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Design of a Digital Temperature-Controlled Fan Based on a Microcontroller

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Abstract: The 21st century is an era of rapid scientific and technological development, and this progress has continuously improved people's living standards. In a society where daily life is becoming increasingly intelligent, intelligent devices of all kinds keep emerging. In this paper, a digital temperature-controlled fan is designed and implemented on the basis of a microcontroller unit (MCU). The hardware system is divided into six modules: the MCU control module, the keyboard control module, the temperature display module, the temperature sensing module, the motor control module, and the alarm module. The hardware circuit diagrams of these modules are presented, and the soldering of the corresponding hardware circuits is completed. Furthermore, the MCU control program is developed and burned into the microcontroller, and the corresponding functions are realized. The proposed design features a simple structure as well as a certain degree of intelligence and human orientation.

Keywords: Microcontroller; Automatic control; Temperature sensor.

1. Introduction

Today, with science and technology advancing day by day, all kinds of intelligent devices have permeated our daily lives. Among them, intelligent devices built on sensor-based network nodes represent the forefront of intelligent technology. In industrial production, the combination of a control chip and sensors has always been favored, and the pairing of a microcontroller (MCU) with sensors is a representative example of this approach [1-8].

With the development of technology, air conditioners have become increasingly common in daily life, and many people assume that electric fans will inevitably be phased out by air conditioners. Market experience has proven that this is not the case: under the impact of air-conditioner products, the electric fan still shows strong vitality and, far from fading out of the market, has flourished in an increasingly competitive environment. However, such vitality requires continuous self-improvement, which calls for constant enhancement of the fan's functions and advantages. Our survey shows that contemporary electric fans commonly suffer from wasted energy and bulky size; if the size is reduced, the air flow weakens accordingly, while a strong air flow can easily cause colds. Therefore, this paper employs the combination of an MCU and a temperature sensor to design a fan that can intelligently adjust its air flow according to the ambient temperature [8-12].

This system is a typical application combining an MCU with sensors. First, a DS18B20 sensor is used to detect the ambient temperature; the MCU then generates pulse signals with different frequencies according to the measured temperature. When the stepper motor receives a pulse, it rotates by a certain step angle; different pulse frequencies correspond to different step angles and hence different rotational speeds. While sending signals to the stepper motor, the MCU also sends segment-select and digit-select signals to the seven-segment LED display, which dynamically shows the currently measured ambient temperature. In addition, the system can be set to the manual mode via push buttons (the designed temperature-controlled fan supports both a manual mode and an automatic mode). In the manual mode, a fixed temperature value can be set through the buttons, and the fan speed is controlled according to the difference between the actual temperature and the preset value. In this way, all functions of the proposed MCU-based temperature-controlled fan are realized [12-18].

The overall system consists of six parts: the MCU control module, the keyboard control module, the temperature display module, the temperature sensing module, the motor control module, and the alarm module. The MCU control module is centered on the AT89S52 microcontroller. In the temperature sensing circuit, the DS18B20 temperature sensor serves as the key component of this module. It detects the ambient temperature, and whenever the surrounding temperature changes, it sends a temperature signal to the MCU. After receiving the signal, the MCU sends a pulse wave to the Darlington inverting driver in the motor control circuit (pulses of different periods produce different stepper motor speeds), and the rotational speed of the stepper motor is changed by means of pulse amplitude modulation. The temperature display circuit shows both the ambient temperature and the preset temperature. The ambient temperature comes from the DS18B20, whereas the preset temperature is set by the user in the manual mode. A dynamic display method (digit-select plus segment-select) is adopted so that both values are displayed in real time and continuously, with a resolution of one decimal place. In the keyboard control circuit, two push buttons are used to increase or decrease the preset temperature. When the ambient temperature exceeds 40 °C, the buzzer in the alarm circuit is triggered.

2. Hardware System Design

The proposed design is an MCU-based temperature-controlled fan whose main components include the AT89S52 microcontroller, the DS18B20 temperature sensor, a common-cathode LED seven-segment display, the ULN2003 Darlington inverting driver, and a stepper motor. The AT89S52 is a low-voltage, high-performance CMOS 8-bit

microcontroller produced by Atmel in the late 20th century. It contains 8 KB of reprogrammable Flash read-only program memory and 256 bytes of on-chip RAM, adopts Atmel's high-density non-volatile memory technology, and is compatible with the standard MCS-51 instruction set, with a general-purpose 8-bit CPU and Flash memory cell built in. The DS18B20 digital temperature sensor from Dallas Semiconductor uses on-board patented technology. Thanks to its 1-Wire bus, users can conveniently build sensor networks, which introduces a brand-new concept for the development of modern measurement systems. The DS18B20 measures temperatures from −55 °C to +125 °C, with an accuracy of ±0.5 °C in the range of −10 °C to +85 °C.

The Darlington inverting driver acts as an intermediary between the MCU and the stepper motor: it converts the signals transmitted by the MCU into signals capable of driving the stepper motor. The motor is controlled by one output port of the MCU, and the driver can drive up to eight motors. A stepper motor is essentially a type of induction motor. Its basic principle is to construct an electronic circuit controlled by a DC component and a polyphase sequence of currents. Only when powered by such currents can a stepper motor operate normally; in essence, the driver is a polyphase timing controller whose main function is to supply power to the stepper motor in a time-division manner.

The temperature sensor adopted in this design is the DS18B20. Its greatest advantage is that it performs analog-to-digital signal conversion directly, which reduces circuit complexity and improves the operating quality of the circuit. It supports a supply voltage range of 3 V to 5.5 V, making the system design more flexible and convenient.

In this design, the DS18B20 works in cooperation with the AT89S52 in the temperature sensing module, and the schematic diagram is shown in Fig. 1. The AT89S52 serves as the processor and receives the temperature data collected by the DS18B20 through port P3.7.

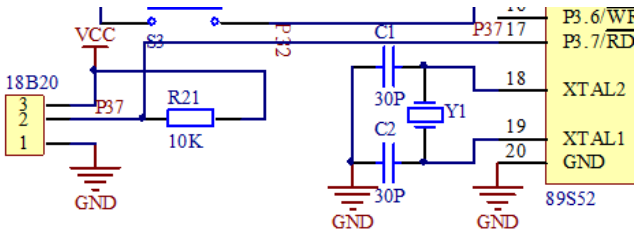


Fig. 1 Digital temperature sensor circuit

In practical applications, the MCU is an indispensable part of data acquisition with the DS18B20. Once a single-wire output port is connected to the sensor, the MCU can process the temperature signals sent by the sensor. Moreover, since one output port of the MCU can be connected to multiple DS18B20 devices, temperature detection at multiple points can be realized.

The fan motor selected for this system is a stepper motor, which attains different rotational speeds only when the ULN2003 Darlington inverting driver receives pulses of different frequencies. As shown in the circuit in Fig. 2, the stepper motor is connected to the power supply and to four pins of the driver, and the four inputs of the ULN2003 are connected to the four output pins P1.0, P1.1, P1.2, and P1.3 of the MCU. When the waveforms output by the MCU pass through the ULN2003, its internal circuit processes them and forwards them to the stepper motor as driving signals, thereby controlling the speed and the on/off state of the fan motor.

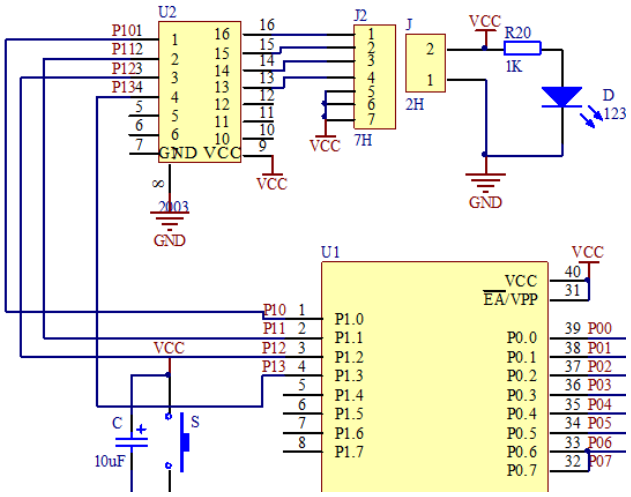


Fig. 2 Motor speed regulation and control circuit

The keyboard is an important part of the control section of this design. Its purpose is to simplify operation and provide a better human–machine interaction environment. The keyboard control is divided into two parts: the manual mode and the automatic mode. When switched to the manual mode, two functions—speed-up and speed-down—are provided, allowing the fan speed to be adjusted manually. When switched to the automatic mode, the circuit automatically adjusts the speed according to changes in the ambient temperature: the fan does not rotate below 15 °C, runs at the lowest speed between 15 °C and 24 °C, at a medium speed between 24 °C and 33 °C, and at the highest speed above 33 °C. This feature greatly simplifies the user's operation. The button circuit is shown in Fig. 3.

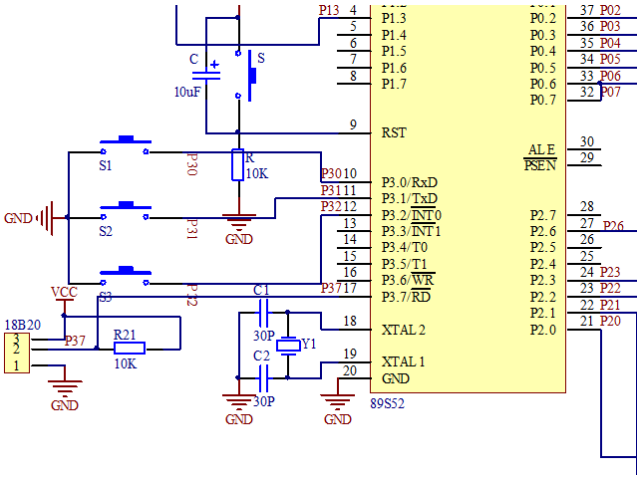


Fig. 3 Keyboard control circuit

The temperature alarm module serves as a safety warning in this design, as shown in Fig. 4. The buzzer is connected to the capacitor of the display segment-select line. When the ambient temperature exceeds 40 °C, Q5 in the display circuit receives the segment-select data, and the buzzer is then triggered by the voltage and sounds an alarm. The design of this module emphasizes the concept of human-oriented design.

The display device used in this design is a four-digit common-cathode seven-segment LED display, as shown in Fig. 5. When the DS18B20 temperature sensor detects the temperature, it transmits the detected signal to the MCU; after

processing, the MCU sends it to the display in the form of digital signals. The signals received by the display are divided into two types: segment-select and digit-select signals. In Fig. 5, the segment-select input is composed of a driver chip together with a resistor network, while the digit select is controlled by making use of the switching characteristics of transistors; in this way, the dynamic display of the seven-segment LED display is realized.

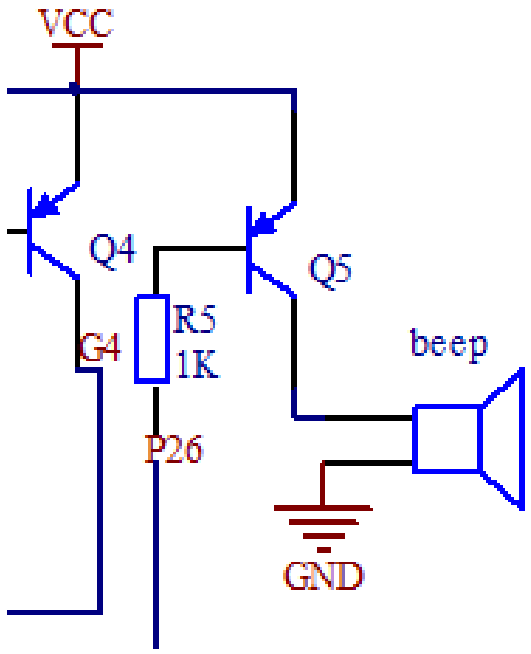


Fig. 4 Temperature alarm circuit

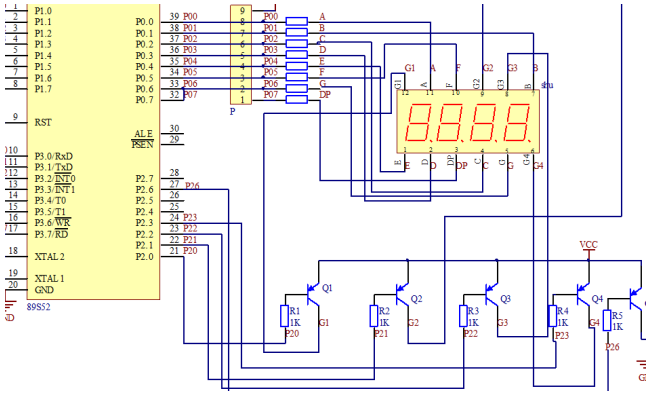


Fig. 5 Temperature display circuit

3. System software design and test

The program in this design is written in the C language and adopts a modular structure. The overall program consists of the main program, the temperature acquisition subroutine, the automatic speed-regulation subroutine, and the key-scanning subroutine. In essence, the temperature acquisition program performs the conversion from an analog signal to a digital signal. After the analog signal is transmitted to the MCU through port P3.7, the MCU performs a series of internal processing operations and produces two digital signals, which are sent respectively to the temperature display module and to the stepper motor drive system.

There are three control buttons in the system: K1, K2, and K3. K1 is used to switch between the automatic and manual speed-regulation modes, and K1 and K2 are used to adjust the fan speed in the manual mode (K1 for speed-up and K2 for slow-down). The program first checks whether K3 is pressed: if not, the automatic speed-regulation mode is enabled; if pressed, the manual mode is enabled. In the manual mode, the program first checks whether K1 is pressed. If it is, the program further checks whether the fan is already running at the highest speed: if so, the speed is kept unchanged; otherwise, the fan speed is increased by one gear. If K1 is not pressed, the program then checks whether K2 is pressed. If it is, the program checks whether the fan is currently stopped: if it is stopped, the state remains unchanged; otherwise, the fan speed is decreased by one gear.

When K3 is not pressed, the fan executes the automatic speed-regulation mode. The program first checks whether the temperature is below 15 °C: if so, the temperature is low and the fan does not need to work. If the temperature is above 15 °C, the program checks whether it is below 24 °C; if so, the temperature is slightly high and the fan is set to rotate at a low speed. If the temperature is above 24 °C, the program checks whether it is below 33 °C; if so, the temperature is fairly high and the fan is set to a medium speed. If the temperature is above 33 °C, it indicates a very high temperature, and the fan is set to rotate at a high speed. Finally, the program checks whether the temperature exceeds 40 °C; if so, the temperature is too high and the buzzer sounds an alarm.

The prototype provides two major functions: the manual mode and the automatic mode. In the manual mode, the displayed temperature can be increased or decreased by operating K2 and K3, thereby changing the rotational speed of the stepper motor. In the automatic mode, the surrounding temperature is detected by the temperature sensor, different temperatures are displayed, and the motor runs at different speeds. As shown in Fig. 6 and Fig. 7, when the system is switched to the manual mode, the motor speed can be controlled through K2 and K3 on the circuit board, thereby adjusting the fan speed.

As shown in Fig. 8 and Fig. 9, when the system is switched to the automatic mode, the display shows the ambient temperature detected by the sensor. When the sensor is gently pinched with a finger, the temperature shown on the display gradually rises, and the motor reaches its highest rotational speed at the same time. When the finger is released, the temperature gradually falls, and the motor speed decreases accordingly.

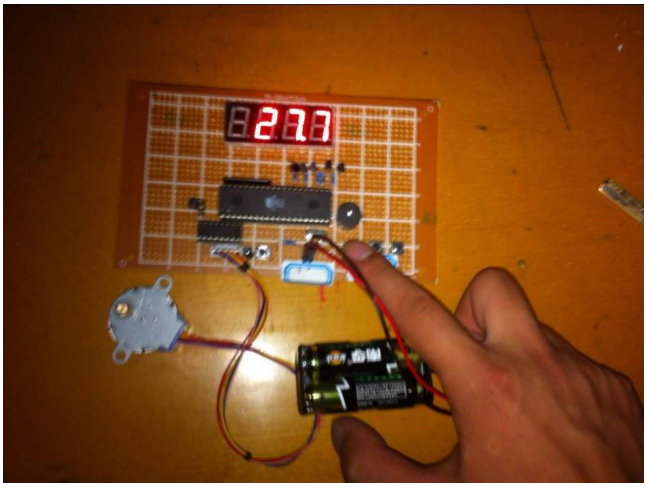


Fig. 6 Prototype in the manual mode

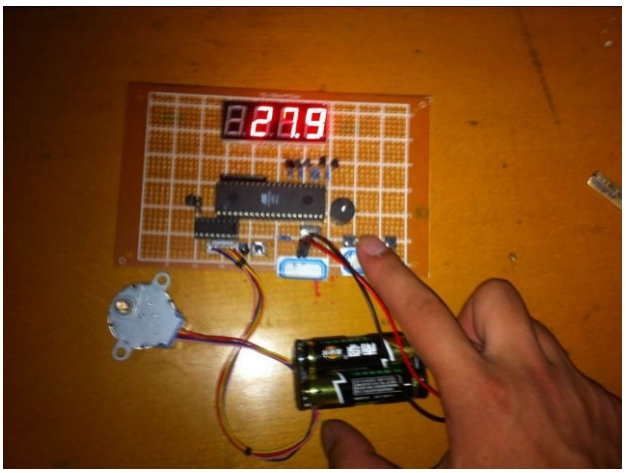


Fig. 7 Prototype in the manual mode

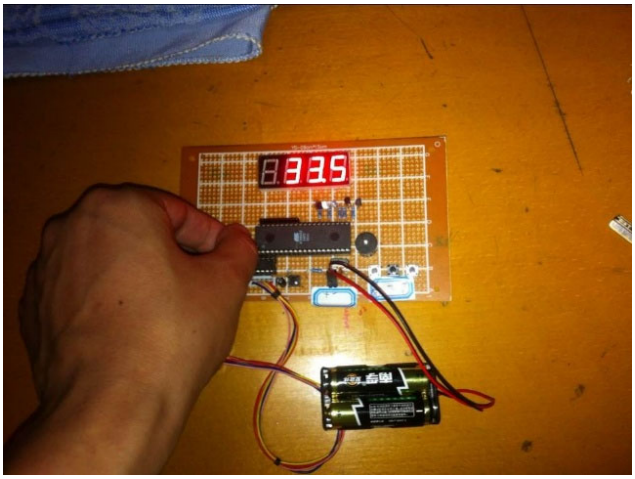


Fig. 8 Prototype in the automatic mode

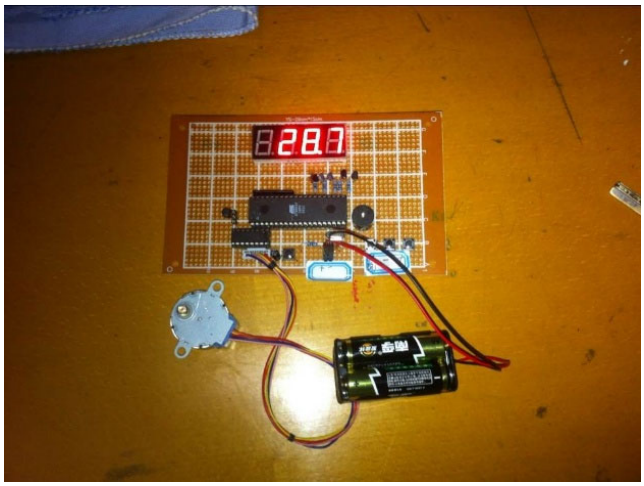


Fig. 9 Prototype in the automatic mode

4. Conclusion

This paper presents an MCU-based temperature-controlled fan that can adjust its rotational speed according to the ambient temperature. The system supports two operating modes: the manual mode and the automatic mode. In the automatic mode, the temperature sensor DS18B20 plays the leading role: when the sensor transmits the detected external temperature to the MCU, the MCU processes the signal and forwards it to the drive system, which then drives the stepper motor. As the external temperature changes, the signal sent by the sensor changes accordingly, and the motor speed is adjusted in response. In the manual mode, the push buttons take control of the whole system: a temperature value can be preset with the buttons, after which the system continuously compares the external temperature with the preset value and controls the motor speed according to the difference between the two.

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