Experimental Design of Temperature Adjustment Based on PWM of STC15 Microcontroller

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Abstract: In order to meet the teaching needs, the experimental design of temperature regulation based on PWN of STC15 microcomputer is designed to teach the application and temperature control principle of single-chip microcomputer. The system uses the STC15 microcontroller to monitor the temperature value in real time through the NEC protocol, and uses the PWM function to adjust the heater power to control the temperature accurately. The experiment uses two STC15 microcontrollers with infrared transceiver modules, allowing students to communicate between devices via CAN bus. At the same time, the single-chip microcomputer is also connected to the PC side, uploading temperature data and control results to the PC side, and receiving instructions and management messages issued by the PC for monitoring and operation, thereby driving temperature control experiments and viewing experimental results. Real-time, flexible and easy to operate, the system can effectively assist teaching and provide a platform for communication and collaboration between students and teachers.

Keywords: STC15 Microcontroller; CAN Bus; PWM; NEC Protocol

1. Introduction

In recent years, with the continuous expansion and development of the application field of single-chip microcomputer, the teaching demand for single-chip microcomputer application and temperature control principle is also increasing. In order to meet this demand, this paper designs the experimental design of PWM temperature regulation based on STC15 microcontroller, aiming to demonstrate the application of microcontroller in temperature control to students through practical application cases. The system uses the STC15 microcontroller to monitor the temperature value in real time through the NEC protocol, and precisely adjust the heater power through the PWM output function, so as to achieve precise temperature control. In this lab, two STC15 microcontrollers are combined with infrared transceiver modules to enable students to communicate between devices through the CAN bus. In addition, the system is also connected to the PC, which can upload temperature data and control results to the PC, and receive instructions and management messages issued by the PC to realize monitoring and operation. With this design, students can not only conduct temperature-controlled experiments, but also easily view the results of experiments and communicate and collaborate.

2. System Structure design

The PWM temperature regulation experimental design based on STC15 microcomputer is mainly composed of two STC15 test chambers, 4*4 matrix keyboard, NTC thermistor, infrared module, AD data acquisition module, and heater, as shown in Figure 1.

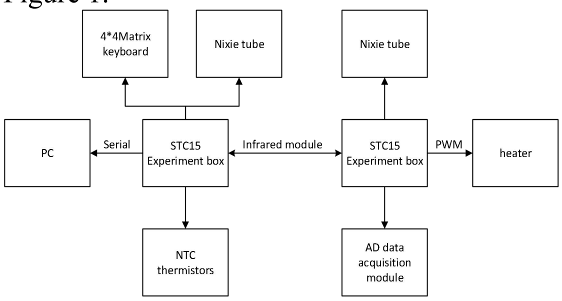

Figure 1. System Structure Diagram

No. 1 single-chip microcomputer uses NTC thermistor to measure temperature, and through low-pass filtering to smooth denoising the data, the filtered data is displayed on the digital tube, when the temperature exceeds the set threshold (the temperature threshold defaults to 28 °C, if you need to modify it can be set by the 4*4 matrix keyboard), send an alarm to the PC through the serial port, and use infrared communication to send the serial port data to the No. 2 single-chip microcomputer.

The No. 2 single-chip microcomputer will display the received infrared data on the Nixie tube and return the signal whether to accept success, and use the received data to adjust the duty cycle of PWM to control the heater power, and use the ADC to read the PWM and display it on the Nixie tube. The PC side can adjust the PWM of the heater and adjust the ambient temperature by sending instructions to the MCU.

3.Implementation of Each Part of System

3.1 Experimental Equipment Interface Driver

The equipment for this experiment is two STC15 development boards. The IAP15W4K58S4 development board consists of individual functional modules, and the module library that unifies each functional module is defined as a header file <intrins.h>, which includes functions of different experimental modules and register configuration addresses.

In this experiment, CAN single-line communication is mainly used. The CAN bus works by transferring data through electromagnetic coupling. Data transmission between nodes is one-way communication, that is, data can only be received from the sender. If you want to send data, you need to establish a transmission line between the nodes and send the data through the controller. CAN buses use unidirectional communication, and CAN buses can be easily expanded because they only require one cable to connect multiple nodes.

signal	ISO11898(High Speed)					
	recessive (1)			dominant (0)		
	Minimum	typical value	Maximum	Minimum	typical value	Maximum
CAN_High (V)	2	2.5	3	2.75	3.5	4.5
CAN_Low (V)	2	2.5	3	0.5	1.5	2.25
High-low PD (V)	-0.5	0	0.05	1.5	2	3
signal	ISO11898(Low Speed)					
	recessive (1)			dominant (0)		
	Minimum	typical value	Maximum	Minimum	typical value	Maximum
CAN_High (V)	1.6	1.75	1.9	3.85	4	5
CAN_Low (V)	3.1	3.25	3.4	0	1	1.15
High-low PD (V)	-0.3	-1.5	/	0.3	3	/

Figure 2. Table of Signal Logic Represented by the CAN Bus Protocol Standard

In order to complete the required effect of this experiment, the following main communication functions are integrated to facilitate the use of the experimental module:

The serial port initialization functions are mainly data sending and receiving functions, When the serial port sends data, the data is sent from the serial send pin of the microcomputer TxD sends out.

When the host executes an instruction to write SBUF, it starts the data transmission process of the serial port, loads the SBUF signal 1 into the 9th bit of the transmit shift register, and notifies the Tx control unit to start sending. A divide-by-16 counter sends a serial bitstream synchronously.

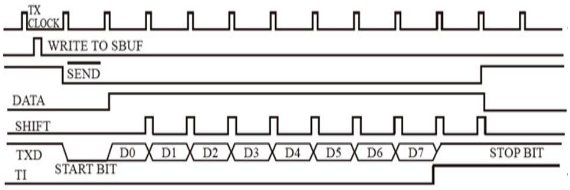

Figure 3. Serial Port Sending Process

The received data moves in from the right side of the receive shift register, moving the loaded 0x1FF out to the left. When the start bit 0 moves to the far left of the shift register, cause the RX controller to make one last shift to complete the reception of one frame.

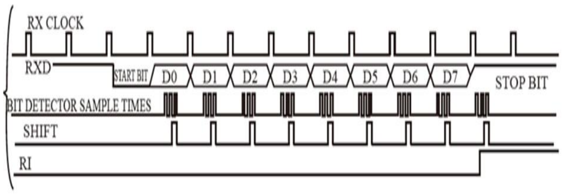

Figure 4. Serial Port Reception Process

3.2 Temperature Regulation Function

The temperature regulation function of the experiment is mainly divided into three parts: real-time temperature detection, temperature regulation, and PC monitoring. Mainly using STC15 single-chip microcomputer through NEC protocol real-time monitoring temperature value and display on the digital tube, processing temperature value information through PWM output function to accurately adjust the heater, so as to achieve accurate control of temperature, and through serial port and PC communication, to achieve control command issuance and background detection function.

3.2.1 Real-time temperature detection

The STC15 microcontroller monitors the

temperature value in real time through the NEC protocol and displays it on the digital tube. When the infrared signal transmission and reception process, need to modulate and demodulate the signal, modulation is used in the process of transmission, de-call in the process of receiving, NEC protocol is one of the infrared remote control protocol, the protocol composition consists of boot code, address code, address anticode, command code and command anticode.

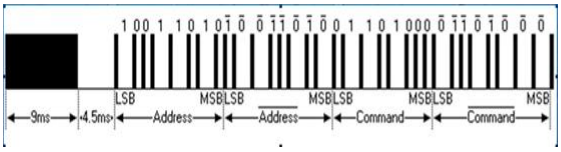

Figure 5. Schematic Diagram of NEC Protocol

NEC logical sending process:

① When the button is pressed, a falling edge is generated into the interrupt function generated by INT0, and after delay, monitor whether the IO port is high, if it is high, wait for the high level of 9ms to pass, and then wait for the low level of 4.5ms to pass

② Then receive the remaining 4 groups of 8-bit data, the remaining 4 groups first receive a high level of 0.56ms (observe logic 0 and logic 1 are starting with a high level of 0.56ms), secondly, if after 1.12ms is still low is logic "0" signal, if after 2.25ms is still low, it is logic "1"

③ Finally, the receiving end monitors whether the received data code is the same as the data reverse code, that is, the accuracy of the received data is monitored.

3.2.2 Precise temperature adjustment

Configure the CCR/PCA/PWM working mode to control the GPIO interface output duty cycle of the corresponding PWM to achieve the effect of accurately driving the motor speed. When the single-chip microcomputer detects that the temperature is too high, the motor starts at a certain speed to achieve the effect of accurate and rapid cooling.

3.2.3 PC side monitoring

The system communicates with the PC through the serial port, transmits the detected temperature information and control experimental results to the PC in real time, and receives the instructions and management messages issued by the PC for monitoring and operation, thereby driving the temperature control experiment and viewing the experimental results.

3.3 STC15 Related Register Configuration

In the experimental design of PWM temperature regulation based on STC15 microcomputer, the experimental system can monitor the temperature value in real time by properly configuring and setting the following registers, accurately adjust the heater power using the PWM function, and communicate between devices through the CAN bus. At the same time, the single-chip microcomputer connected to the PC can upload temperature data and control results, and receive instructions and management messages from the PC to realize the monitoring and operation of the experiment. The configuration of these registers provides real-time, flexibility, and ease of operation for experiments, effectively aiding teaching and facilitating communication and collaboration between students and teachers.

The following is the configuration information for the specific relevant registers:

3.3.1 Timers

In the experimental design of PWM temperature regulation based on STC15 microcomputer, the function of the timer is to control the period and duty cycle of the PWM signal, so as to achieve accurate adjustment of the heater power, and then control the temperature. The timer can trigger an interrupt or generate a periodic pulse signal by setting a specific time interval. In PWM temperature regulation experiments, the timer is configured to generate a pulse signal of a certain frequency, known as a PWM signal. The period and duty cycle of PWM signals can be controlled by adjusting the reload value of the timer and the settings of the compare/capture channel. Through the configuration and control of the timer, the experimental system can achieve precise regulation of the heater power and thus control the temperature. The role of the timer is key in this experiment, providing the basic functions for temperature control and providing real-time, flexibility, and ease of operation for teaching.

During initialization, the following registers need to be configured: TCON registers to control timers/counters T0 and T1, TMOD registers to set the operating mode of timers/counters, AUDR registers for auxiliary function configuration, IE and IE2 registers to set interrupt allows, and IP registers to control interrupt priority. For details about register configuration, refer to Table 1.

Tabel 1. Common Configuration Parameters for Timers

register	Register description
TCON register	Control registers for timers/counters T0 and T1, as well as latches T0, T1 overflow interrupt sources and external request interrupt sources
TCOM registers	The selection timing and counting functions are carried out by the control bit C/T of the special function
AUCR auxiliary registers	Used to configure and control specific functions such as timer crossover, external interrupt triggering, and UART baud rate multiplier
IE timers 0, 1 interrupt allow registers	Interrupt control for timers 0 and 1
IE2 interrupts allow registers	Interrupt control for timer 2
IP interrupt priority control register	IP interrupt priority control

3.3.2 Serial port

In the experimental design of PWM temperature regulation based on STC15 microcomputer, the function of the serial port is to realize the data transmission and communication between the microcomputer and the PC. Specifically, the serial port is used to upload temperature data and control results from the single-chip microcomputer to the PC, and receive the instructions and management messages issued by the PC. Through the serial port, the single-chip microcomputer can send the real-time monitored temperature value to the PC for users to view and analyze. At the same time, the PC can send control instructions to the single-chip microcomputer through the serial port to achieve accurate adjustment of the heater power, so as to control the temperature. The role of serial port is crucial in this experiment, which provides a data exchange channel between the single-chip microcomputer and the PC side, so that the experimental system can carry out data transmission, command control and information exchange with the PC side. Through the configuration and use of serial ports, the system has real-time, flexibility and easy operation, which can effectively assist teaching and provide a communication and collaboration platform between students and teachers.

Tabel 2. Common Configuration Parameters of Serial Port

register	Register description
Serial Control Register	Configure and control the parameters and operating modes of serial port communication
Power Control Register	Set the baud rate of Method 1, Method 2, and Method 3 to double
Auxiliary Register	Configure and control baud rate speed selection for serial communication
IE interrupt allows registers	Controls the enabling of serial port interrupts
IP interrupt priority control register	Sets the priority level of serial port interrupts
CLK_DIV registers	Configure the clock division factor for serial communication

3.3.3 PCA

In the experimental design of PWM temperature regulation based on STC15 microcomputer, the role of PCA (Programmable Counter Array) is to achieve accurate control and regulation of PWM functions. Specifically, PCA is a functional module in the STC15 microcontroller, which can be used to generate and control multiple PWM signals. In this experimental design, PCA is configured to generate a PWM signal that is used to precisely regulate the power of the heater and thus control the temperature. By configuring the relevant registers of the PCA, parameters such as the period, duty cycle, and output pin of the PWM signal can be set. By adjusting the value in the PCA_PWMn register, the duty cycle of the PWM signal, that is, the ratio of the heater's operating time to the stop time, can be controlled. By setting the counters of the PCA and the compare/capture channels, the period of the PWM signal can be determined. In this experiment, the role of PCA is key, providing flexible control and regulation of PWM functions, so that heater power can be precisely adjusted as needed, so as to achieve temperature control. Through the configuration and use of PCA, the experimental system can monitor the temperature value in real time and adjust the heater power as needed, thus controlling the temperature within the set range.

PCA initialization mainly needs to configure the following registers: PCA operating mode register CMOD is used to configure the operating mode of the PCA module, including clock source selection, automatic reload enable, PCA counter overflow interrupt enable, etc. The control register CCON is used to control the start, stop, and counting mode selection of the PCA counter, and can also configure the clock source and divider factor of the PCA counter. The Compare/Capture Register CCAPMx is used to configure the operating modes of the PCA module's compare/capture channel, including compare/capture function enable, output mode selection, interrupt enable, and more. The AUXR1(P_SW1) register is used to configure the PCA module's accessibility functions and other special functions, such as setting the PCA module's pin multiplexing function. The functions and configurations of these registers are described in Table 3 below.

Tabel 3. Common Configuration Parameters for PCA

register	Register description
CMOD registers	Set the operating mode of the PCA counter and clock source selection
CCON register	The PCA module's operating mode, interrupt enablement, and counter start-stop control
CCAPM0 register	Channel 0 operation mode and interrupt enable of the PCA module
AUXR1(P_SW1) register	The PCA module operates on the clock source and counter overflow interrupt enable

3.3.4 A/D conversion

In the experimental design of PWM temperature regulation based on STC15 microcomputer, the function of A/D conversion is to convert the analog temperature signal into a digital signal so that the microcontroller can monitor and process the temperature in real time. Specifically, the A/D converter is a module in the STC15 microcontroller that converts the analog signal into the corresponding digital value. In this experimental design, an A/D converter is used to convert the analog signal output by the temperature sensor into a digital value so that the microcontroller can monitor and control the temperature in real time. By configuring the relevant registers of the A/D converter, parameters such as conversion accuracy and reference voltage can be set. After the analog signal of the temperature sensor is converted by A/D, a corresponding digital value will be obtained, which represents the current temperature value. The microcontroller can obtain this digital value by reading the result register of the A/D converter and perform the corresponding temperature control operation. The role of A/D conversion is very important in this experiment, it realizes the conversion of analog signal to digital signal, so that the microcontroller can accurately monitor and control the temperature. Through the configuration and use of the A/D converter, the experimental system can obtain the temperature value in real time and adjust the PWM power accordingly as needed, so as to control the temperature within the set range.

PCA initialization mainly requires the

following registers: A/D conversion control register ADC_CONTR which is used to configure and control the working parameters and modes of the A/D conversion module. It can set the clock source, conversion channel, conversion accuracy, conversion rate, etc. of A/D conversion. The P1 port analog function control register P1ASF is used to control the analog function of the P1 port to turn on and off. By setting the corresponding bits of P1ASF, specific pins of port P1 can be configured as analog input channels for use by A/D conversion modules. The corresponding description is shown in Table 4 below.

Tabel 4. Common Configuration Parameters for A/D Conversion

register	Register description
ADC_CONTR registers	ADC block operating mode, channel selection, and conversion start control
P1ASF register	Configure whether the pin of port P1 is used as an analog input channel

3.3.5 Program register configuration:
Transmitter:
Timer:AUXR |= 0x04; T2L = 0x5C; T2H = 0xF7; AUXR |= 0x10; IE2 |= 0x04;
Serial:SCON = 0x50; AUXR &= 0xBF; AUXR &= 0xFE; TMOD &= 0x0F; TL1 = 0xFC;
TH1 = 0xFF; SD1 = 0; TR1 = 1;PS=1; ES=1;
PCA (High Speed Pulse Output Mode): CCON = 0x00; CCAPM0=0x48|0x01; PPCA=1; CMOD= (CMOD&~0xe0) | 0x08;
A/D: P1ASF = (1 << 5);ADC_CONTR = 0xE0;
Receiver:
Timer:AUXR |= 0x04; T2L = 0x5C; T2H = 0xF7; AUXR |= 0x10; IE2 |= 0x04;
PCA (High Speed Pulse Output Mode): CCON = 0x00; CCAPM0=0x48|0x01; PPCA=1; CMOD= (CMOD&~0xe0) | 0x08;
PCA(PWM Mode):CCAPM0 = 0x42; CCON=0x00; CMOD= (CMOD&~0xe0) | 0x08; ACPP=1;
A/D: P1ASF = (1 << 5);ADC_CONTR = 0xE0;

4. Conclusion

The design relies on the two-way data transmission system realized by serial communication and infrared communication, and realizes the data acquisition and control function through temperature monitoring and PWM control. Real-time, flexible and easy to operate, the system can effectively support teaching and provide a platform for communication and collaboration between students and teachers. Two-way data transmission is realized through serial communication and infrared communication, and the data collection and control function is realized. Integrate the temperature measurement results into the system, realize the unified storage and management of the overall experimental link, and improve the stability and reliability of the system. The system has certain practicability and feasibility in practical applications, and has reference value for research and application in related fields.

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