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Design of an Intelligent Fan Based on STM32

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Abstract

In the era of rapid development, people are increasingly eager to improve their quality of life. As a basic household appliance, fans are no exception. I plan to design an intelligent fan based on the popular STM32 microcontroller unit (MCU). By integrating components such as an LCD1602 display, temperature sensor module, and infrared motion sensor module, and through software programming, I aim to develop an advanced smart fan system. This system will automatically adjust its operation, including startup/shutdown and speed control, based on real-time temperature measurements and the presence of people in the vicinity. Compared with traditional fans, this intelligent fan offers remote control capabilities and displays real-time temperature and operating status. The temperature sensor continuously monitors the ambient temperature, while the LCD1602 screen shows current settings and allows users to adjust parameters. The infrared motion sensor detects human presence to automatically control the fan's operation, enhancing energy efficiency and user convenience. All modules interact with each other, sending data to the MCU for processing. The software programming is developed using Keil 5 and deployed on the STM32 MCU to accomplish complete system control.

Keywords

STM32 single-chip microcontroller; Electric fan control; Intelligent fan control system.

1. Introduction

In the field of modern engineering, fan technology is widely applied in various aspects such as aerospace, industrial manufacturing, and daily life. Take the aviation field as an example. Although traditional turbofan engines provide powerful power for aircraft, they still have many obvious drawbacks. In terms of the control system, the manual control mode not only has high requirements for operators but also makes it difficult to achieve precise and efficient adjustment under complex working conditions, which greatly limits the full play of engine performance. In terms of speed regulation, the speed adjustment range of traditional engines is relatively limited, and they cannot flexibly and timely optimize according to drastic changes in flight status, such as high-speed cruising and low-speed take-off and landing, thereby affecting the overall flight performance and efficiency of the aircraft. In terms of noise issues, the exhaust noise of traditional turbofan engines is at a high level, which not only seriously interferes with the ride comfort inside the aircraft but also causes significant noise pollution in the surrounding environment such as airports, triggering widespread environmental and social problems. In terms of response speed, the speed regulation response time of traditional engines is short, making it difficult to quickly and effectively respond to sudden changes in flight conditions. For example, when an aircraft encounters sudden changes in airflow and needs to quickly adjust thrust, it may not be able to provide appropriate power support in a timely manner, thus posing a potential threat to flight safety. In addition, its fixed oscillation mechanism is prone to cause fatigue damage to engine components during long-term operation, reducing the reliability and service life of the engine, and increasing maintenance costs and operational risks.

In order to break through these technical bottlenecks and meet the growing demand for efficient, intelligent, and reliable operation, we have innovatively designed an intelligent fan. This fan integrates advanced LCD display technology, automatic temperature sensing technology, and intelligent control algorithms. By integrating an LCD display, this intelligent fan can intuitively display the current fan speed and various setting parameters to users in real-time. Whether in industrial production, where engineers need to accurately understand the operating status of equipment, or in daily life, where users expect to conveniently grasp the working conditions of the fan, the LCD display can clearly present relevant information, greatly improving the convenience of operation and the transparency of information. The automatic temperature sensing function endows the fan with the ability to "perceive the environment". The temperature sensor is like the "temperature antenna" of the fan, which can accurately collect temperature data of the surrounding environment. These real-time data are quickly transmitted to the control core, which is like the "intelligent brain" of the fan, using built-in intelligent control algorithms to conduct in-depth analysis and processing of the data. According to changes in ambient temperature, the control core will automatically and accurately adjust the rotation speed and power state of the fan accordingly. For example, in a hot environment, the fan automatically increases its speed and air supply to enhance the heat dissipation effect; while in a lower temperature, the fan reduces its speed to reduce energy consumption and achieve energy-saving operation.

Among the numerous referenced literatures, the design concepts of many intelligent devices are consistent with the research and development ideas of this intelligent fan. For instance, the intelligent traffic light control system in Literature [1] realizes the optimization of traffic flow through intelligent algorithms, which is similar to the way this fan uses algorithms to process temperature data to optimize its operating state; the indoor delivery robot in Literature [3] realizes autonomous operation based on advanced technologies, which is consistent with the intelligent operation of this fan through the integration of multiple technologies. These fully reflect the importance and development trend of intelligence in various fields, and also provide strong theoretical and practical support for the design of this intelligent fan. To sum up, this intelligent fan effectively solves various problems existing in traditional turbofan engines through innovative technology integration, and is expected to be widely applied in multiple fields, bringing new development opportunities to related industries.

Conventional turbo-fan engines still have numerous drawbacks, such as manual control systems, limited speed adjustment ranges, high exhaust noise levels, short speed regulation response times, and fixed oscillating mechanisms. To address these technical limitations, we designed an intelligent fan that integrates LCD display technology, automatic temperature sensing, and smart control algorithms. This smart fan displays real-time speed and fan settings on an LCD screen while automatically adjusting its operation based on ambient temperature readings collected by a temperature sensor. The data is processed by the control core, which then modulates the fan's rotational speed and power state accordingly[1-10].

During seasonal transitions, sudden temperature fluctuations often catch people off guard, prompting the use of traditional fans. However, these devices' limitations—such as those mentioned above—become particularly apparent. As living standards improve, consumers increasingly demand smarter, more convenient household appliances. While traditional fans sufficed in the past, modern consumers seek upgrades that enhance comfort and efficiency. Responding to this need, our design incorporates intelligent modules into conventional fans, creating a new class of smart home appliances. By integrating low-power modules like infrared sensors and temperature detectors, the system efficiently resolves the aforementioned issues. The LCD screen displays both current temperature and fan settings, while the temperature control module automates power management. This allows the STM32 MCU to regulate fan speed and activate preset temperature thresholds automatically[11-16].

In southeastern China, densely populated coastal regions with high temperatures rely heavily on cooling appliances. Despite air conditioners' prevalence, fans remain popular due to their energy efficiency and affordability. While the market offers various fan types—including smart and rechargeable models—most mainstream products still rely on outdated single-chip microcontrollers with limited functionality. In contrast, our smart fan utilizes the advanced STM32 MCU series, offering superior control capabilities and expandability. This innovation has significant market potential, as consumers recognize the value of upgrading essential household items like fans to smarter, more user-friendly solutions.

2. Design of the Intelligent Fan

The DS18B20 will be employed for temperature collection, which is an integrated information acquisition module. This temperature sensor can directly convert and output the detected temperature changes into digital temperature signals, making it more convenient for the control and processing of our microcontroller. This temperature sensor is a relatively convenient and accurate temperature collector with fast and precise data transmission. It is easy to use and has high stability, making it a suitable choice. The module can also directly convert the detected temperature value signals into analog-to-digital signals for output, thereby simplifying the design. It typically adopts single-bus interface technology, which simplifies the interface itself and also provides strong anti-interference capability.

The highly integrated control chip STM32 will be used to control temperature measurement, shift gears, and display temperature through programming. With this microcontroller as the control core, many powerful functions can be realized through programming. For example, software can be used to display temperature values, and it is also convenient for us to adjust the upper and lower temperature limits to meet more needs. The temperature detected in this way is often more accurate with very small errors. The LCD1602 will be adopted as the overall display module to show information such as gear position, temperature, and on/off status. The LCD screen can display various patterns, graphics, and numerical values, which is more aesthetically pleasing, easy to understand, and comfortable to observe. Additionally, its hardware connection is relatively simple. PWM (Pulse Width Modulation) technology will be used for speed regulation. PWM is a technique that adjusts the output signal's bandwidth and waveform parameters by varying the pulse width within a fixed pulse cycle. In systems driven by PWM signals, especially those using rectangular waveforms, the most commonly adjusted parameter is the duty cycle—defined as the percentage of time a high-level signal persists within one complete oscillation cycle. This method enables precise control over power delivery by modulating the effective voltage applied to the motor. In the context of controlling a fan motor with PWM: A higher duty cycle (e.g., 100%) corresponds to maximum voltage applied, resulting in the fan running at full speed. A lower duty cycle (e.g., 30%) reduces the average voltage, slowing the fan down proportionally.

The enhanced system retains the original microcontroller's temperature measurement and control circuitry while introducing a programmable PWM control module. This module generates two PWM signals with identical duty cycles but different frequencies, derived from the CPU temperature readings. The PWM waveform is a square wave, with a duty cycle defined as the ratio of high-level duration to the total period. The basic PWM control circuit consists of four transistors, with the final transistor directly connected to the PWM signal source. When the PWM input is high, the transistor conducts, allowing current flow; when low, the transistor switches off. By adjusting the duty cycle, the average voltage applied to the fan motor is regulated, enabling precise speed control. This PWM-controlled smart fan directly get CPU temperature data via the microcontroller, eliminating the need for additional temperature sensors on the fan blades. Compared to traditional thermal fans, this design achieves a broader speed range, effectively balancing cooling efficiency with noise reduction. The PWM control module also enables diagnostic capabilities, such as detecting overheating or malfunction, making it a reliable indicator for assessing the quality of cooling systems. This design is developed in the Keil C51 environment, using the C programming language as the foundation. The software architecture follows a structured approach, with interrupt-driven routines managing time-critical tasks (e.g., temperature sampling) and a main loop handling system state updates and display refresh. This modular design ensures scalability and ease of maintenance, allowing future enhancements such as wireless connectivity or advanced scheduling algorithms.

3. Testing of Flexible Raindrop Sensor

The design of this intelligent fan adopts a modular architecture with high integration, centered on the STM32 MCU as the core control unit. This choice of microcontroller is strategically based on its proven performance in numerous intelligent systems—similar to its application in the STM32-based intelligent strawberry picking robot [6] and fire-fighting robot[8], where its high processing efficiency and multi-interface compatibility enable precise coordination of multiple peripherals. The STM32 chip serves as the central hub, receiving real-time data streams from various sensors, executing control algorithms, and issuing command signals to actuators, ensuring millisecond-level response speed in the entire system. The human-computer interaction module employs an LCD display, which not only shows current fan parameters such as rotational speed gear and power status but also dynamically updates the ambient temperature detected by the DS18B20 sensor. This temperature sensor, renowned for its ±0.5℃ measurement accuracy, continuously collects environmental data and transmits it to the STM32 through a one-wire communication protocol—mirroring the multi-sensor data fusion approach in the intelligent alarm system [5], where data accuracy forms the foundation of reliable decision-making. The displayed information allows users to intuitively grasp the system's operating status, while also providing a visual reference for subsequent parameter adjustments.

The fan's actuation mechanism relies on PWM (Pulse Width Modulation) technology, which enables stepless speed regulation across multiple gears. By adjusting the duty cycle of PWM signals, the STM32 precisely controls the fan's rotational speed, with each 1℃ increase above the preset temperature threshold triggering an automatic one-gear speed increment. This gradient adjustment logic not only ensures comfortable air supply but also achieves energy-efficient operation—similar to the speed control strategy in the intelligent shopping cart [7], where power output is dynamically optimized based on real-time demand. A key innovation lies in the integration of the DYP-ME003 infrared motion sensor module, which monitors human presence within a 10-meter radius using pyroelectric infrared detection technology. This module adds a critical safety interlock: even if the ambient temperature exceeds the preset threshold, the fan remains in standby mode unless human activity is detected. This dual-condition activation mechanism effectively prevents energy waste in unoccupied spaces, aligning with the energy-saving concept embodied in the intelligent traffic light control system [1], where operational logic is dynamically adjusted based on real-time demand (traffic flow in that case, human presence here).

As illustrated in Figure 1, the physical prototype undergoes rigorous functional testing and debugging to verify system stability. During testing, when ambient temperature rises above 26℃ (default threshold) and the infrared sensor detects a person within its range, the STM32 immediately activates the fan at the initial gear. Subsequent temperature increases trigger corresponding speed increments: at 27℃, the fan shifts to gear 2; at 28℃, gear 3, and so on, up to a maximum of 5 gears. Conversely, if the temperature drops below the threshold or the infrared sensor detects no human activity for 30 seconds, the system automatically enters low-power mode, with the LCD displaying "standby" to indicate the state transition. The hardware architecture's reliability is further enhanced by draw on the CPN (Colored Petri Net) modeling method for STM32 programs [2], which ensures logical consistency between sensor data acquisition, algorithm execution, and actuator response. This modeling approach helps identify potential bottlenecks in data transmission—such as delayed communication between the DS18B20 and STM32—and optimizes the control flow to maintain system stability under varying environmental conditions.

In summary, this intelligent fan achieves a seamless integration of environmental perception, adaptive control, and energy management through its modular design. By combining STM32's processing capabilities with specialized sensors and actuators, it overcomes the limitations of traditional manual-controlled fans, setting a new standard for intelligent cooling devices in both residential and industrial applications.

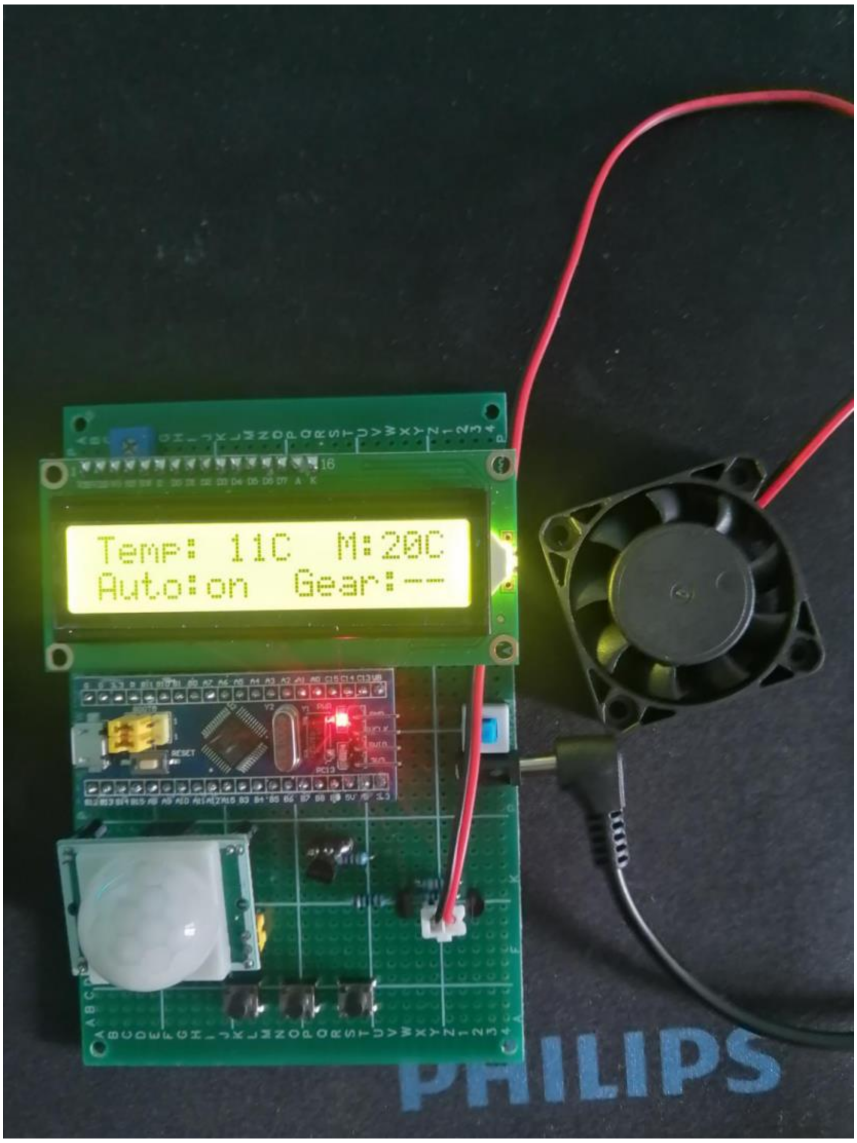

Figure 1 Physical diagram

4. Conclusion

The design centers around an STM32 microcontroller as the main control unit, integrated with functional modules such as the DS18B20 temperature sensor and LCD1602 display. The digital-integrated DS18B20 module collects temperature data, which is then transmitted and analyzed by the STM32 to control the fan's speed settings and power state. Concurrently, all operational information is displayed on the LCD1602 screen for real-time debugging and monitoring. This system automates temperature detection and fan control, offering a more user-friendly and efficient alternative to manual operation. Beyond domestic fan applications, this modular design can be integrated into electronic systems or power equipment for intelligent thermal management. Its adaptability and scalability position it as a versatile solution for various cooling needs. Given the growing demand for smart, energy-efficient technologies, this design holds significant potential for widespread adoption in modern society.

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