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THE DESIGN OF INTELLIGENT TEMPERATURE MEASUREMENT SYSTEM BASED ON THE MICROCONTROLLER

Abstract. As times progress and science develops, single-chip microcomputer technology has been popularized in our life, scientific research, and various fields. It has been a relatively mature technology. This paper mainly introduces a temperature measurement system based on 51 singlechip microcomputers and describes in detail the process of developing a temperature measurement system using the digital temperature sensor DS18B20. It focuses on the detailed analysis of the sensor's hardware connection, software programming, and system flow of each module. The system can measure and display the real-time temperature and set the upper and lower limits of the temperature. When the temperature reaches the upper and lower limits, the system has an automatic alarm function. The system can easily realize temperature acquisition and display. It is quite convenient to use and has the advantages of high precision, wide range, high sensitivity, small size, and low power consumption. It is suitable for temperature measurement in our daily life and industrial & agricultural production. And it can also be embedded in other systems as a temperature processing module or as an auxiliary extension of other main systems. The combination of the temperature sensor DS18B20 and 51 single-chip microcomputers realizes the simplest temperature detection system. The system has a simple structure and strong anti-interference ability. It is suitable for on-site temperature measurement in harsh environments and has wide application prospects.

Keywords: Microcontroller, Thermometer, Temperature Sensor, Liquid Crystal Display (LCD), Proteus.

1. Introduction

Temperature control is widely used in our daily life. People use thermometers to collect temperature and manually operate heating, ventilation, and cooling equipment to control temperature. This not only has low control accuracy and poor real-time performance but also increases the labor intensity of the operators. In some industries, the requirements for temperature are higher, and accidents caused by unreasonable working environment temperature often occur. It affects the reliability of industrial production and even endangers the operators' safety. In order to avoid these disadvantages, it is necessary to install digital temperature measurement and control equipment in some specific environments. This design uses a new type of single-chip microcomputer to measure the temperature which has high measurement accuracy and simple operation. With the advantages of strong operability and low price, it is especially suitable for temperature measurement in our life, medical treatment, industrial production, and so on.

2. Literature Review

With the development of science and technology, the requirements of modern society for the accuracy and precision of various information parameters have increased geometrically. And how to obtain these parameters accurately and quickly needs to be subject to the development level of modern information infrastructure. In the three major information collection (sensor technology), information transmission (communication technology), and information processing (computer technology), sensors belong to the cutting-edge products of information technology. Especially temperature sensor technology, which has been used in various fields in my country. It can be said that it penetrates into every field of society. People's lives are closely related to the temperature of the environment. In the process of industrial production, it is necessary to measure the temperature in real-time. In agricultural production, it is also inseparable from the measurement of temperature. Therefore, studying the measurement method of temperature and the devices is of great significance.

The key to measuring temperature is a temperature sensor. The development of temperature sensors has gone through three stages of development: traditional discrete temperature sensors, analog integrated temperature sensors, and intelligent integrated temperature sensors. In the development of the information age, functional devices for sensing, collecting, converting, transmitting, and processing various information have become indispensable and important technical tools in various application fields. The sensor is the primary component of the information acquisition system. It is the main link to realizing modern measurement and automatic control. It is not only the source of the modern information industry but also the material and technical foundation for the existence and development of the information society. Thus, the knowledge and technology of understanding and holding the sensor is of great significance.

With the continuous advancement of science and technology, the temperature is a commonly

used controlled parameter in industrial production. The application of single-chip microcomputers to control these controlled parameters has become mainstream today. The digital temperature sensor DS18B20, because it integrates an A/D converter inside, which makes the circuit structure simpler and reduces the precision loss during temperature measurement conversion. It also makes the temperature measurement more accurate. The purpose of this paper is to focus on designing an intelligent temperature measurement system, which can measure the ambient temperature in real-time and realize real-time display. It can set the upper and lower limits of the temperature. When the temperature reaches the upper and lower limits, the system has an automatic alarm function.

3. Methodology 3.1 Design Ideas

The system is mainly composed of two circuits temperature measurement and data acquisition. The main controller adopts 51 single-chip microcomputers. The temperature measurement adopts a DS18B20 temperature sensor. After setting the temperature, when the temperature reaches the set limit, it can be prompted by flashing lights and buzzing, and the temperature can be displayed on the LCD in real-time.

In this paper, the digital temperature chip DS18B20 was used to measure the temperature, and the output signal is fully digital. It is convenient for single-chip processing and control and many peripheral circuits of traditional temperature measurement methods are omitted. The system used the AT89S51 chip to control the temperature sensor DS18B20 for real-time temperature detection and display, which can quickly measure the ambient temperature and can set the upper and lower limit alarm temperatures as needed. The system is very scalable. It could add a clock chip DS1302 to the design to obtain time data, and display the time at the same time during data processing. It also could use the AT24C16 chip as a storage device to store temperature data at certain time points and use the keyboard to adjust the time and query the temperature. The obtained data can communicate with the RS232 interface of the computer through the MAX232 chip, which is convenient to collect and organize the time and temperature data. The temperature measurement device of this scheme has a simple circuit, high accuracy, convenient implementation, and a relatively simple software design.

3.2 Hardware Circuit Design

This design is an intelligent temperature test system with 51 single-chip microcomputers as the core. The overall hardware circuit of the system includes a sensor data acquisition circuit, temperature display circuit, upper and lower limit alarm adjustment circuit, and single-chip motherboard circuit.







Figure 2. Overall Circuit Diagram of the System

The system is mainly composed of the main controller, single-chip reset, alarm button setting, clock oscillation, LED display, and temperature sensor. The basic block diagram of the system is shown in (Fig. 1).

The overall circuit diagram of the system is shown in (Fig. 2). The temperature sensor is connected to the P3.3 port. K2 is the key to displaying the alarm temperature, which is connected to P1.4. K1 is the normal display temperature, which is connected to P1.7. It can display the current temperature by pressing K1, and it can display the upper and lower temperature limits by pressing K2. P2.3 and P2.6 are the ports for flashing of high temperature and low temperature respectively. When the measured result is higher or lower than the set temperature upper and lower limits, it will flash, and alarm and the buzzer connected to P3.7 will alarm.

3.3 Introduction of Main Components

This design is an intelligent temperature test system with 51 single-chip microcomputers as the core component. The overall hardware circuit of the system includes a sensor data acquisition circuit, temperature display circuit, upper and lower limit alarm adjustment circuit, and single-chip motherboard circuit [1; 2; 3].



Figure 3. DS18B20 Interface Circu

(1) DS18B20 temperature sensor

For DS18B20 temperature measurement as shown in (Fig. 3), the oscillation frequency of the low-temperature coefficient crystal oscillator is little affected by the temperature, which is used to generate a fixed frequency pulse signal and send

it to counter 1. The oscillation rate of the hightemperature coefficient crystal oscillator changes significantly with the temperature change. The generated signal is used as the pulse input of counter 2. Counter 1 and the temperature register are preset to a base value corresponding to -67°F. Counter 1 counts down the pulse signal generated by the lowtemperature coefficient crystal oscillator. When the preset value of counter 1 is reduced to 0, the value of the temperature register will increase by 1. The preset of counter 1 will be reloaded, and counter 1 will restart to count the pulse signal generated by the low-temperature coefficient crystal oscillator. When repeating this cycle until counter 2 counts to 0, it will stop the accumulation of the temperature register value. At this moment, the value in the temperature register is the measured temperature.

(2) 1602 liquid crystal display

1602 LCD is also called 1602-character LCD, which is a dot matrix LCD module specially used to display letters, numbers, symbols, etc. It consists of several 5X7 or 5X11 dot matrix character bits, and each dot matrix character bit can display a character. There is a dot space between each bit. There are also spaces between each line, which play the role of character spacing and line spacing. Therefore, it cannot display graphics, as shown in (Fig. 4). 1602 LCD means that the displayed content is 16X2, which can display two lines. Each line has 16 characters LCD module (displaying characters and numbers) [4].





3.4 Software Programming

The software of this system can be divided into two categories according to its functions. One is the monitoring software (main program), which is the core of the entire control system and is specially used to coordinate the relationship between each execution module and the operator. The second is the execution software (subroutine), which is used to complete various substantive functions such as measurement, calculation, display, communication, and so on. Each execution software is also a small function execution module. Here, each execution module is listed one by one. The function definition and interface definition are carried out for each execution module. After each execution module is planned, the monitoring program can be planned [5].





The system program mainly includes the main program, the temperature reading subroutine, the temperature conversion command subroutine, the temperature calculation subroutine, the display data refresh subroutine, etc.

(1) Main program

The key function of the main program is to display the temperature in real time, read out and process the measured temperature value of DS18B20. Temperature measurements are made every 1s. The main program flow chart is shown in (Fig. 5).

(2) Read temperature subroutine

The main function of reading out the temperature subroutine is to read out 9 bytes in RAM. CRC verification must be performed when reading. Temperature data cannot be rewritten if there is an error in the check. The flow chart of reading temperature subroutine is shown in (Fig. 6).

First, choose the most suitable monitoring program structure according to the overall function of the system. And then reasonably arrange the scheduling relationship between the monitoring software and each execution module according to the real-time requirements.



Figure 6. Subprogram Flow Chart of Reading Temperature Value

(3) Temperature Conversion Command Subroutine

The temperature conversion command subroutine mainly issues the temperature conversion start command. When using 12-bit resolution, the conversion time is about 750ms [6]. In this program design, the 1s display program delay method is used to wait for the completion of the conversion. The temperature conversion command subroutine is shown in (Fig. 7).



Figure 7. Subprogram Flow Chart of Temperature Conversion

(4) Display data refresh subroutine

When the highest data display bit is 0, the symbol display bit is moved into the next bit.

The display data refresh subroutine is mainly to refresh the display data in the display buffer.



Figure 8. Subprogram Flow Chart of Refreshing Display Value

The flow chart of the display data refresh subroutine is shown in (Fig. 8)

(5) Calculate temperature subroutine

The temperature calculation subroutine performs BCD code conversion operation on

the value read in RAM, and judges whether the temperature value is positive or negative. Its flow chart is shown in (Fig. 9).



Figure 9. Subprogram Flow Chart of Calculating Temperature's Value

4. Simulation

Proteus software is EDA tool software published by the British Labcenter electronics company. It not only has the simulation function of other EDA tool software but also can simulate the microcontroller and peripheral devices. It is currently the best tool for simulating microcontrollers and peripheral devices. Although the domestic promotion has just started. It has been favored by MCU enthusiasts, teachers engaged in MCU teaching, and scientific and technological workers who are committed to the development and application of MCU. Proteus is a world-renowned EDA tool (simulation software), from a schematic layout, and code debugging to cosimulation of microcontroller and peripheral circuits, one-click switching to PCB design, truly realizing the complete design from concept to product [7]. It is the only design platform in the world that combines circuit simulation software, PCB design software, and virtual model simulation software. thermometer is set to 70 °C degrees Celsius, and the lower line is set to -20 °C, the simulation diagrams are shown in (Fig. 10) and (Fig. 11) respectively.

Using Proteus software to carry out computer simulation, when the upper limit of the smart



Figure 10. Simulation Diagram of Exceeding the Lower Limit Temperature



Figure 11. Simulation Diagram of Exceeding the Upper Limit Temperature

As shown in (Fig. 11), when the set temperature is 80.6 $^{\circ}$ C, the upper temperature limit is exceeded, the first red light D1 flashes, and the buzzer alarms.

As shown in (Fig. 10), when the set temperature is -22.4 °C, the lower limit is exceeded, the second red light D2 flashes, and the buzzer alarms. As shown in (Fig. 12), it is the simulation diagram when the temperature is in the normal temperature range. The real temperature is -16.4 °C. Because it is in the normal temperature range, the two red lights D1 and D2 are not flashing. The buzzer is not alarming.



Figure 12. Simulation Diagram in Normal Temperature Range



Figure 13. Simulation Diagram of Displaying Alarm Temperature When Pressing K2

As shown in (Fig. 13), it is the simulation diagram displaying the alarm temperature when pressing the K2 button. Currently, the two red lights are not flashing. The buzzer is not alarming. The lower and upper limit temperatures (70 °C,-20 °C) are shown on the liquid crystal display.

5. Conclusion

In this paper, the purpose was to design an intelligent temperature measurement system based on 51 single-chip microcomputers. It analyzed the whole design of the hardware circuit and software program. This paper introduced the current situation and development of intelligent thermometers. And it also introduced the structure and characteristics of 51 single-chip microcomputers and so on. This paper introduced the design scheme selection and principal introduction of digital thermometers. This topic used the digital temperature sensor DS18B20 to collect temperature. The temperature signal does not need A/D conversion and can directly carry out temperature collection, display, and alarm design of an intelligent thermometer. The system included a sensor data acquisition circuit, temperature display circuit, upper and lower limit alarm circuit, single-chip motherboard circuit, and other components.

This system is easy to use and has the advantage of high precision. It had a wide range and high sensitivity. It had a small size and low power consumption, etc. It was suitable for temperature measurement in our daily life and industrial and agricultural production and can also be embedded in other systems as a temperature processing module. It was simultaneously an assisted extension to other primary systems. The system had a simple structure and strong anti-interference ability. It was suitable for on-site temperature measurement in harsh environments and had wide application prospects.

6. Conflict of Interest

The authors declared no conflict of interests.

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