The Design of Intelligent Temperature Controller Based on AT89C51

BaoYi Wang\textsuperscript{a}, Tingqi Yan\textsuperscript{b, *}
School of Shandong University of Science and Technology, Shandong 266590, China.
\textsuperscript{a}1140152689@qq.com, \textsuperscript{b, *}837885467@qq.com

Abstract: This article mainly introduces the application of 51 SCM in intelligent temperature control. First of all, it outlines the design plan and content requirements, further defines the design direction and provides clear design ideas. In the second chapter, some necessary chips and software used in this design are introduced in detail, including MCU AT89C51, LED driver 74LS47, 8-bit latch 74LS373, and Proteus and Keil uVision4 software. And introduced some important circuits, including temperature sampling circuit, temperature display circuit, oscillation circuit, key switch circuit, reset circuit and so on. The third chapter mainly introduces the design idea and the programming of the program.

Keywords: A/D conversion circuit, temperature display circuit, temperature input circuit, driving circuit.

1. Introduction

The intelligent temperature controller mainly consists of single chip, time series circuit, temperature sampling circuit, A/D conversion circuit, temperature display circuit, temperature input circuit, driving circuit and so on.

This design takes the MCS-51 Series SCM as the core, uses the common electronic device design, a power switch, two control temperature setting keys (increase / decrease), four-digit digital tubes display set temperature and actual temperature respectively, the range is 0~99 degrees, and the set temperature value is initialized to 88 degrees after opening the power switch. The key input is interrupted, and the two keys are connected to INTO and INT1 respectively. Using a temperature sensor for temperature measurement, analog-to-digital conversion using ADC0808. The microcontroller controls the operation of the relay J according to the set temperature T0 and the measured temperature T1, and the dead zone is set to 2 degrees: When \( T1 \leq T0-1 \), control J turns on the electric heating circuit;
When $T_1 > T_0 + 1$, control $J$ disconnects the electric heating circuit;  
When $T_0 - 1 < T_1 \leq T_0 + 1$, $J$ remains unchanged.

### 2. System Hardware Design

#### 2.1 Introduction of Single Chip Microcomputer and Software

##### 2.1.1 Overview of C51 Microcontroller

AT89C51 is a low voltage, high-performance CMOS 8-bit microprocessor with 4K byte scintillable, erasable read only memory, commonly known as single chip microcomputer. The single-chip eraseable read-only memory can be erased 100 times repeatedly. The device is manufactured using ATML high density nonvolatile memory manufacturing technology, compatible with the industrial standard MCS-51 instruction set and output pins. Due to the combination of a multi-function 8-bit CPU and flash memory in a single chip, ATML’s AT89C51 is a highly efficient microcontroller. The AT89C microcontroller provides a highly flexible and inexpensive solution for many embedded control systems. The outline and pinout are as follows:

![AT89C51 Single Chip Pin Diagram](image)

**Fig 1. AT89C51 single chip pin diagram**

Pin description:

- **VCC**: Supply voltage
- **GND**: Ground
- **P0 mouth**: P0 port is an 8-bit open-drain bidirectional I/O port that can sink 8 TTL gate currents per pin. When pin P0 is written for the first time, it is defined as a high-impedance input. P0 can be used for external program data memory. It can be defined as the eighth bit of data/address. In the FLASH programming, P0 port as a source input; When the FLASH is verified, the P0 port outputs the source code. At this time, the external port P0 must be pulled high.
P1 mouth: P1 port is an 8-bit bidirectional I/O port with internal pull-up resistor. P1 buffer can receive 4 TTL gate currents. After P1 port pin is written to 1, it is internally pulled high and can be used as an input. When P1 port is externally pulled down to a low level, the current will be output. This is due to the internal pull-up. In FLASH programming and verification, P1 port is received as the eighth address.

P2 mouth: P2 port is an 8-bit bidirectional I/O port with an internal pull-up resistor. P2 port buffer can receive 4 TTL gate currents. When P2 port is written to 1, its pin is pulled up by internal pull-up resistor. And as an input, it is pulled low externally to output current. When the P2 port is used for accessing an external program memory or a 16-bit external eight-bit data memory, the P2 port outputs the upper eight bits of the address. When address 1 is given, it utilizes an internal pull-up advantage. When reading and writing to the external eight-bit address data memory, the P2 port outputs the contents of its special function register. The P2 port receives high eight address signals and control signals during FLASH programming and verification.

P3 mouth: P3 port pins are 8 bidirectional I/O ports with internal pull-up resistors that can receive 4 TTL gate currents. When port 1 is written to P3, they are internally pulled high and used as inputs. Because the external pull-down is low, P3 will output current.

2.1.2 Protues and Keil uVision4 Overview

Proteus software is the EDA tool software published by Lab Center Electronics of the United Kingdom (the software distributor in China is Guangzhou Electronic Standard Technology Co., Ltd.). It not only has the emulation function of other EDA tool software, but also can emulate MCU and peripheral devices. It is a better tool for emulating microcontrollers and peripheral devices. Although the current domestic promotion has just started, it has been favored by microcontroller enthusiasts, teachers engaged in SCM teaching, and scientific and technical workers dedicated to the development and application of SCM.

The use of Proteus software for MCU system simulation and design is a comprehensive application of virtual simulation technology and computer multimedia technology, which is conducive to the training of students' circuit design capabilities and simulation software operating capabilities; in the single-chip curriculum design and national undergraduate electronic design competition, we use the Proteus development environment to train students. Without the need for hardware investment, students generally report that learning a single-chip computer is easier to accept and easier to learn than simply learning a book. Practice has proved that after the successful development of system simulation using Proteus, the actual production can greatly improve the efficiency of the SCM system design.
Keil C51 is a 51-series compatible single-chip microcomputer C language software development system produced by Keil Software of the United States. Compared with assembly, C language has obvious advantages in terms of function, structure, readability, maintainability, and it is easy to learn and use. Keil provides a complete development program including a C compiler, macro assembler, linker, library management, and a powerful emulator debugger. These parts are combined in an integrated development environment (μVision). Running Keil software requires WIN98, NT, WIN2000, WINXP and other operating systems.

Keil uVision4 was released in February 2009, and Keil uVision4 introduces a flexible window management system that allows developers to use multiple monitors and provides a visual surface to any place where the window position is fully controlled. The new user interface can make better use of screen space and organize multiple windows more efficiently, providing a clean, efficient environment for developing applications. The new version supports more recent ARM chips and adds some other new features.

### 2.2 A/D Conversion Circuit

#### 2.2.1 ADC0809 Introduction

The ADC0809 is an 8-bit full MOS medium-speed A/D converter. It is a successive approximation A/D converter with on-chip three-state data output latches that can be directly interfaced to the microcontroller. Its main pin function is as follows:

1. **RD, WR**: Read strobe signal and strobe signal (active low).
2. **CLK**: clock pulse input, rising effective.
3. **DB0-DB7**: Input signal.
4. **CLKR**: The external clock resistance of the internal clock generator, which can be used by the chip itself to generate a clock pulse with the frequency of 1/1.1RC.
5. **CS**: Chip select signal input, active low, once CS is active, indicating that the A/D converter is selected and can be started.
6. **WR**: Write signal input, accept the start input of the microcomputer control system or other digital system control chip, active low, CS, WR is low at the same time, start conversion.
7. **INTR**: the end of the conversion output signal, active low, the output low indicates that the conversion is complete. This signal is often used as an interrupt request signal to the microcomputer system.
8. **CLK**: External clock input, high clock frequency, fast A/D conversion speed. The allowable range is 10-1280KHZ, and the typical value is 640KHZ. Currently, the A/D conversion time is 10us. Normally, the ALE of the MCS-51 microcontroller is connected directly or after frequency division. When the MCS microcontroller and read and write,
RAM operation, ALE signal is fixed at 1/6 of the CPU clock frequency, if the monolithic external crystal oscillator is 6MHZ, then 1/6 is 1MHZ, A/D conversion time is 64us.

2.2.2 A/D Conversion Circuit Working Principle
Two analog signal input terminals of ADC0809 are used to accept unipolar, bipolar and differential-mode input signals. At the same time as WR, the low-level A/D converter is started and switched to complete 100 modulo conversions after the rising edge of WR. The result of the conversion is stored in the data latch. At the same time, INTR automatically goes low, indicating that the conversion has ended. If CS and RD go low at the same time, the three-state gate of the data latch is opened, the digital signal is sent out, and the three-state gate is in a high-impedance state after the high level of RD arrives.

![A/D conversion circuit](image)

Fig 2. A/D conversion circuit

2.3 Temperature Sampling Circuit
2.3.1 Platinum Resistance (Pt100) Temperature Sensor
When the PT100 is at 0 degrees Celsius, its resistance is 100 ohms, and its resistance will increase as the temperature rises to an approximately uniform speed. However, the relationship between them is not a simple and proportional relationship, but more should be a parabola.
2.4 Press the Switch

Set buttons (increase/decrease). The four digits display the set temperature and actual temperature respectively. The range is 0~99 degrees. After the power switch is turned on, the set temperature is initialized to 88 degrees. The key input is interrupted. The two keys are connected to INT0 and INT1 respectively.

2.5 Temperature Display Circuit

2.5.1 Led Driver

74LS47 Description: 74LS47 is a BCD code into a 7-segment LED digital decoder driver IC, 74LS47’s main function is to output low-level drive display code to promote the
common anode 7-segment LED digital display corresponding figures. The corresponding pin function is as follows:
(1) QA, QB, QC, QD, QE, QF, QG: 7-segment LED digital output pins.
(2) A, B, C, D: Input pins.
(3) RBO, BT, LI High level output is valid.

2.5.2 Operating Principle of Temperature Display
It consists of two TTL74LS47 and two 7-segment LEDs. The LED uses a common anode connection. QA-QG of 74LS47 connects to a-g of BCD. Segment selection signal is provided by P1 port of 8051. LED display data is determined by the output of 74LS47, which is determined by the value of P1 port signal.

2.6 Thermal Resistance Driving Circuit
Thermal resistance drive control, the pin of P3.0 of 89C51 relates to the pin of ULN2003A, the control signal sent from P3.0 arrives at the electromagnetic relay through ULN2003, driving the running and stopping of thermal resistance. ULN2003 is a series of Darlington transistor arrays with high voltage and high current. It features high current gain, high operating voltage, wide temperature range, and strong load capacity. It is suitable for all types of systems that require high-speed and high-power drive.
ULN2003 is composed of 7 Darlington transistors with 7 NPN's high-voltage output characteristics with common cathode clamping to convert the inductive load. The current pair of single-precision models have a rated current of 500mA and a relatively high current capacity. Its application software includes relay drivers, display drivers, line drivers, and logic buffers. The role in this drive circuit is to increase the current drive capability. The chip uses a 16-pin DIP package. The 9th one is the common output COM. One output is high and COM is high.

2.7 Microcontroller Auxiliary Circuit Design
2.7.1 Design of Reset Circuit
The reset of the microcontroller is the same concept as the restart of the computer. Any microcontroller must have a reset process before it works. Reset For the microcontroller, the program has not started execution and is doing preparation. Reset operations usually include: power-on reset and push-button reset. The power-on reset is an external reset circuit that directly operates the microcontroller after the system is powered on, and the microcontroller starts and stops through the power supply control. Manual reset is the design of the key switch in the reset circuit trigger reset level, control the microcontroller reset. The working principle is: when the MCU is powered on, both ends of the capacitor are short-circuited, then the RST pin is high level, and
then the power is charged by the electronic capacitor. The voltage at both ends of the RST is gradually reduced, and dropped to a certain degree, that is, low power. Ping, the microcontroller began to work. Power-on reset time should be more than 10ms to ensure power-up. Generally, the size of the capacitor is 10μF and the resistance is 10 kΩ.

2.7.2 Oscillation Circuit
The oscillation circuit is very important for the microcontroller. Without the crystal oscillator, there is no clock cycle. Without a clock cycle, the program code cannot be executed and the microcontroller cannot work. When the microcontroller is working, instructions are fetched from the ROM one by one, and then executed step by step. The microcontroller has a high-gain inverting amplifier that is used to construct an on-chip oscillator. Pins XTAL1 and XTAL2 are the input and output of the amplifier. This amplifier, together with an off-chip quartz crystal (or ceramic oscillator) as the feedback element, constitutes a free-running oscillator, as shown in Figure 3-4. In the figure, an external quartz crystal (or ceramic oscillator) and capacitor C1 or C2 form a parallel oscillation circuit, which is connected to the feedback loop of the amplifier. There is no strict requirement on the size of the capacitor, but it will also affect the oscillator frequency, the stability of the oscillator, the rapidity and stability of the start-up. External quartz crystal, C1 and C2 generally go 30pf-10pf, external ceramic oscillator, C1 and C2 generally take 40pf-10pf. The system uses a 12MHz crystal and the capacitance is 30pf.

2.8 8-Bit Latch 74LS373
The outputs 373 of Q373 can be directly connected to the bus. When the three-state allowable control terminal OE is low, Q0 to Q7 are normal logic states that can be used to drive the load or the bus. When OE is high, Q0~Q7 is in a high-impedance state, that is, it does not drive the bus nor the load of the bus, but the logic operation inside the latch is not affected. When the latch enables LE is high, Q varies with data D. When LE is low, D is latched at the established data level. When the Schmitt trigger input at the LE side lags, the AC and DC noise immunity is improved by 400mV.

3. System Software Design
3.1 Software Design Ideas
Software design tasks include starting A/D conversion, reading A/D conversion results, setting temperature, temperature control, etc., in which start A/D conversion, reading A/D conversion results, temperature control, etc. are completed in the main program, setting the temperature is completed in the interrupt service routine, and the control
signal is given based on the comparison result, so that the thermal resistor runs or stops and the temperature regulation is realized.

3.2 Programming

ORG 0000H
JMP START1
ORG 0003H
LJMP INTER1
ORG 0013H
LJM INTER2
ORG 0100H
START1: MOV SP, #60H
SETB IT0
SETB IT1
MOV IE, #85H
ANL P1, #00H
MOV P1, #26H
LCALL START
LCALL C1
LJMP $ 
ORG 0200H
INTER1: PUSH ACC
PUSH PSW
CLR C
LCALL DELAY
A1: JB P3.2, A1
SET1: LCALL DELAY
MOV A, P1
ANL A, #0FH
INC A
MOV 30H, A
MOV A, P1
ANL A, #0F0H
ADDC A, 30H
DA A
MOV P1, A
POP PSW
POP ACC
RETI
ORG 0300H
INTER2: PUSH ACC
PUSH PSW
CLR PSW.6
A2: JB P3.3, A2
SET2: LCALL DELAY
MOV A, P1
ANL A, #0FH
SUBB A, #01H
JB PSW.6, Q0
MOV 35H, A
MOV A, P1
ANL A, #0F0H
ADD A, 35H
JMP Q1
Q0: MOV A, P1
ANL A, #0F0H
CLR C
SUBB A, #10H
JC Q2
ADD A, #09H
JMP Q1
Q2: MOV A, #99H
Q1: MOV P1, A
POP PSW
POP ACC
RETI
START: MOV R1, #20H
MO VX @DPTR, A
WAIT1: JB P3.1, WAIT1
WAIT2: JNB P3.1, WAIT2
MO VX A, @DPTR
LCALL BINBCD1
MO V @R1, A
MO V P0, A
RET
ORG 0400H
4. Conclusion

1. ADC0809 is an 8-bit full MOS medium-speed A/D converter. It is a step-by-step A/D converter. There are three-state data output latches on the chip and can be directly connected to the microcontroller.

2. The resistance of the platinum resistance temperature sensor will increase as the temperature rises to approximately uniform speed. The relationship between them is not a simple proportional relationship, but more should tend to a parabola.
3. The key input is interrupted. The two keys are connected to INT0 and INT1 respectively.

4. 74LS47 is a decoding driver for converting a BCD code into a 7-segment LED digital tube.
   The LED display data is determined by the output of 74LS47, which is determined by the value of the P1 port signal.

References


