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Research on High Precision Temperature Acquisition System for Radiofrequency Ablation System

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Abstract: RFA (radiofrequency ablation) is a new type of tumor treatment in recent decades. It has excellent effects in treating certain tumors. Radiofrequency ablation technology is a physical-type treatment technology. At present, RF ablation technology has been very successful in medical clinics. Radiofrequency ablator, as a kind of medical device, implemented directly on the organs, which must ensure good stability and high safety. RF ablators can work in temperature control mode. In this mode, the accuracy of temperature sampling is critical. When working in temperature control mode, the ablator must monitor the temperature of the polar needle tip in real time. In this paper, we study the temperature sampling system for RF ablators, including hardware circuit design and filtering algorithm design.

Keywords: Radiofrequency Ablator; Temperature Sampling; High Precision; Power Control.

1. Overview

At present, methods to monitor the temperature of radiofrequency ablation instrument are thermistor, infrared, thermocouple and so on. For radiofrequency ablation, thermocouple is often used to monitor the temperature. The thermocouple is characterized by simple structure, high temperature measurement accuracy and wide detection range, which is very suitable for in-contact measurement. The thermocouple is a temperature sensing element consisting of two homogeneous long metal conductors of different compositions connected at their two ends.

A copper-nickel-copper thermocouple (T-type thermocouple) is used as the temperature sensor in the design. The T-type thermocouple is simple and temperature stable. The RF ablator transfers heat by contact between the polar needle tip and the tissue cells. Therefore, the temperature sensor must be installed at the tip of the pole needle as shown in Figure 1. The positive and negative electrodes of the sensor consist of wires made of pure copper and copper-nickel materials, respectively. They are soldered to the inside of the pole needle, and then the two wires are connected together in the head of the pole needle to form a circuit. In this way, when the head of the pole pin heats the target tissue, a small current is generated in the wires according to the Seebeck effect.

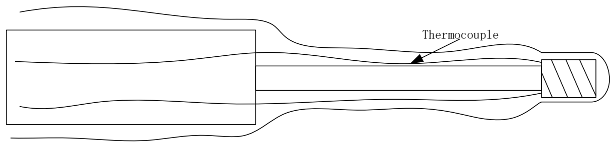

Fig 1. Thermocouple structure of polar needle for RFA

2. Sampling Circuit Design

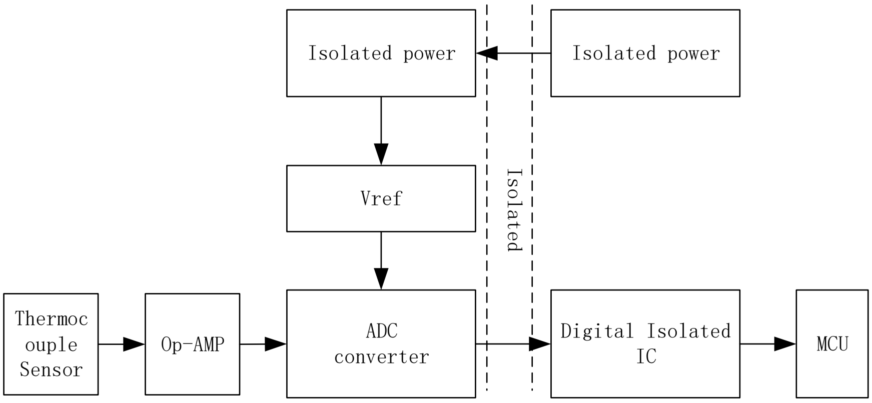

Fig 2. Block diagram of temperature sampling circuit

As shown in Figure 2, the high-voltage sampling is done on the high-voltage side and then transmitted via digital signals (e.g., SPI), and the isolation is done through the digital signal transmission. There are many manufacturers of digital isolation chips to choose from, such as TI, ADI, Silicon Labs. Here, the direction of the digital signal must be taken into account in order to select the correct number of forward and reverse channels.

A thermocouple is used as the temperature sensor, and the sensor signal is amplified by an op-amp, which is captured by the ADC. ADS1255 is used for high precision sampling and ADUM1412 is used as the digital isolation chip.

The thermocouples used in this paper measure temperatures in the range of 0 to 200 degrees Celsius and generate a corresponding thermopotential in the range of 0 millivolts to 20 millivolts. Considering that the integrated IC is more reliable, using the internal amplifier of the ADS1255 is a better choice. However, the lowest measurable voltage inside the ADS1255 is 78.125 mV, so it is necessary to amplify 20 mV to 78.125 mV with a magnification of 3.90625 times. In the design, it is difficult to find a fixed resistor value to match the gain, and it is necessary to use an adjustable resistor to match the gain.

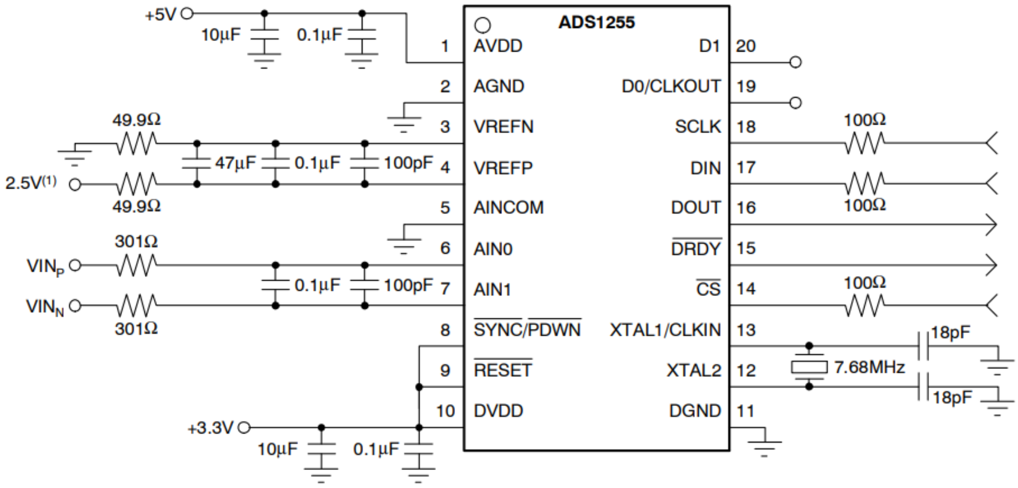

Fig 3. ad1255 circuit schematic

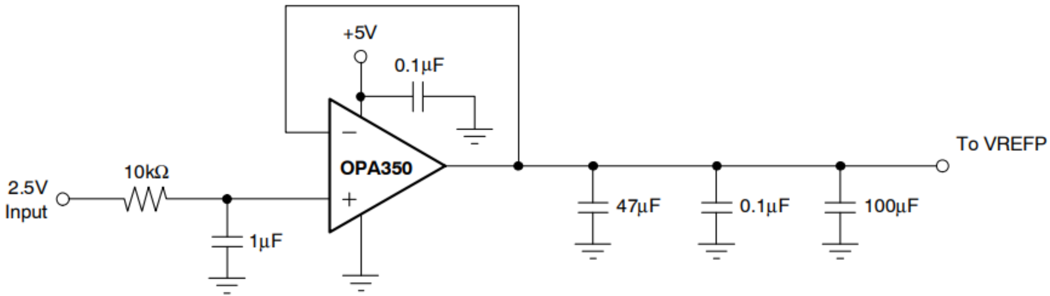

Fig 4. Schematic of reference voltage acquisition for ADC

Table 1. Gain of the ad1255 internal amplifier

PGA SETTING	FULL-SCALE INPUT VOLTAGE VIN (1) (VREF = 2.5V)
1	±5V
2	±2.5V
4	±1.25V
8	±0.625V
16	±312.5mV
32	±156.25mV
64	±78.125mV

3. Filtering Algorithm Design

Temperature signal is not high frequency, it is more appropriate to use the median filtering algorithm. The median filtering method refers to the method of continuously collecting multiple data in one cycle, arranging the data according to size, and taking the median value as the valid value. This method can effectively remove the occasional pulse noise, and is not applicable to flow, speed and other fast-changing signals. The data is sampled N times continuously (generally N is an odd number), and the N sampled values in the cache are arranged according to the size, and the middle value is taken as the final value output. The data in the cache must be arranged using the bubbling algorithm, which treats the cache as an array N. There are m samples in the array. There are m samples in the array (m ≥ 2 and odd). N [0] denotes the first sample value, N [1] denotes the second sample value, and so on, N [m-1] denotes the mth and last sample value. The details are as follows.

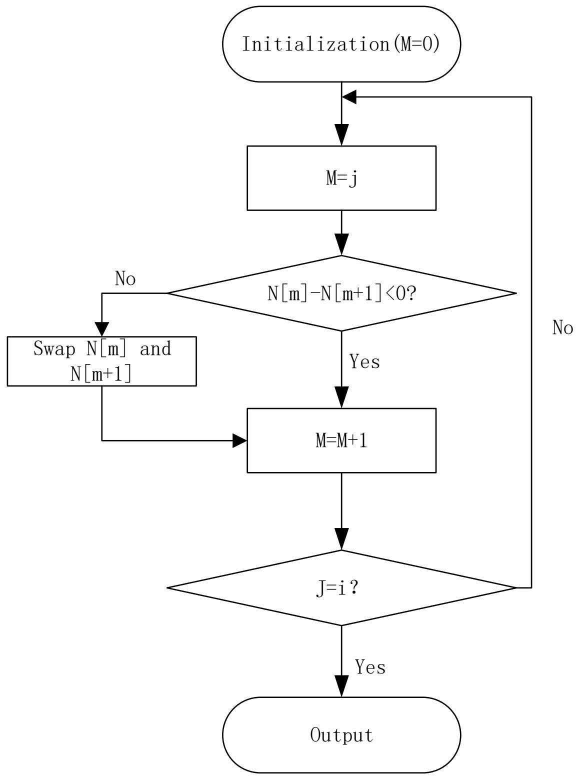

Fig 5. Flowchart of median filtering algorithm

4. System Test

Although a high-precision ADC chip is used, the existence of errors cannot be completely avoided. Multiple point tests are collected and the error is finally fitted into a curve function. To ensure that the MCU can obtain a high-precision temperature value, this curve function is loaded into the software code in the MCU and then calibrated. After calibration, the parameters are obtained as shown in Table 2.

Table 2. Temperature tests (after filtering and error correction)

Acquired temperature (°C)	Error (°C)	Acquired temperature (°C)	Error (°C)
0	0.8	110	0.3
20	0.2	120	0.4
40	0.3	140	0.3
60	0.2	160	0.6
80	0.2	180	0.5
100	0.3	200	1.1

As can be seen in Table 1, the 0 degree and 200-degree acquisition errors are larger, i.e., the errors are larger at the limits. This is because their actual ADC acquisition value is close to the reference voltage. For example, since the output voltage at 0 degrees Celsius is 0 mV, which is close to the ground signal, the presence of ground noise leads to a large error in the test. Except for the two extreme points, the accuracy is within 1°C, which is quite high.

5. Conclusion

Higher accuracy temperature values can be obtained by using a 24-bit high precision ADC sampling chip (ads1255). However, the filtering algorithm is still required. The median filtering algorithm can effectively eliminate and suppress the noise, and the data is stable and accurate. At the same time, the error point must be adjusted by software correction. Through the above method, it realizes the completion of high-precision measurement with low-cost sensors and acquisition equipment.

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