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Method for Improving Temperature Measurement Accuracy of NTC Thermistors Based on Multisegment Linear Regression

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Abstract: With the continuous advancement of technology and the increasing demand for temperature measurement accuracy in various industries, the design and implementation of a high - performance digital thermometer have become an urgent problem to be solved. In this study, a digital thermometer was successfully designed, which could be widely applied to multiple fields, such as water temperature measurement, temperature monitoring in daily life, and temperature control in industrial production processes. In the hardware architecture of this thermometer, the NTC thermistor and NY8B062D single - chip microcomputer were respectively assigned key functional roles. The former was used to sense the subtle changes in ambient temperature and convert them into electrical signals, while the latter was responsible for the subsequent conversion, analysis, and processing of these electrical signals. The temperature data processed by the single - chip microcomputer would be transmitted to the display module through a specific communication protocol, thus realizing the real - time display of the measured temperature values. In order to effectively overcome the impact of the nonlinear characteristics of the thermistor itself on the measurement accuracy, this study adopted the multisegment linear regression technology. Through the collection and analysis of a large number of experimental data, multiple temperature segmentation intervals were determined, and the optimal linear regression equations were fitted for each interval. At the same time, combined with the 12 - bit ADC technology, the resolution and quantization accuracy of signal sampling were greatly improved. After a series of rigorous experimental tests and optimization adjustments, the measurement accuracy of this thermometer was significantly enhanced, and its measurement error was successfully limited within ±1%, providing reliable technical support for accurate temperature measurement in practical applications.

1. Introduction

With the rapid development of science and technology, people's demand for accurate temperature measurement and control is increasing. Among the many types of thermometers, thermistor thermometers have become an important tool in the field of modern temperature measurement due to their unique advantages [1-2]. It uses the characteristics of the resistance of the thermistor material to change with the temperature to achieve accurate measurement of temperature, which provides great convenience for scientific research, industrial production and daily life. At the heart of a thermistor thermometer is the thermistor material. The material is significantly temperature sensitive, resulting in a significant change in its resistance value as the temperature changes. Based on this principle, thermistor thermometers are able to respond quickly to temperature changes and convert this change into a measurable electrical signal, enabling accurate temperature measurements [3-4]. The advantages of thermistor thermometers are their high measurement accuracy, fast response, good stability and small size. These advantages make it widely used in various fields. In some specific occasions, there are certain requirements for the accuracy, stability and real-time performance of temperature[5-6]. As an important device for sensing temperature, the temperature sensor plays a vital role in the accuracy of temperature measurement, and the thermistor sensor is suitable for occasions with fast response speed,and the thermistor sensor can detect the temperature in the range of -55 ℃-125 ℃.

However, although the NTC thermistor temperature shows good performance in temperature measurement, the linearity of the function relationship between temperature and resistance of NTC thermistor sensor is poor, resulting in a large temperature error in the process of use, and a multi-segment linear regression method is proposed to deal with the nonlinear relationship between temperature and resistance, that is, to solve the error of nonlinear changes in the temperature resistance table [7-8]. In the process of working in this paper, the accuracy and real-time performance of temperature measurement are improved by designing a stable reference power supply, improving the resolution of ADC, and processing temperature data in piecewise linear manner[9-10]. In this paper, a high-precision and low-cost digital thermometer is designed with the NY8B062D microcontroller as the main control, combined with the software program, which can be applied to water temperature detection and production workshop temperature detection[11-12].

2. Hardware circuit design

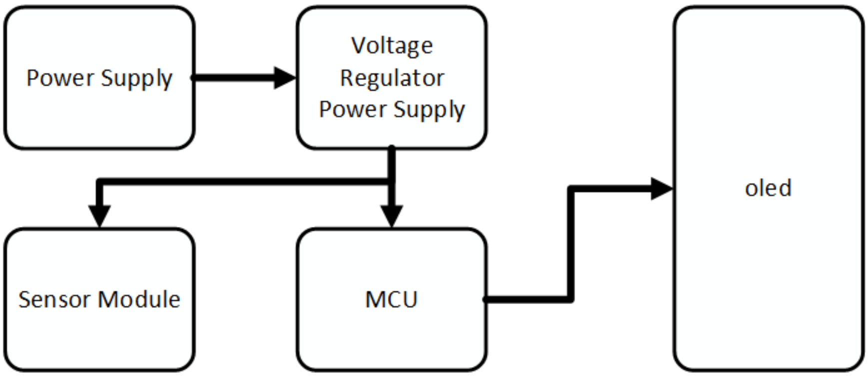

Figure 1 Overall Block Diagram

The NTC thermometer consists of a power supply, a stabilized power supply module, an MCU controller, an NTC sensor module, and a display module circuit, and the circuit implementation framework diagram is shown in Figure 1. In the circuit design, the NY8B062D single-chip microcomputer produced by Jiuqi Co., Ltd. is selected as the MCU microcontrol chip. NY8B062D is an 8-bit single-chip microcomputer architecture control chip, working voltage 2.0~5.5V, NY8B062D integrated a 12-bit resolution analog-to-digital converter (ADC), its conversion frequency reaches 133.3KHZ, with ADC fast acquisition function and rich peripheral resources. The DC power supply is 12V as the power supply, and the input power supply is stepped down to 5V through the voltage regulator module, which is supplied to the NY8B062D MCU controller and display. The analog to digital conversion (ADC) function of the MCU is used to convert the analog voltage value of the thermistor to a digital quantity, and the temperature value is calculated based on the relationship between the digital quantity and the thermistor value as a function of the temperature value. The temperature value is displayed by the NY8B062D microcontroller driver digital screen. According to the working principle of the thermometer, the schematic diagram of the design circuit is shown in Figure 2.

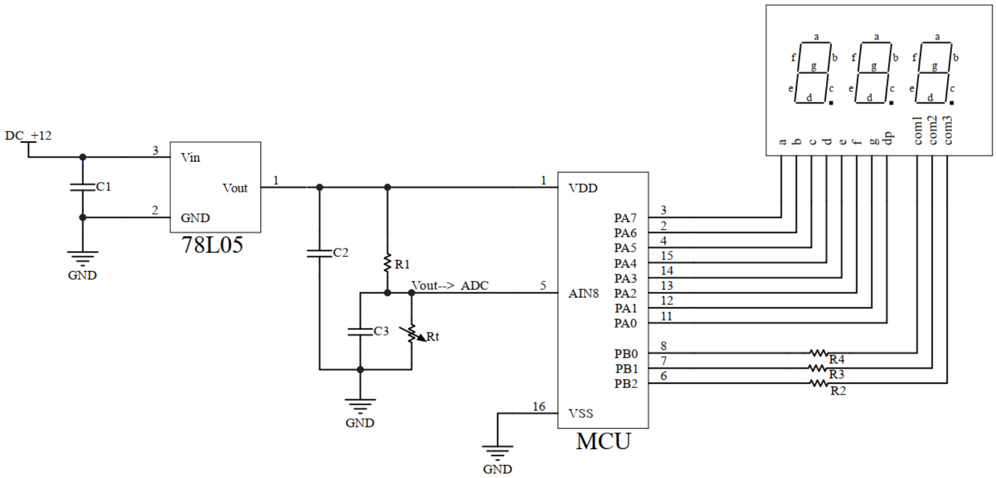

Figure 2 Overall circuit schematic diagram

As shown in Figure 2 above, R1 is a fixed resistance of 10K with an accuracy of 1%. Rt is an NTC thermistor, the material constant of NTC is 3950, and the resistance of NTC is 10K at 25 ℃. When the NTC is affected by the ambient temperature, the Rt resistance value will also change, and the change relationship is determined by Eq. 1 below.

$$R_t = R * e^{(1/T_1 - 1/T_2)} \tag{1}$$

R_t is the resistance of the thermistor. The resistance value of 10K, which is the resistance value of the thermal change, is 25 ℃. By collecting the voltage of Vout by using the ADC of the MCU, the resistance of the NTC can be calculated, and the temperature can be calculated according to the resistance table. According to the national standard NTC temperature resistance table, when the temperature is an integer, the data is shown in Figure 3 below.RT_1T_2

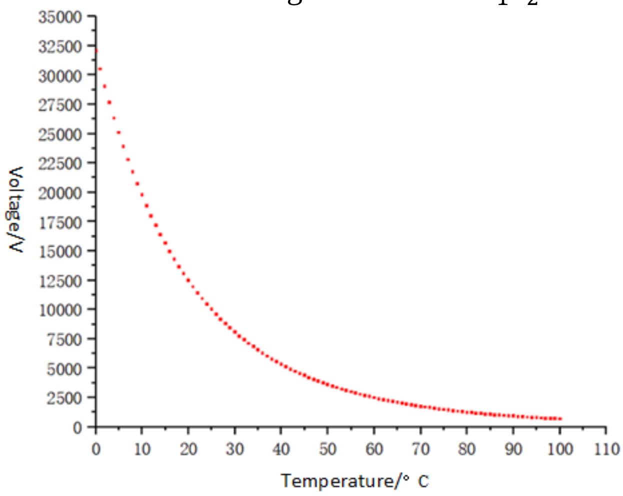

Figure 3 Relationship between temperature and resistance

3. Data processing

The data in the NTC resistance table is discrete, and when the signal collected by the ADC is not an integer, the temperature value cannot be obtained by looking up the table, as shown in Figure 3 above. According to the voltage collected by the ADC, the relationship between temperature and resistance can be converted into the relationship between temperature and voltage by combining the temperature resistance relationship diagram in Equation 2 below, and the relationship between temperature and voltage is shown in Figure 4 below.

$$V_{out} = \frac{R_t}{R_t + R_1} \times V_{cc} \tag{2}$$

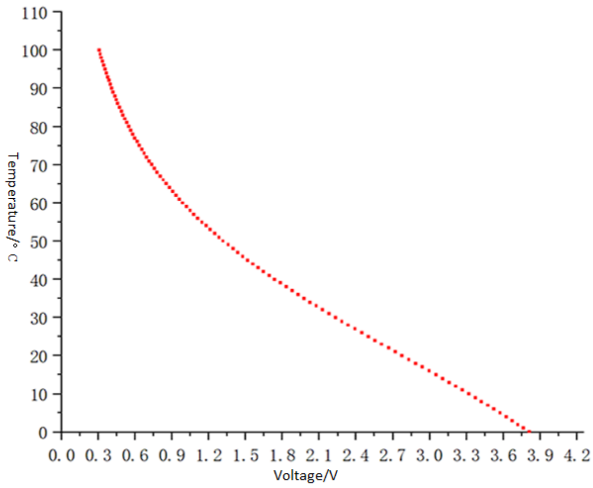

Figure 4 Temperature and voltage relationship diagram

As can be seen from Figure 4, the relationship between voltage and temperature is nonlinear, so in order to effectively improve the accuracy of temperature measurement and meet the high-precision requirements in practical applications, it is decided to use the fitting method to process the data. In the whole temperature range of 1 ℃~100 ℃, since 1 ℃~35 ℃ is a common temperature range, the accuracy of its data is crucial for practical application, so 3 segments are divided into this range. In general, the more intervals are divided, the smaller the fitting error will be, and the more accurate the approximation of the true temperature and voltage relationship. In the range of 35 ℃~100 ℃, it is divided into 4 segments. The specific division method is to divide each small section according to the curvature change of temperature and voltage. The smaller the curvature value, the smoother the change in the function, which contains a wide temperature range in a small segment. Conversely, when the curvature value is larger, the curve of the function is steeper, which means that the voltage changes more drastically with temperature, and it is necessary to divide multiple small segments to reduce the error. If the division in the small interval is not detailed enough, the fitting result will deviate greatly from the actual data. By flexibly dividing the interval according to the change of curvature, the temperature and voltage data can be fitted more reasonably, so as to improve the accuracy of temperature measurement. The temperature range is divided into 7 segments, and the fitting results are shown in Figure 5 below. As shown in Figure 5, the linear regression fit approximates the discrete point from the temperature value, and the linear regression fitting coefficient for each segment exceeds 0.995, when the regression coefficient approaches 1, which indicates that the closer the data fit is to the true value, the smaller the error will be.

By designing hardware circuits and data processing, writing software programs, and using 12-bit

ADC acquisition in software, the acquisition error can be further reduced and the accuracy of temperature measurement can be improved. The regression fitting function is programmed into the program, and finally the overall design of the NTC thermistor thermometer is realized.

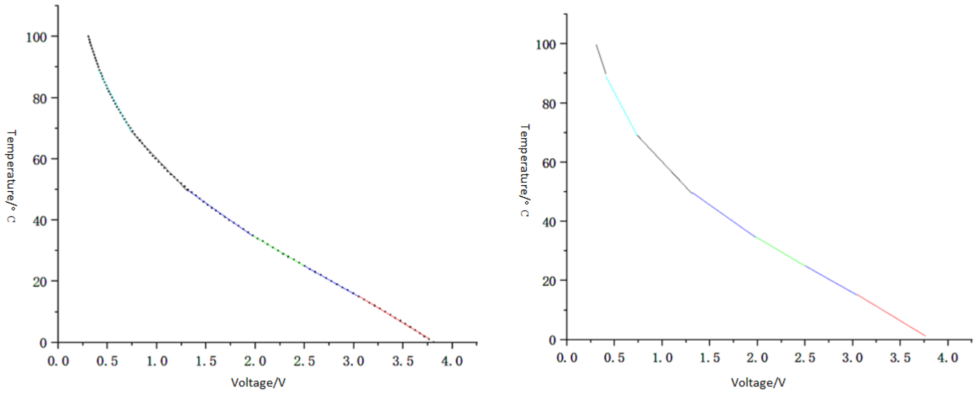

Figure 5 Comparison of temperature and voltage fitting curves

4. Experimental research

In the temperature measurement experimental study, in order to compare the performance difference between the NTC thermistor thermometer and the thermocouple thermometer on the market, the experimental steps and processes are as follows: first, prepare the experimental equipment, including the NTC thermistor thermometer, thermocouple thermometer, appropriate amount of water and heating device. To reduce the effect of temperature fluctuations on the measurement results, a thermal conductive device is used to bind the probes of the two thermometers together. Next, the NTC thermistor thermometer and thermocouple thermometer are placed in cold water, and the initial temperature is recorded after the indication is stabilized. Heating is then started, from about 8 ℃ to 100 ℃. Since the NTC thermistor responds very quickly, and the thermocouple thermometer displays it differently from its real-time display, it is necessary to wait for the two thermometers to stabilize the indication during the heating process, and then record the corresponding temperature values respectively, as shown in Table 1 for specific data.

Table 1 Statistical table of the measurement data

Thermistor thermometer/°C	Thermocouple thermometer/°C	absolute error/°C	relative error/%
8	8	0	0
11.0	11.1	0.1	0.9
18.8	18.9	0.1	0.53
22.5	22.5	0	0
25.9	25.9	0	0
29.5	29.8	0.3	1
31.5	31.4	0.1	0.32
39.3	39.2	0.1	0.25
44.7	44.5	0.2	0.45
55.8	55.8	0	0

From the above test data, the absolute error and relative error can be calculated. The measured values of the two thermometers are relatively close, and the absolute error is mostly within 0.3 ℃, and the relative error is mostly 1% or less. This shows that both the NTC thermistor thermometer and the thermocouple thermometer have good measurement accuracy and similar performance under these experimental conditions.

5. Conclusion

In this paper, a high-precision thermometer based on NTC thermistor sensor is designed, which is proved by experiments and analyzed by analyzing the measurement data, and the accuracy of the temperature can be improved by using the multi-segment linear regression processing method, and the error of the NTC thermistor thermometer is within 1%. The thermometer has a high practical value and has a broad application prospect in industrial production, furniture and electrical appliances and daily life.

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