Design of Mine Temperature Measurement System

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Abstract: This paper introduced a method of mine temperature measurement. The system used PT100 temperature sensor as sensing unit, constant current source composed of operational amplifier as excitation source, amplification circuit and A/D conversion circuit to process the output signal of Pt100 sensor, and STM32F103 microprocessor was used for data calculation and display, and the temperature data was converted into a 485 signal for long-distance transmission and temperature measurement system. The experimental results show that the system has high temperature measurement accuracy, wide measurement range, and low cost. Reliable measurement of temperature parameters in coal mines can be carried out, which is of great significance to ensure coal mine safety production.

1. INTRODUCTION
Temperature is a very important physical quantity in production and life. The fields that need to measure temperature are almost ubiquitous. With the increasing level of intelligent mining in coal mines, in order to ensure the safe production of coal mines, there is an increasing demand for temperature monitoring in underground coal mines, such as detecting temperature in the roof voids and preparing the roadway support space, the temperature of mining area and goaf, etc. The temperature monitoring of important places in the mine is of great significance in ensuring the safe production of coal mines. The current temperature measurement methods commonly used in coal mines include digital temperature measurement technology, platinum resistance-based temperature measurement technology, and so on. The Pt100 platinum thermal resistance temperature sensor has very good measurement accuracy, measurement range and linearity, and it is widely used in industrial production. This paper designs a mine temperature measurement system based on platinum thermistor temperature sensor.

2. PRINCIPLE OF TEMPERATURE MEASUREMENT
Pt100 is a platinum thermal resistance, and its resistance changes with temperature. If we know the relationship between temperature and resistance, we can calculate the temperature by converting the change of platinum resistance into the voltage change of corresponding temperature. According to the technical standard of Pt thermistor of International Electrotechnical Commission, the temperature resistance relationship of Pt100 in the range of 0 ~ 650 ℃can be expressed as a function of Rt. R_t = R_o (1+At+Bt^2). Wherein R_t and R_o are the platinum resistance at t ℃ and 0 ℃, respectively A, B are constants. For Pt100, when the temperature is 0 ℃, the resistance of Pt100 is 100Ω. With the change of temperature, the platinum resistance also changes, and the resistance change rate is 0.3851Ω/ ℃. In the temperature range of 0-100 ℃, the resistance of Pt100 is 100-138.51Ω. According to the calculation, the relationship between temperature and resistance of Pt100 is very close to a straight line, ignoring the high-order term, it can be treated as linear.
3. SYSTEM DESIGN
According to the characteristics of the PT100 temperature sensor, the system has designed a hardware processing circuit, including a constant current source circuit, a signal processing circuit, an A/D conversion circuit, a microprocessor circuit, and a display circuit. The constant current circuit provides stable current excitation to the Pt100. The signal processing circuit amplifies and matches the voltage signal generated by the Pt100 and sends it to the AD chip. After the A/D conversion circuit, it is sent to the microprocessor to calculate and display the temperature value. The overall block diagram of the system is shown in Figure 1.

![Figure 1 System diagram](image1)

3.1. Constant current source circuit
The analysis in the previous section shows that to accurately measure temperature, you need to know the resistance of Pt100 thermal resistance. This system builds a constant current excitation system to accurately provide the current flowing through Pt100, convert the change of resistance into voltage, get the resistance value from the voltage value, and get the temperature value. In this paper, a constant current source circuit based on operational amplifier AD826 is used, as shown in Figure 2. With the introduction of positive and negative feedback, closed-loop control system is configured so that its output current stability has good quality, high precision, and low output impedance. The constant current source input does not use the traditional power supply voltage as the input, because the general power supply chip is not as good as the voltage reference source chip in terms of stability and accuracy. Therefore, this article uses the high-precision voltage reference source ADR4533 as the constant current source input to ensure the stability of the constant current. ADR4533 is a high-precision, low-power, low-noise reference voltage source, with excellent temperature stability and low output noise, and an output voltage of 3.3V. According to the circuit analysis in Figure 2, when certain balance conditions are met and the matching relationship between resistances is strictly guaranteed, the output current can be expressed by Formula 1,

$$I_{Pt100} = \frac{R_6/R_7 \cdot U_{in}}{R_{10}}$$

Formula 1

$I_{Pt100}$ is the current flowing through the platinum resistance, $R_6$, $R_7$, and $R_{10}$ are precision resistance, $U_{in}$ the input voltage of constant current source. The corresponding current can be obtained by selecting the appropriate resistance value. In this paper, the current is 1mA, which is conducive to calculation, and PT100 will not heat seriously and affect the measurement accuracy.

![Figure 2 (a) Reference source circuit](image2)
3.2. Signal processing circuit

The main function of the signal processing circuit is to send the voltage generated by the constant current flowing through Pt100 to the A/D conversion circuit. This article uses a first-level amplifying circuit and a second-level follower circuit to complete the signal processing part. Frontstage amplifying section using instrumentation amplifier amplifies a signal output, and differential input mode effectively eliminates the error. In addition, it has a very high input impedance. In the actual circuit, this article uses TI's INA111 instrumentation amplifier to form the amplifying circuit, and the subsequent follower circuit also uses this chip, which achieves the purpose of following, simplifies the design, realizes impedance matching and enhances the load capacity. INA111 can be set to any gain value from 1 to 1000, and the magnification can be calculated by formula 2, where K is the magnification, RG is the gain resistance, and the actual circuit is selected as 3.57KΩ precision resistance. Because the temperature measurement range in this article is in 0~100 ℃, the resistance of Pt100 is 100~138.51Ω, the voltage drop thereon is 100mV~138.51 mV, the design gain is 15 times, and the output voltage is limited to 50% of the full scale of AD input, which is conducive to subsequent processing.

$$K = 1 + \frac{50k}{R_g}$$

Formula 2

3.3. A/D conversion circuit design

After the signal processing circuit, the temperature change of the Pt100 temperature sensor has been converted into a voltage signal. The processor is required to calculate the temperature value, and the microprocessor can only recognize digital signals. Therefore, bridges and bonds are needed between analog and micro-processing. This article uses Linear Technology’s 16-bit A/D conversion chip LTC1865 to complete this function. The chip converts the analog voltage from the upper output into digital quantity and sends it to the microprocessor for calculation. LTC1865 uses a single power supply, the processing speed is fast, and it exchanges information with the microprocessor through SPI bus, which simplifies the circuit design and makes the system more concise and efficient.
3.4. Processor circuit and display circuit

The microcontroller chip selects STM32F103 as the core of data processing and signal control. The chip is based on the 32-bit Cortex-M3 core enhanced series CPU, the main frequency reaches 72MHz, which is a wide voltage range power supply, and has a wealth of peripherals and on-chip RAM, including watchdog, timer, PWM, timer capture and square wave output, etc. STM32F103 is used as a system control center to complete data acquisition, temperature calculation, communication with the host computer, etc. In terms of display, this article uses a customized LCD as the display module, which can be controlled only by connecting the ordinary I/O port of the controller. This article also uses a dedicated LCD driver chip as the driving part of the LCD. And a 485-communication circuit is designed, which is conducive to the transmission of temperature signals and networking. I won't repeat it here.

4. SOFTWARE DESIGN

The software design part is mainly for voltage acquisition and temperature conversion calculation, as well as display communication and so on. The software design adopts a modular design concept. The system software design flow chart is shown in Figure 5, which mainly includes system initialization. The microcontroller reads the voltage change value through the bus and displays the data after temperature conversion.

The resistance is calculated from the collected voltage, and the temperature value is obtained by the method of looking up the table. Because of the temperature measurement range in this article, the resistance value change can be approximated as linear, which simplifies the program design and can also control the error within a certain range. In addition, in order to improve the measurement accuracy,
the program also uses the median filter method. After calculating the temperature value for 10 times, this filter method is used to remove the maximum and minimum values and then do the average processing, and finally display the obtained temperature value.

5. EXPERIMENTAL RESULTS

5.1. Laboratory test
The temperature measurement system designed in this paper was tested in the laboratory, and the temperature data obtained is shown in Table1. From the experimental data, it can be seen that the temperature measurement system designed by the system is within the design temperature measurement range, and the absolute error of the system is up to 0.5 °C. Within the allowable range of industrial error, it can meet the temperature measurement requirements of mine tunnels.

| Standard temperature / (℃) | Measured temperature / (℃) | Absolute error |
|----------------------------|-----------------------------|----------------|
| 0                          | 0.5                         | 0.5            |
| 10                         | 10.4                        | 0.4            |
| 20                         | 19.5                        | -0.5           |
| 30                         | 29.6                        | -0.4           |
| 40                         | 40.3                        | 0.3            |
| 50                         | 50.5                        | 0.5            |
| 60                         | 59.6                        | -0.4           |
| 70                         | 70.3                        | 0.3            |
| 80                         | 79.5                        | -0.5           |

5.2. Application examples
The temperature measuring device designed in this paper has been applied in the temperature monitoring of mine roadway. In a mine floor pumping roadway, the occurrence of coal seam is relatively stable, the structure is simple, and the air volume of roadway is stable. The temperature measuring device designed in this paper is installed in three different monitoring points which need to monitor the temperature on the side of roadway, and the distance between each measuring point is about 20 m. The temperature measured by the system is observed at any time point in a day. The measurement results are shown in Figure 6. The system shows that the temperature of the monitoring point is always maintained at about 26 °C. The measurement results are verified by the temperature measuring instrument with higher accuracy of the mine. This is also consistent with the stable air flow in the roadway and the relatively stable mining activities in the roadway for a period of time. The tunnel temperature always keeps in a stable state, which shows the accuracy and stability of the system.

![Figure 6 Temperature monitoring curve](image-url)
6. CONCLUSION
In this paper, the Pt100 sensor is used as the temperature sensing component, and the constant current source is used as the excitation to effectively solve the temperature measurement interference problem caused by the line impedance. After signal conditioning, the 16-bit A/D converter converts the voltage into digital amount, with STM32F103 controller as a calculation system and a processing unit, and a liquid crystal display system as a display module. Through laboratory tests and practical application, the absolute error of the system is controlled within 0.5 ℃, which meets the needs of mine roadway temperature measurement, and has the characteristics of high reliability, simple application and low cost. Moreover, it has practical guiding significance for temperature measurement of coal mine roadway.

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