Design of Numerical Electronic Soldering Station

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Keywords: Electronic Soldering Station; Constant Temperature; Thermocouple; PID

Abstract: MCU STC15F2K60S2 was taken as the core controller. The heating core referred to white light T12 soldering head consisting of the thermocouple sensor in series with heating wire. The energy generated by the heating wire was used to control the temperature through PID. Multi-functional NCN digital display soldering station based on MCU was designed to achieve accurate temperature detection and control of soldering iron, which remained in a constant temperature working state. Experimental results showed that the system had controllable welding temperature, high precision, little temperature error (±1%) and wide temperature control range (10-550 °C). Five sets of user parameters were saved to achieve numerical control, digital display, automatic standby, automatic sleep, voice prompts and electrostatic prevention. Therefore, the system had strong practicality, high reliability and low cost.

1. Introduction

Soldering iron is an indispensable tool for the development, debugging and maintenance of electronic products. Its performance and stability directly affect the quality of welding, assembly as well as electronic products [1]. Pei Yang [2] designed portable anti-static constant-temperature soldering station based on T12 heating core to find a convenient, durable and intelligent soldering iron with good performance and high stability. It has high-precision temperature control, portable convenience and self-contained power supply. Xuehua Qiu [3] proposed tin-implanted soldering pen with simple operation and powerful functions to achieve the combination of welding and sketching. Qiang Song [4] used the induction heating mode to directly heat the welding head. Constant-temperature control system is designed to realize fast, efficient and safe soldering iron design, thus compensating the traditional "dry burning" deficiency. Longteng Wang [5] designed a high-efficiency soldering iron with high-frequency eddy current mode, which has the characteristics of short heating time and high heating efficiency. Multi-functional NCN digital display soldering station uses MCU STC15F2K60S2 as core controller in the work. The control board processed the collected data through the ADC acquisition unit. PWM output was then controlled by PID for temperature control of soldering iron. The system has functions such as power supply voltage recognition, automatic standby, automatic sleep and prompts. Users can also set multiple sets of temperature values to facilitate quick switching when soldering different devices. A rotary encoder is used as user setting selection key. Simple UI (User Interface) is designed to display the set and present temperature of soldering iron.

2. Overall system design

The system is mainly composed of hardware and software parts. Wherein, the hardware part consists of MCU minimum system, voltage collection unit, temperature detection module, data storage unit, OLED display, audio prompting, encoder, and power conversion modules. The software part contains system initialization, temperature acquisition control, menu, EEPROM storage and encoder modules. Figure 1 shows system block diagram.

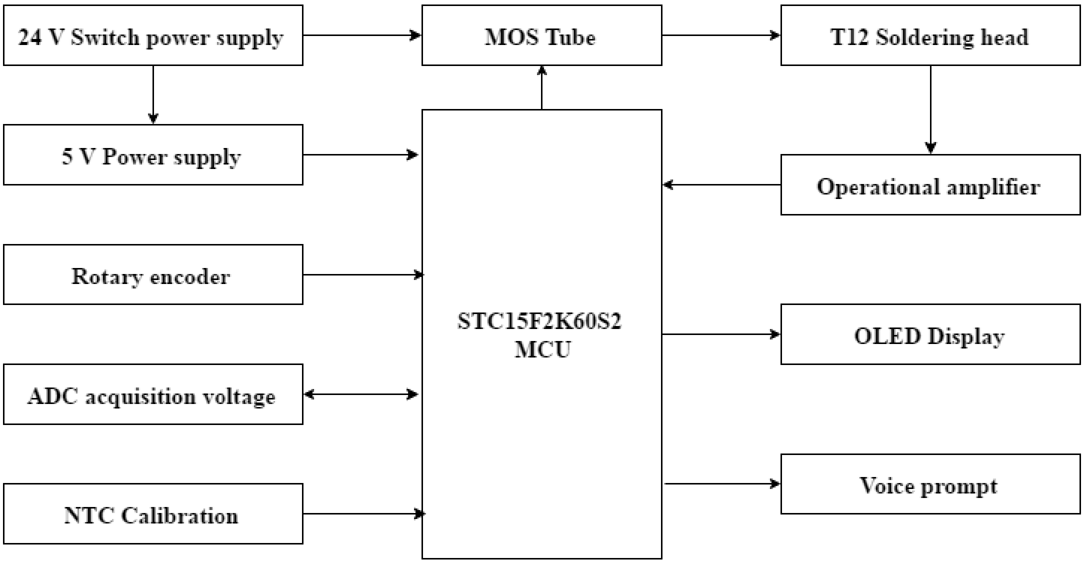

Figure 1 System block diagram

When the system is powered on, the MCU reads the data and user setting parameters saved before the last shutdown in the internal EPROM. The collected data are processed through the ADC acquisition unit to detect whether the handle is connected to the host. After that, the PID controller controls the PWM output and the switch of the MOS tube to supply soldering head with power. Then, thermocouple signal is collected by the ADC acquisition unit, and fed back to the PID controller. The system finally reaches a constant temperature after repeated circulation. Meanwhile, the set and present temperatures of soldering iron are displayed. The control board identifies the power supply voltage to ensure normal working voltage of the whole system for undervoltage and overvoltage protection. Without using the soldering station for a long time after starting up, the system will automatically enter the standby state and finally enter the sleep state. Users can also set 6 sets of temperature values for quick switching when soldering different devices. Meanwhile, rotary encoder is used as user action key.

3. System hardware design

Based on control core MCU, the hardware part of system realizes the control and display functions of soldering iron temperature through peripheral circuits such as power conversion, temperature acquisition, OLED display and encoder modules.

3.1 Temperature acquisition and control module design

Soldering head T12 consists of heating wire in series with thermocouple sensor. The two pins are the power input and thermocouple signal output terminals. The thermocouple of T12 belongs to the K-type thermocouple. The thermoelectromotive force of thermocouple is approximately 0-24.519 mV at 0-600 °C. Therefore, the signal needs to be amplified to process the thermoelectromotive force from temperature change of thermocouple collected by internal ADC acquisition unit. In this design, the temperature control range is between 100 and 550 °C. When the amplification factor of operational amplifier is calculated about 250 times, the signal can be amplified to 0-5 V for signal collection by MCU. However, the general-purpose operational amplifier cannot be selected for the voltage amplification of Grade mV because the general-purpose operational amplifier has an offset voltage close to 1 V. Therefore, this design uses the precision operational amplifier rail-to-rail to amplify SGM8551. Figure 2 shows the small signal amplification circuit.

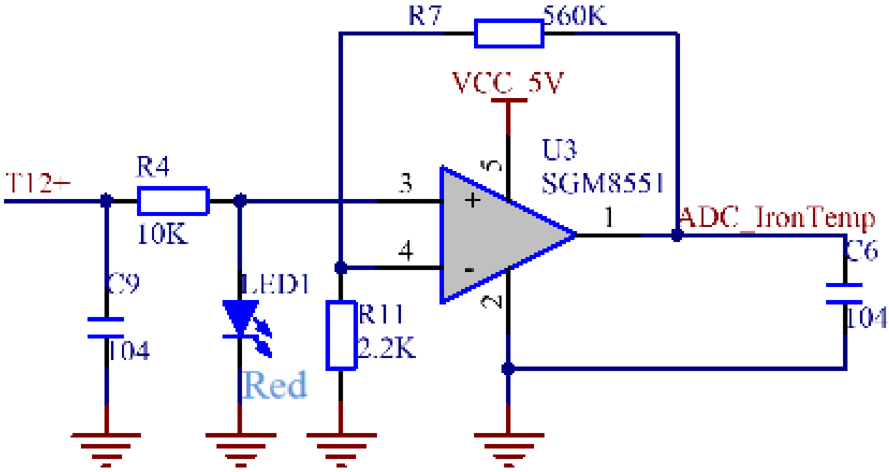

Figure 2 Small signal amplification circuit

Combined with the triode and tube MOS, the I/O port of MCU outputs PWM square waves to complete temperature control. The PWM square wave output is turned off to prevent the power supply from interfering with the thermocouple signal during temperature acquisition. Figure 3 shows MOS tube drive circuit design.

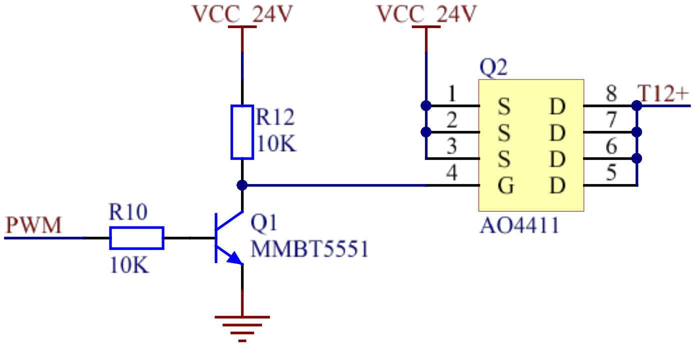

Figure 3 MOS tube drive circuit design

In Figure 3, the selected MOS transistor chip is AO4411 with a maximum voltage of 30 V, a maximum current of 8 A, a small volume, and a package of SOIC-8. The triode acts as a switch in this circuit. The triode is turned on as the PWM terminal controlled by MCU outputs a high level. Then, the MOS tube is turned on to supply the soldering head with power. As the MCU outputs a low level, the triode is turned off to stop supplying soldering head with power. The PWM square wave is output through the control of program, thus achieving stable temperature control at last.

3.2 OLED display circuit design

The OLED display module is used to display the relevant parameters of soldering station, completing the functions of display part. Display OLED12864, driven by SSD1306, communicates by SPI. The display part completes the relevant action display of the user throughout the operation, including pre-set, present temperature, and operation menu.

3.3 Encoder circuit design

In the A, B and Z phase signals of encoder, the phase lines are respectively connected to the I/O of MCU. Generally, the A and B phase signals are orthogonal pulse signals, namely square waves. The encoder rotates once to generate 20 orthogonal pulse signals. Therefore, the A and B phase lines are connected to the external interrupt pin of MCU for faster response to user operation. Here, the middle button is set to the confirmation button, and connected to an external interrupt pin of MCU.

4. System software design

The software part consists of system initialization, temperature acquisition control, menu, EEPROM storage and encoder modules.

4.1 Main program process

When the system is powered on, the MCU reads the data and user setting parameters saved before the last shutdown in the internal EPROM. After that, the I/O port is initialized. If the current temperature does not reach the set value, the PWM output is turned on, and the MOS tube is controlled to supply soldering head with power. After that, the timer generates the interrupt reading temperature. The PWM square waves with different duty ratios are output for the purpose of constant temperature after repeated judgment and calculation. Figure 4 shows main program process of system.

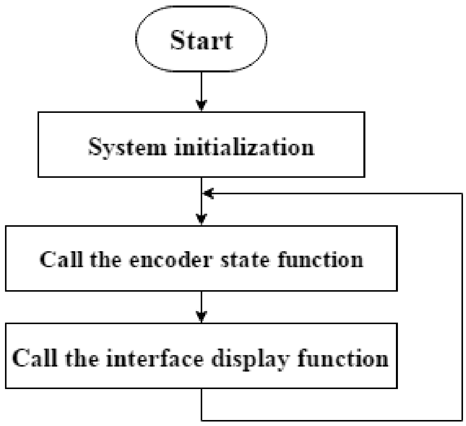

Figure 4 Main program process

4.2 System initialization module

The system initialization consists of four parts: reading EEPROM parameters,I/O port initialization, timer initialization and OLED screen initialization.

(1) Reading EEPROM parameters

The parameters saved before the previous shutdown are read, including the temperature group set by user, the number of soldering heads, the user operating temperature before the last shutdown, the set standby and sleep time.

(2) IO port initialization

The PWM output and buzzer control pins of MCU are set to push-pull output mode. Then, the two pins are set to output low levels to ensure that the soldering iron is not heated with the buzzer turned off during starting up.

(3) Timer initialization

Timer 0 is configured for buzzer and PWM control; Timer 1 for temperature control, sleep and standby timing; Timer 2 for continuous display of current temperature; Timer for interrupt allowance.

(4) OLED screen initialization

OLED screen driver registers are configured to set the display brightness, mode and direction.

Figure 5 shows subprogram process of system initialization.

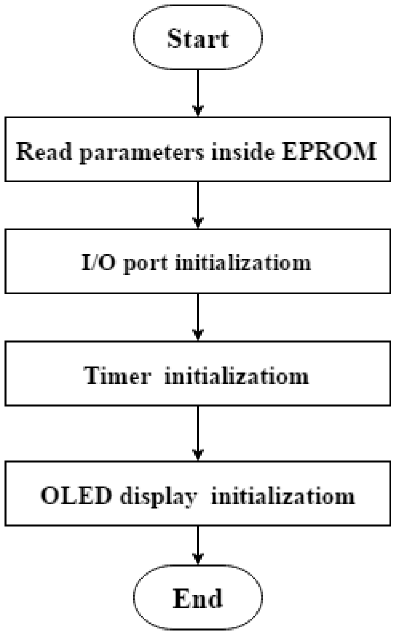

Figure 5 Subprogram process of system initialization

4.3 Temperature acquisition and control module

The temperature acquisition is performed by the internal ADC acquisition unit of MCU. Combined with the triode and tube MOS, the I/O port of MCU outputs PWM square waves to achieve temperature control. The PWM square wave output is turned off to prevent the power supply from interfering with the thermocouple signal during temperature acquisition.

(1) Temperature acquisition

Timing interrupt is generated by Timer 1 to control the temperature sampling time and frequencies. The median filters of 32 samples are averaged after removing the maximum and minimum. The temperature is sampled and filtered to obtain a relatively stable ADC value. Then, the temperature of soldering iron is obtained by table lookup to stabilize the collected temperature. Figure 6 shows subprogram process of temperature acquisition.

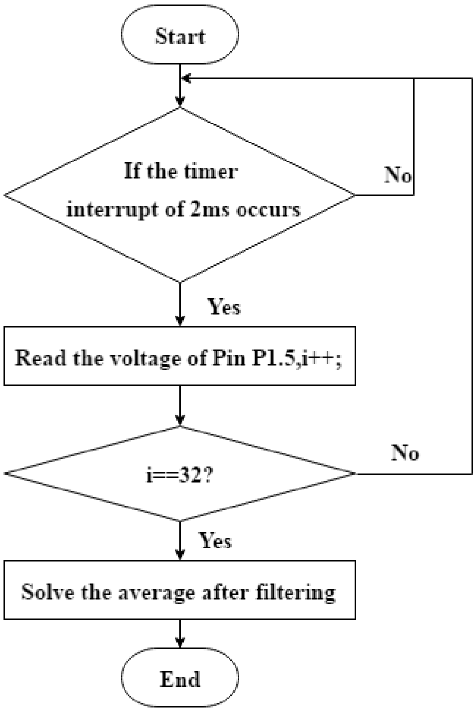

Figure 6 Subprogram process of temperature acquisition

(2) Temperature control

The collected temperature values are fed back to the PID controller. After that, the PID calculation is conducted by calculating the difference between present and set temperatures. The calculated value is converted to the duty ratio of PWM square wave, which is assigned to the PWM controller. The MOS tube is driven by level switching triode with varying output to realize the switching of power supply of soldering head, thus finally achieving stable temperature control.

P is the main parameter for heating soldering iron. Too small P leads to slow heating rate of soldering iron. There is a slight error (steady-state error) between stable soldering iron and set temperatures. Too large P will cause the temperature overshoot of soldering iron.

Parameter I eliminates the steady-state error caused by P. Too small I leads to incomplete elimination of steady-state error. Too large I will cause constant amplitude fluctuation of actual temperature with long period around the set temperature.

D is the main parameter to improve the temperature recovery rate of soldering iron. D is increased to eliminate the temperature overshoot phenomenon caused by P to some extent. Too small D leads to delayed temperature recovery and temperature decline of soldering iron in presence of small disturbance (welding large joint). Too large D offsets the effect of I to cause new steady-state error of system.

Figure 7 shows subprogram process of temperature control.

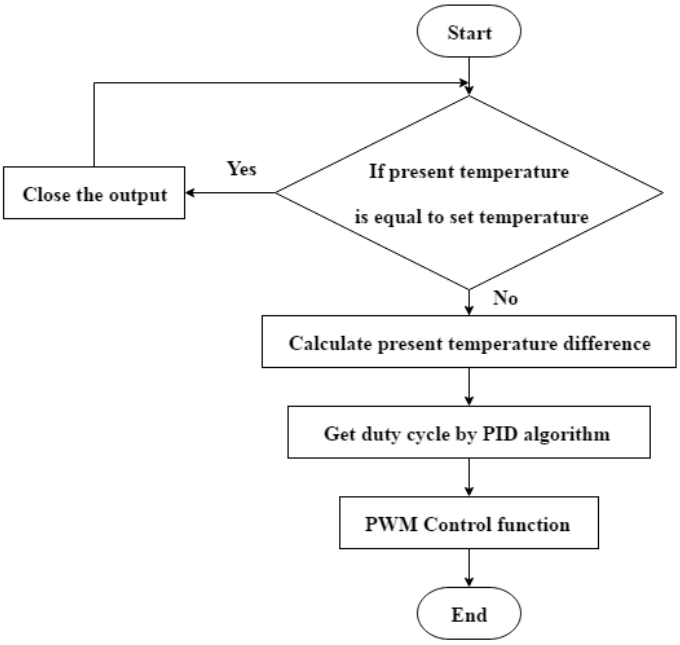

Figure 7 Subprogram process of temperature control

4.4 Menu module

System parameters include temperature, time, channel, other settings, welding tip and other calibrations. Press and hold the encoder 1S to enter the first level menu. Rotate the encoder and the secondary menu by short press. Then rotate the encoder again, and move the cursor to the specific parameter to be modified. The content is selected by short press. The option value is displayed after the text). Rotate the encoder again to modify the value. After the modification, click the encoder to uncheck it (the option value disappears after deselection), thus determining the setting. Rotate the encoder again to select other parameters. Press and hold the encoder to exit the first and second menus. Figure 8 shows the menu structure.

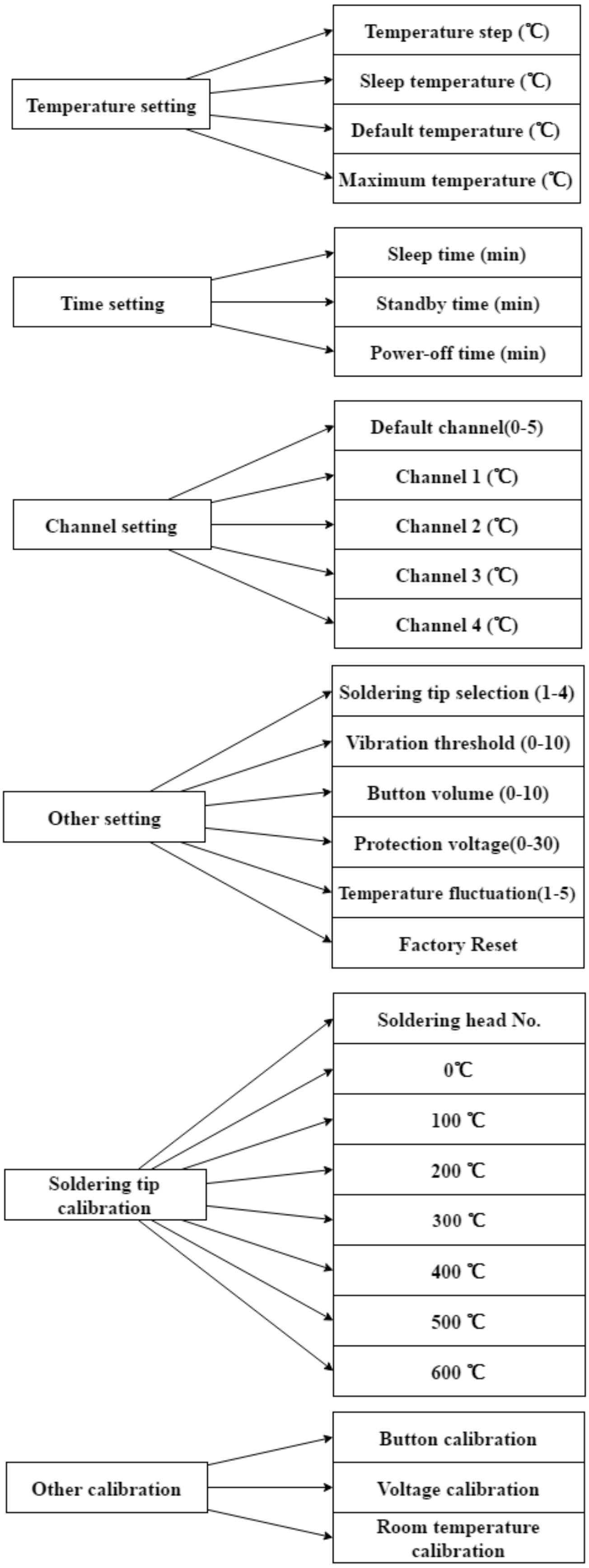

Figure 8 the menu structure

4.5 EEPROM memory module

The memory module is completed by EEPROM unit inside MCU. The data ARE written to the EEPROM each time the setting parameters are changed. When the system is turned on, the data saved last time are read from the EEPROM before initialization and application.

(1) #define MOVC_ShiftAddress 0x2000 is the first offset address of the internal EEPROM.

(2) Function DisableEEPROM () is used to disable the EEPROM in the program.

(3) Function EEPROM_read_n () is used in the program to read the n-byte data of specified address of EEPROM and cache it in the specified array.

(4) Function EEPROM_SectorErase () is used in the program to delete the sector data of EEPROM of specified address.

(5) Function EEPROM_write_n () is used in the program to write the cached n-byte data to EEPROM of first specified address.

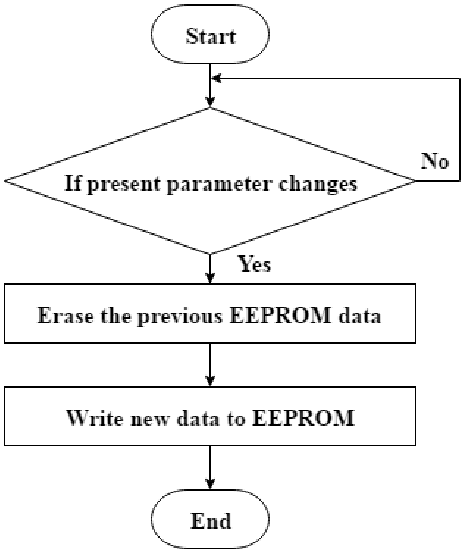

Figure 9 Subprogram process of EEPROM

4.6 Encoder module

The A, B, and Z phases of encoder are respectively connected to the P3.2, P3.1 and P3.0 pins of MCU. The external interrupt of MCU is used to read and recognize the keys. The program uses Function EC11_Capture () to capture the encoder EC11 press and rotate information. When EC11_A and EC11_B are both high levels, then the encoder has been rotated. After second rotation, the pin with low level is determined. Compared with the previous value, the direction of rotation can be obtained. Long press or short press is judged according to the time of pressing the middle button. Figure 10 shows subprogram process of encoder recognition.

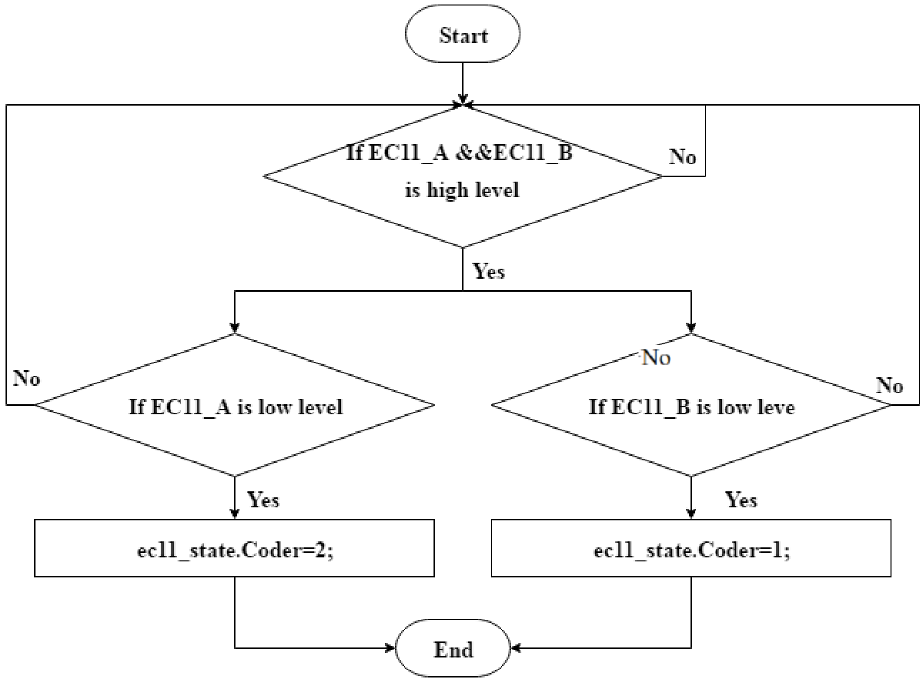

Figure 10 Subprogram process of encoder recognition

5. System testing and results analysis

5.1 System testing

Figure 11 Physical diagram and interface of system

In Figure 11, the content of the interface contains soldering head number, power supply voltage, present soldering temperature, set temperature, and heating power bar. The soldering handle interface and rotary encoder are on the left and right, respectively.

After the completion of system debugging, we tested the temperature control effect of system (See Table 1).

Table 1 Comparison of set and soldering head collection temperatures (Unit: °C)

Set Temperature T0	100	200	300	330	370	400	430	470	500
Soldering Head Temperature T1	101	201	300	332	369	399	431	470	501
T0-T1	-1	-1	0	-2	1	1	-1	0	-1

Table 1 shows that the set and soldering head temperatures are substantially overlapped between 100 and 500 °C. This indicates that the set temperature is basically consistent with the soldering head temperature, which achieves the effect of constant temperature welding.

5.2 Results analysis

After measurements and debugging, the data with large error is removed. Then, the set temperature is basically the same as the soldering head temperature. The deviation is basically maintained at ±1°C, achieving the effect of constant temperature. The operation of encoder can also be smoothly realized, and the buzzer completes the prompt function. The design requirements are met to realize temperature adjustment, constant temperature function of soldering station and the design of multifunctional NCN soldering station with digital display.

6. Conclusions

In this design, the MCU was used as the core to accurately control the temperature of soldering head of soldering station through PID. With simple application, high-precision temperature control and rapid temperature rise, this soldering station was suitable for welding precise electronic products of higher temperature requirements. Meanwhile, the design was added with power-off data storage, automatic standby, automatic sleep, voice prompts and anti-static functions. The soldering heads with different tips were applied to weld different devices according to the specific conditions, facilitating the use of soldering station.

Acknowledgments

The work was supported by Baise College "Electronic Information Engineering" Specialty (Approval No.: Guijiao Higher Education [2018] No. 52; Series No.:119), 2018-2020 Guangxi College Specialty and Experimental Training Base (Center) Construction Project and 2019 Engineering Master Degree Authorization Point (Electronic Information) Construction Project.

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