Design of the Thermistor Tester based on MSP430

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Abstract

With the development of the single-chip microcomputer and integrated circuits, thermal resistance tester has gradually replaced the traditional temperature test equipment. The design uses the low power consumption MSP430 microcomputer as the core processor, heating power is produced by the switch tube FSDM0565RB, EMI filters is joined in the switch power supply in order to inhibit the influence of high frequency interference in AC power network on the equipment. Ref voltage of microcomputer generates through the transformation of voltage conversion chip AMS1117, signal input port uses voltage follower to minimize signal noise. The system circuit also joined some protection circuit, prevention of circuit false operation, etc. In the software design, measuring resistance judgment is achieved through the difference value of comparison measuring and standard resistance, which can shorten measure time and is very suitable for batch into production. Test results show that the thermal tester has a good stability and reliability, and meet the requirements of design.

Keywords: Microcomputers, thermistors, Switching mode, power supplies, filters

1. Introduction

With the development of electronic technology and the wide application of thermistor, it is the popularity of measuring instruments for ultra-low power consumption single chip microprocessor and thermistor sensor [1, 2], which have a significant impact on the industrial economy and people's daily life. The measuring instrument circuit of traditional methods is complexity, cost is high, and many components in circuit directly affect the measurement accuracy.

The design is thermal resistance test equipment, which mainly based on MSP430F5 series single chip microcomputer [3]. General resistance measurement methods have R-V switching voltage measurement method and R-C transformation frequency measurement, but circuits are complexity and cost are high in these methods. The most application is the bridge measurement method [4-6], but debugging is more complex. It can avoid the inconvenience and less dependence on the external environment by using the comparison method to measure the thermal resistance measurement.

MSP430F5 series single chip microcomputer is applied for the main chip processing in the design [7, 8]. According to the design requirements, standard thermal resistor is used for temperature sensor. When the temperature reaches test temperature 150°C, fan works to cool the measuring system and the temperature measurement control system starts to sample at the same time. The main task of design is realizes the comparison measurement between treatment thermistor and standard thermistor, then, the accuracy is controlled according to the difference of judgment. The main hardware circuits have switch power, signal input circuit, single-chip microcomputer control circuit, 3.3 v voltage conversion circuit several parts.

2. System Hardware

2.1 MSP430 Single Chip Microcomputer Interface Circuit Design

The MSP430F5 series single chip that developed by TI company is a 16-bit super-low power consumption mixed signal processor [9, 10]. MSP430 is composed of a high gain reverse amplifier used for oscillator, fine-tuning capacitor size in the circuit will affect the oscillator frequency, the stability of the oscillator and the quickness of start up, therefore, capacitor is selected 22 pF under. Crystal oscillator frequency is 20 MHz. P5.0, P5.1 are reference voltage sides, C53, C54 are filter capacitance with 1μF that are used to stable reference 2.5 v voltage and ensure accuracy of transformation. MSP430 reset uses the most simple external key reset circuit to realize, single chip microcomputer interface circuit design is shown in Figure 1.

Figure 1. Design of Microcomputer Interface Circuit

2.2 Thermistor Signal Input Circuit

In the design, the op-amp selects LM358 and uses ± 5 v power. ADC12 kernel is one of 12 A/D converter and be able to store results in the transform memory, the kernel uses two programmable reference voltage to define converter maximum and minimum value. When the analog voltage input is higher than or equal 2.5 v, the ADC12 output is full scale value 0XFFF. ADC12 output is zero when the input voltage is equal or less than 0 v. The final conversion results of input analog voltage satisfy the formula:

$$N_{ADC} = 4095 \times \frac{V_{in} - V_{r-}}{V_{r+} - V_{r-}}$$

In the system software programming, the reference voltage selects $V_{r+}=2.5$ v, $V_{r-}=0$ v, the V_m should satisfy $0 < V_m < 2.5$, namely, $3.3 \times R_{28} / (R_{26} + R_{28}) < 2.5$ V, $3.3 / (R_{26} / R_{28} + 1) < 2.5$, $R_{26} > 0.32 R_{28}$. Due to the test minimum temperature of the thermistor under test is $50 \pm 1^\circ\text{C}$, thermistor resistance maximum is 148.6 K Ω at this time, so $R_{26} \Omega = 51$ K Ω . Thermistor signal input circuit design is shown in Figure 2.

Figure 2. Design of Thermistor Signal Input Circuit

Here, the R25 and R26 are protection resistance, resistance are $100\text{ k}\Omega$. R22, R23 and C110, C111 constitute a low-pass filter to ensure that the input signal is effective.

2.3 Fan and Electric Heating Control Circuit

P4 and P5 are two 3 pin plug and used to install the fan and heater, respectively. K1 and K2 are two relay parameters, relay is controlled by switch circuit composed of P1.0, P1.1 and triode, control circuit is shown in Figure 3.

Figure 3. The Control Circuit

2.4 The LCD Display Circuit

LCD display circuit is shown in Figure 4, U17、U18 are two pieces of LCD driver chip, respectively, P7 is the LCD display.

Figure 4. LCD Display Circuit

2.5 Switching Power Supply

Switching power supply uses pulse width modulation in the system, switching frequency is 50 KHz. Rated input voltage is 220-240V 50/60Hz, DC output +5 v, +24 v, -5 v supply for fan, heater and op amp, respectively, power is 50 w.

2.5.1 The Input Circuit of Switching Power Supply

Input circuit including insurance circuit, low pass filter and rectifier filter circuit several parts, as shown in Figure 5. Insurance circuit is composed of F1 insurance tube that fusing rapidly when the insurance tube current exceeds rating 5 A to prevent the circuit components damaged due to overheating.

Figure 5. The Input Circuit of Switch Power

Here, TNR1 is varistor, EMI filter circuit consists of C1, R1, R2, L1, CX, CY1, CY2. CY1, CY2 can inhibit the surge current and protect diode. D1 is rectifier bridge pile and constitutes a bridge rectifier circuit. C2 is the power filter capacitor, rectifier filter circuit directly rectifier, filter for 220 v, 50 Hz AC voltage into about 300 v DC voltage.

2.5.2 Pulse Oscillation Circuit

Pulse oscillation circuit including switching transformer primary winding, adjust tube, starting circuit, oscillating circuit, pulse width adjustment, error amplifier circuit, *etc.*, is mainly composed of three loop circuits. Figure 6 is a simplified circuit of the pulse oscillation circuit, the switch tube FSDM0565RB, switch transformer T1, capacitor C7 composed of oscillation circuit, which function is produce high frequency oscillation and output rectangular pulse.

Figure 6. The Simplified Diagram of Pulse Shock Circuit

2.5.3 The Output Circuit of the Switch Power Supply

The output circuit of the switch power supply is shown in Figure 7, 7-8, 9-10, 11-12 are secondary output winding of the switch transformer, C10, L10, C14 composed of Π type filter and change the high frequency pulse of high frequency rectifier output into a smooth DC. Because it is the high frequency filter, filter element value and volume are small.

The switch tube during exit saturation to stop, the same name end of the switch transformer secondary winding will change potential to make the rectifier diode D10, D11 positive conducting, the magnetic energy of secondary coil 7-8, 11-12 can be converted into electrical energy and supply power to the load, and charging for C10, C11 at the same time. During the switch tube saturation and conductivity, the induced voltage of secondary coil 7-8, 11-12 makes D10, D11 cut-off, C10, C11 capacitor began to discharge and supply power to load through the accumulation energy.

Figure 7. The Output Circuit of Switch Power

2.5.4 Voltage Control Circuit

It can be included from $U_0 = (T_1/T) \times U_i$, the high and low of the output voltage can be adjusted as long as the adjust switch pulse duty ratio, namely the control switch tube conduction time. The longer switch tube conduction, the higher the output voltage, the lower conversely. Voltage control circuit is mainly composed of sampling comparison, error amplifier, pulse width adjustment and other parts, which is shown in Figure 8.

Figure 8. The Stabilized Voltage Control Circuit

Resistor R5, R6 constitutes the voltage sampling circuit and TL431, PC817 constitutes voltage comparison circuit, TL431 is integrated voltage regulator block which has three terminals are reference terminal R, anode, A cathode K, respectively. It uses shunt voltage method, namely anode terminal grounding, the reference voltage terminal connects R5 partial pressure, the cathode terminal connects photocell as adjustment terminals. The output of voltage value is:

$$V_{out} = (1 + \frac{R_5}{R_6}) \times U_{Ref}$$

Because the circuit requires stable 5 v voltage value: R5=R6=1.2 KF. The R5 partial pressure is input of the sampling voltage.

3. System Software

System software design mainly includes: main program module, the basic time delay module, clock setting module, AD conversion module, LCD display module, etc. System is firstly initialized, mainly is the chip initialization, the initial time of clock circuit is set up, waiting for buttons command through the query way, the entire system begins to work if the button is pressed. For programming, the main program mainly realize the comparison of the sampling data, display control, key control, collection complete judgment, data archiving, etc. The main program flow chart is shown in Figure 9.

Figure 9. The Flow Chart of Main Program

3.1 The Timer Interrupt Program

Interrupt time interval is controlled by timer A, an interrupt is generated every 240 ms, A/D conversion samples once until the complete of 64 data acquisition. Interrupt cycle produces program is followed:

```

void Timer1Init(void)
{TA1CTL |= MC_1+MC_2 + TASSEL_2;
 TA1CTL |= ID_2;
 TA1CCR0 = 0xEA60;
 CLRB(TA1CTL,TAIFG); TA1CTL |= TAIE;
 __bis_SR_register(GIE);}
Interrupt entry procedures are follows:
#pragmavector=TIMER1_A1_VECTOR
__interrupt void Timer1(void) { }
    
```

3.2 The Heating Module Settings

After the port initialization, the main program comes into the heating module to heat thermistor. The heating temperature is 180 °C. When the thermistor resistance is heated to 180 °C, thermistor is 7 kΩ and the MCU voltage value is: $u=3.3/(50+7) \times 7=0.405v$, $NADC=4095 \times 0.405/2.5=73.71=0X49$. Procedures is follows:

```

do { P2OUT |= 0X01; }
while(ADC12MEM1 < 0X49);
P2OUT |= 0X00;
P2OUT |= 0X02;
    
```

Here, P2.1 is heating control port and effective at high level, ADC12MEMI is temporary address of AD conversion A0 data. When heating temperature reaches 180 °C, fans began to heat dissipation and measure.

3.3 The Data Processing Program

When interrupt data acquisition reaches 64 group, processing program starts to average 64 data. Because the temperature difference control of the thermistor can affect on the fixing system control when it is more than 4 °C, the resistance of the temperature difference 4 °C is 500 Ω. Accuracy control functions:

$$d_{\text{精度}} = \frac{3.3(\Delta + 0.5)}{50.5 + \Delta} - \frac{3.3\Delta}{50 + \Delta}, \quad d_{\text{精度}} = \frac{82.5}{\Delta^2 + 100.5\Delta + 2525},$$

Here, Δ is the thermistor resistance under 50 °C~180 °C. The smaller d value, the higher control precision. When the voltage difference value is 0.006 v through calculation, the resistance is judged as NG, $\Delta \text{ NADC} = 4095 \times 0.006 / 2.5 = 9.8 \approx 10 = 0\text{XA}$. Procedures is follows:

```
while(1){
    if (nADC_Flag )
    {nADC_Flag=0;
    for (i=0;i<64;i++)
    {pBuf_1[i]=ADC_BUF_Temp_1[i];
    pBuf_2[i]=ADC_BUF_Temp_2[i]; }
    sum_1=0; sum_2=0;
    for(i=0;i<64;i++) {sum_1+=pBuf_1[i];
    sum_2+=pBuf_2[i]; }
    sum_1 >>= 6; sum_2 >>= 6;
    fval=(float)(sum_1-sum_2);
    if (fval<0) fval = -fval;
```

4. Conclusions

Before drawing PCB, all components encapsulation need to be added Some packaging can be directly found in Protel standards component library, but some components encapsulation need to be drawn, such as FSDM0565RB, PC817, TL431, T2834, ASM1117 and single chip microcomputer MSP430F5438 and so on.

PCB can be drawn after encapsulation are added into schematic diagram. Circuit board adopts double, the size and shape of the circuit board should be considered. The automatic wiring easys to cause the interference of high frequency on signal lines, if the top and the bottom line are parallel, capacitive coupling is easiley conduced and lead to signal interference. Design uses manual wiring, and the simple circuit part adopts automatic wiring, PCB circuit board is shown in Figure 10.

Figure 10. PCB Circuit Board

In the design, thermal resistance tester is a kind of high precision, wide range high speed impedance measurement instrument. Thermal resistance tester based on single chip

microcomputer reading is convenient and precision is high. The thermal resistance tester has high measurement precision, fast speed, wide range, *etc.* At any scale range, it has the same test speed and stable performance.

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