and other workplaces.

1. Introduction
Ventilation is a necessary factor for all kinds of people's places of activity, and with the rapid development of network information technology, the demand for intelligent and unmanned management in these places is getting stronger and stronger. For example, tunnel ventilation monitoring, fire prevention and smoke extraction [1-2]; Air volume control of ventilation system in deep mine [3], influence of ventilation on greenhouse plant growth [4], and influence of different ventilation methods on temperature environment [5]. The influence of different season ventilation mode on greenhouse vegetables; Fire prevention, smoke exhaust and risk control system for subway tunnels; Home space is the main place of activity, but building decoration materials, furniture, carpets and other textiles, office equipment and supplies widely used in modern buildings will volatilize or produce volatile organic compounds (VOC), leading to low-concentration chemical pollution. People are constantly exploring new ways to realize the ventilation control of various places. Therefore, this paper takes home intelligent ventilation system as an example to design a remote control intelligent ventilation monitoring system, which can effectively solve the above research and application needs.

2. System design scheme

2.1. System Scheme Overview
It is composed of indoor host control system and several outdoor slave control systems. The two systems collect the sensor data at the same time. The master control system is responsible for
accessing the network, completing the corresponding operation according to the remote network instructions, and controlling the slave working state after comprehensively analyzing all the data. The slave system uploads the collected data to the master control system, and receives the host instructions to complete different communication Wind mode operation. The structure of the host system and the slave system is roughly the same, only the processor and some functional modules are different. The processing structure of the slave is shown in Figure 1.

Figure 1 composition block diagram of slave system

2.2. system working mode

The working modes of the system include: day and night working modes. For the sake of anti-theft safety, the off mode and light wind mode can be selected preferentially at night or during the day. Anti-moisture mode, the system collects temperature and humidity, when the external temperature and the humidity is high, the indoor temperature and the humidity is low, in this case, the indoor moisture is easy to return, it is not suitable to open the window for ventilation; Intelligent ventilation mode, the system according to the threshold parameters have been set to intelligently select the working mode; Ventilation size pattern; Fan working mode, and divided into: strong ventilation mode and natural ventilation mode; Manual operation mode, in this mode, the user can send instructions to control the relevant equipment through the mobile phone app software, and can also use the camera to observe the indoor situation in real time to realize remote monitoring; For the sake of safety and humanization (forget), the system will still automatically shut down the ventilation system in dark, rainy, windy, poor air quality and other conditions.

2.3. Working principle and program control flow of the system

Users can set a variety of working modes: day and night, for safety reasons, the ventilation mode is divided into light wind, stroke and gale, which are different according to the size of the window clearance. In order to save energy, the processor samples data once every certain time, and the system is in standby state at other times. Except the processor, all modules are shut down. The interval time can be set flexibly and stored in the internal EEROM after the parameters are set. System workflow: The first step is to collect illumination through AD conversion to identify day and night; The second step is to collect temperature and humidity for anti-moisture mode; The third step is to collect PM2.5 dust concentration, and the parameter threshold can be set flexibly; The fourth step is to measure the external wind speed, which is used to determine the window opening mode; The fifth step is to collect smoke sensor values for fire ventilation and alarm; The sixth step is to measure the content of indoor formaldehyde and other toxic gases; In order to ensure the accuracy of measurement, different sensors have different measurement time and times, and software filtering is used for data processing; In the seventh step, the system packages the collected data according to the data communication protocol through the network module and sends it to the indoor general control center. According to the above parameters, the general control center carries out comprehensive data analysis and processing, and finally issues the control command type (window mode: strong wind, stroke, light wind) and fan speed
mode (starting at a certain time interval is conducive to the uniform distribution of indoor air, and then starting again). The display module is used to initialize the parameters and display the working status. The total hardware circuit diagram of the system design is shown in Figure 2.

![Figure 2 General schematic diagram of slave system](image)

3. Hardware circuit design

3.1. Slave hardware circuit design

The main function of the slave is to measure the environmental parameters, make corresponding measures, and send the data to the host. The core part of the slave system uses C8051 processor, and the circuit contains multiple environmental measurement sensor modules. PM2.5 sensor measures the concentration of dust particles in the indoor environment and feeds back to the processor. When the concentration is too high, the system opens the window and starts the corresponding purification measures; The formaldehyde sensor measures the indoor formaldehyde concentration, and when the formaldehyde concentration is too high, the system opens the window and starts the purification device; The temperature and humidity sensor measures the indoor temperature and humidity, and the system will compare the measured value with the threshold value, and then decide whether to open the window and whether to ventilate. The external humidifier can be connected, and when the indoor air humidity is low, the humidifier can be turned on to replenish the indoor water; the light intensity sensor measures the current outdoor illumination, distinguish between day and night, and judge whether to open the window Open or close the window.

The circuit design takes into account the factors of performance, cost and function expansibility. The processor is C8051 series single chip microcomputer, the model is C8051F350, which contains 8-channel programmable conversion rate 24 bit AD conversion module, the sampling input channel has 1 ~ 128 times of programmable amplifier, the system internal oscillator 24.5MHz accuracy is up to 2%; the internal programmable counter can produce 4-channel 16 bit or 8-bit pulse width modulation wave (PWM), which is used for intelligent speed regulation of fan to realize natural control Ventilation: it
contains two current mode digital to analog converters (DAC) as current sources for various resistive sensors, and different current outputs can be set according to different performance, which is conducive to flexible selection of sensors, as shown in Figure 2 U1.

- The light intensity sensor is realized by using the photoresistor PTSMD021, that is, R3 in Figure 2. The spectral response curve is close to the linear relationship between 500 nm and 8 nm, which can meet the needs of light measurement and is mainly used to distinguish day and night. Wind speed sensor, special models such as three cups of anemometer FS-N01, QS-FS, but the cost is relatively high; Since the direction of the ventilated window is fixed, the pressure sensor can be used for indirect measurement. In this paper, the film pressure sensor, whose model is FSR402, namely R2 in Figure 2, is selected and installed at the bottom of the "L" type bracket to convert the wind force into pressure, and then the measured data can be quantified with the standard wind force; The light intensity and wind speed sensors are modulated by the op amp amplifier and sent to the processor AD sampling port ADC0 and port ADC1.

- Select DHT11 as the temperature and humidity sensor, the sensor output digital signal has been internally calibrated, and the internal composed of resistance humidity sensor and a negative temperature coefficient (NTC) temperature measuring element. The output signal has high reliability and stability. The sensor contains a processor and communicates with the outside world in a single bus mode, as shown in P3 in Figure 2. The interface circuit R1 is a pull-up resistor, which is read by the processor p2.0 port. Used for measuring outdoor temperature and humidity, according to the two parameter values, reasonable control vent opening and closing, effectively prevent indoor moisture.

- PM2.5 dust measurement sensor: The PM2.5 sensor adopts sharp model GP2Y1010AU0F, Its features are: low cost, low power consumption, the output voltage is analog signal, 6 pins, of which pins 1, 3 and 6 are connected to the power supply, pins 2 and 4 are grounded, 5 pins of the signal voltage output end are connected to the ADC2 port, encapsulated as P2 in Figure 2;According to the relationship between dust concentration and output voltage characteristics, it can also be flexibly distinguished from dust or smoke, saving special smoke sensor.

- Formaldehyde sensor: the model is KB03, which can detect volatile organic compounds such as formaldehyde, benzene, carbon monoxide, ammonia, essence and other volatile gases. It is mainly used to detect indoor formaldehyde and other toxic gases and mainly installed in the bedroom, can also detect smoke. For the surrounding chemical plants, outdoor toxic gas sensors can be selected for detection.

- The model of liquefied gas sensor is MQ-2, and the model of natural gas sensor is MQ-5, can choose one flexibly according to the need. The two sensors have good repeatability in measurement accuracy, but they need to be preheated for 20 seconds before measurement. They are mainly installed in indoor kitchens and give corresponding alarms according to the set threshold value. The designed software program has fault tolerance and reminder functions. Whenever the gas concentration is detected to exceed 90% of the set threshold value, flash reminder will be given. When the accumulated two or more times exceed the threshold value, a long time should be given call the police.

- For the measurement of the above parameters, if the cost factor is not considered, the composite sensor module can be selected, such as lgaqs-ht01, and the detection materials are formaldehyde, temperature and humidity, carbon dioxide and formaldehyde. The advantage is to save the external circuit space and reduce the development cycle, which is suitable for indoor installation.

- The fan can be a floor fan, as shown in P7 in Figure 2, which can be flexibly placed in the ventilation window and can be used normally in the later stage; The control circuit is mainly composed of power thyristor Q1, optocoupler driver U3 and processor port P1.1. When P1.1 outputs high level, the output end of U3 is closed, and the current flows from R6 to the trigger
end of Q1, driving Q1 on, otherwise Q1 off; If P7 is a separate AC fan, the fan speed can be controlled by P1.1 output PWM wave to achieve the effect of energy-saving ventilation.

- The window switch driving circuit uses four phase five wire stepping motor to drive the window switch. Its working principle is to use the received pulse signal to drive the stepping motor to rotate a certain angle according to the set direction. The stepping motor driving module composed of ULN2003 chip can be used, and the system can directly send commands to control the rotation angle. The driving circuit can set the mode, the stepper motor can rotate forward and backward, corresponding to the opening and closing of the window, and the rotation angle of the stepper motor can also be set to completely close, half open and all open. At this time, the fan drive module can select different working modes according to the opening angle of the window. When the window is completely closed, it can be set to the low wind or no wind mode. When the window is half opened, it is set to the stroke mode. When the window is fully opened, it is set to the high wind mode, so as to realize the intelligent ventilation function.

- The power module P6 uses 220 V to 12 V DC, and then through the linear regulator chip lm7805 to stabilize +5 V for the whole circuit system. For the newly decorated rooms, it can be considered as a whole. In order to install more intelligent devices in the future, special wiring 12V DC to the corresponding position of the wall can save redundant power adapter. The device U2 in Figure 2 is ULN2003, with a port output capacity of about 1A, which supplies power to various sensor modules. When the system is in standby mode, the control port is set to "zero", that is, the output voltage of U2 is turned off, so as to achieve energy saving. P1 is a ZigBee (a 2.4G wireless communication mode) wireless communication module, which uses ZigBee protocol wireless sensor network [6-7] to realize data communication between single host and multiple slaves. During the communication period, the clock of indoor host shall prevail. After checking the time, both parties can stop the power supply of wireless module to realize energy saving.

3.2. Indoor host control system
The host control system consists of: LCD display module with touch function, WiFi network module, ZigBee network module and indoor relevant gas sensor module; Negative ion generator control circuit (or corresponding air purifier); Camera module; Optional four-way infrared emission module, etc, The overall structure of the system is shown in Figure 3. The hardware circuit adopts modular design, and the drive of the purification equipment is the same as that of the fan in Figure 2. Although the control of the relay is simpler, the switch of the relay has sparks. If the combustible gas leaks, it is easy to cause explosion, and the relay has operation noise, which is not conducive to night rest. The total hardware circuit is no longer drawn separately.

![Figure 3 block diagram of main control system](image-url)
The host processor adopts arm STM32F103E series processor design, which supports parallel port LCD interface. The host processor is designed with ARM STM32F103E series processor. The processor supports parallel port LCD interface and is compatible with 8080 mode. The system has low power consumption and does not need external crystal oscillator. There are 11 internal timers, three 12-bit analog-to-digital converters and 13 communication interfaces, including infrared IrDA interface and modulation and demodulation control, CAN interface, 5 serial ports, 512k internal memory and special memory expansion Interface; it is very conducive to the subsequent expansion control of other smart home devices. For more functions, high-performance STM32F407 and STM32F429 series chips can be selected.

On the one hand, the ZigBee communication module controls the slave devices; on the other hand, it collects the sensor data in a certain order, and then collects the data of the slave devices one by one; finally, after comprehensively processing all the data, it logically controls the slave devices according to the set threshold value: window ventilation (strong wind, stroke, light wind), fan speed, air purification equipment (negative ion generator), etc. The additional infrared receiving and transmitting module is used to control all kinds of home appliances without network module and act as its remote controller. After the completion of the control operation, the data will be detected and uploaded to the network.

The host ZigBee module, based on CC2530, works in the gateway mode and is used for the data of each slave of the mobile phone. The system WIFI module, esp8266, which is commonly used in the serial port mode, is used to access the Internet through the home WIFI router. On the network platform, an exclusive smart home monitoring app is designed, which can be used for real-time remote monitoring through the mobile phone.

4. Summary
The designed intelligent ventilation system integrates a variety of sensors, which can correctly identify the state of indoor and outdoor environment and realize intelligent ventilation; users can monitor the state of indoor environment in real time through app to provide guarantee for comfortable and safe life. The system has strong expansibility and good compatibility with different quality sensors; the open design of data acquisition and control instructions is compatible with other types of smart home systems; the system also has a high reference value for the design of ventilation systems in chemical plants, mines, subway stations and so on.

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