Design and Implementation of Fire Prevention and Anti-Theft Alarm System Based on Single-Chip Microcomputer

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Abstract. With the advancement of the times, the living conditions of people have improved significantly, and high-rise buildings and comprehensive buildings have risen from the ground. Once these buildings are caught in a fire or theft, they will cause great losses to people's life safety and property safety. There are many alarms on the market that solve security risks, but their functions are relatively single and the cost is high. This paper designs a fireproof and anti-theft intelligent alarm system based on a microcomputer to address the issues, using a smoke sensor, a temperature sensor, a pyroelectric infrared sensor to achieve fireproof and anti-theft functions. This paper analyses the requirements and the hardware circuit module of the fire and anti-theft system, designs the system software, and introduces the software design ideas. Based on simulation software, tests were carried out to verify the feasibility of the proposed design. The fireproof and anti-theft system in this paper can detect the leakage of combustible gases, the sudden rise in temperature and the function of human body intrusion, and automatically alarm. The system in this paper has low cost and can expand the function, which helps to protect people's lives and property safety, and has high practical significance.

Keywords: Fire Prevention and Anti-Theft Alarm System; Single-Chip Microcomputer; sensor; hardware circuit module.

1. Introduction

With the continuous progress of science and technology and the continuous development of the economy, people's living standards are improving day by day, and the living environment has also changed, from bungalows to high-rise buildings and even super high-rise buildings. However, at the same time, it is more difficult to prevent fire, theft, and other behaviours that harm people's lives and property safety. In order to solve the above problems, scientists and enterprises have developed various types of alarms, but the alarms on the market are difficult to use on a large scale due to high cost and the function of the alarms is single [1]. And it is difficult to expand other functions later. Therefore, this paper develops a fire prevention and anti-theft integrated system based on a microcomputer to address the existing challenges, which has low cost, freely expandable functions, and a high market competitiveness.

The main research content of this paper is as follows: (1) Analyse the functions required for the fire prevention and anti-theft system and its implementation method, and determine the design scheme with the microcontroller as the core. (2) Analyse the hardware circuit of the fire prevention and anti-theft system and its required components, and mainly introduce the following modules: microcomputer module, smoke sensor module, temperature sensor module, pyroelectric infrared sensor module, display module and alarm module. (3) Design the system software, and along with the text and flow chart introduce the system's software design concepts, fire prevention sub-function and anti-theft sub-function, as well as how each function is carried out. (4) Software simulation is used to model and test the system circuit, confirming the viability of the proposed design.

The fire prevention and anti-theft integrated alarm based on a microcomputer in this paper, using the smoke sensor, temperature sensor and pyroelectric infrared sensor, fills the gap in the market of multi-functional alarms. At the same time, this system plays an important role in the elderly living alone, no one at home on business trips, complex personnel in the building, etc., which greatly reduces human resources and costs and protect people's life safety and property safety. And it also promotes the development of the alarm industry and has a role in promoting social security and stability.

2. Program Design

The system designed in this paper based on the microcontroller is used for fire prevention and theft prevention, which includes two parts: fire prevention function and anti-theft function. As the core module of the design scheme of this paper, the microcontroller is designed to use STC89C52. In addition, for the control components, the following modules are included: sensor detection module, minimum system module, key control module, LCD module. For the sensor module, the smoke sensor MQ-2 is used to gauge the quantity of flammable gases present in the space. The temperature sensor DS18B20 is used to detect the indoor temperature, and the pyroelectric infrared sensor is used to monitor human intrusion. For the LCD module, numerical values are displayed on the LCD1602 display. When the system detects an abnormal situation, the audible and visual alarm will automatically alarm, reminding the user that there may be a danger at present.

Considering that the functions of the fire prevention system and the anti-theft system are quite different and do not affect each other, this paper independently designs the fire protection system and the anti-theft system, and describes its design scheme and introduces its specific functions respectively, so that the structure of the paper is clear.

2.1. Fire prevention function design scheme

The fire protection function is mainly implemented by the following two parts: the detection of fire disaster and the triggering of an alarm when a disaster is detected.

For the detection of fire disasters, considering that the temperature will rise in the event of a fire and a fire will produce a relatively high concentration of smoke, this design uses smoke sensor MQ-2 and temperature detector DS18B20 to work together to increase detection accuracy and make sure that the fire can be spotted quickly and precisely, protecting the user's life safety and property safety. In this design scheme, as long as the detected temperature exceeds the set value or the detected smoke concentration exceeds the set value, the alarm system will work. The LED bulb will light, and the buzzer will sound, reminding the user that there is a dangerous situation, and timely evacuation or self-help is required, which protects the user's life safety.

After considering the characteristics and improvements of existing products and the factors such as cost, this paper uses smoke sensor M2-Q, temperature sensor DS18B20, analogy-to-digital converter ADC0832, liquid crystal display LCD2602, buttons and an audible and visual alarm, with the microcomputer as the core module to constitute a fire alarm system. The specific composition structure is as follows figure 1.

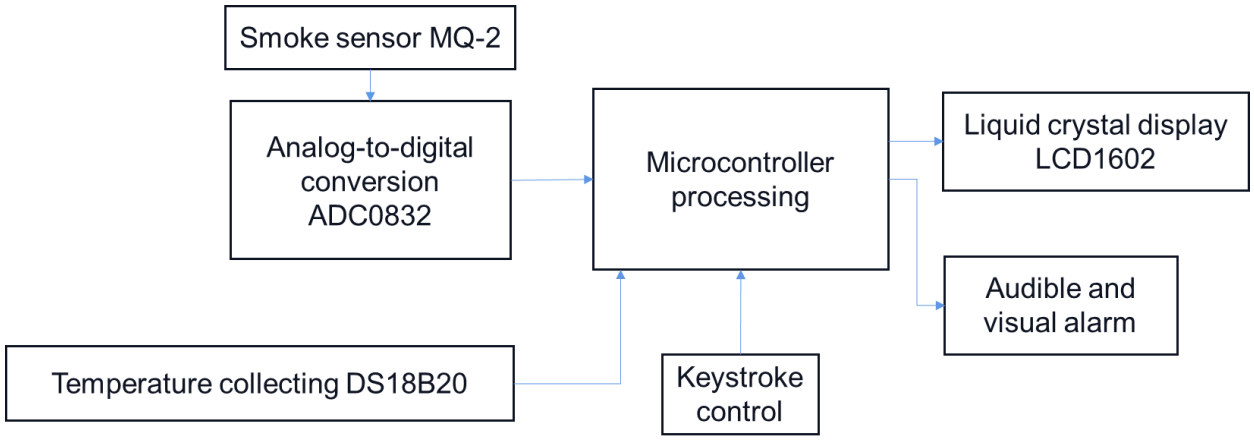

Figure 1. Fire protection function design scheme.

The fire prevention function works as follows: First, initialize the smoke sensor and temperature sensor. Second, detect the smoke and temperature values in the room. Finally, check to see if the temperature and smoke levels in the room are above the predetermined limits, and if the limit value is exceeded, the audible and visual alarm works. Conversely, it is necessary to determine whether the key is pressed. In order to enable the system designed in this paper to work normally in different

scenarios and environments, the user can set the required smoke and temperature alarm values through the keys, which expands the scope of application of the system and greatly improves the cost performance.

2.2. Anti-theft function design scheme

The anti-theft function is mainly realized by the following two parts: the detection of human intrusion and alarm function.

For the detection of human intrusion, considering that the human body emits 10-micron infrared light at a normal body temperature of 36-37 degrees Celsius, this design uses a pyroelectric infrared sensor. In this design, if a human intrusion occurs, the pyroelectric infrared sensor will detect a tiny infrared change signal, and then the signal will be amplified through the amplification circuit and compared to determine whether there is theft. If the system detects a theft, the alarm system will work immediately to alert the user to the theft.

After comprehensively considering the product cost, size and other factors, this paper uses a pyroelectric infrared sensor, LCD2602, buttons and an audible and visual alarm, and the microcomputer as the core module to form an anti-theft alarm system. The specific composition structure is as follows figure 2.

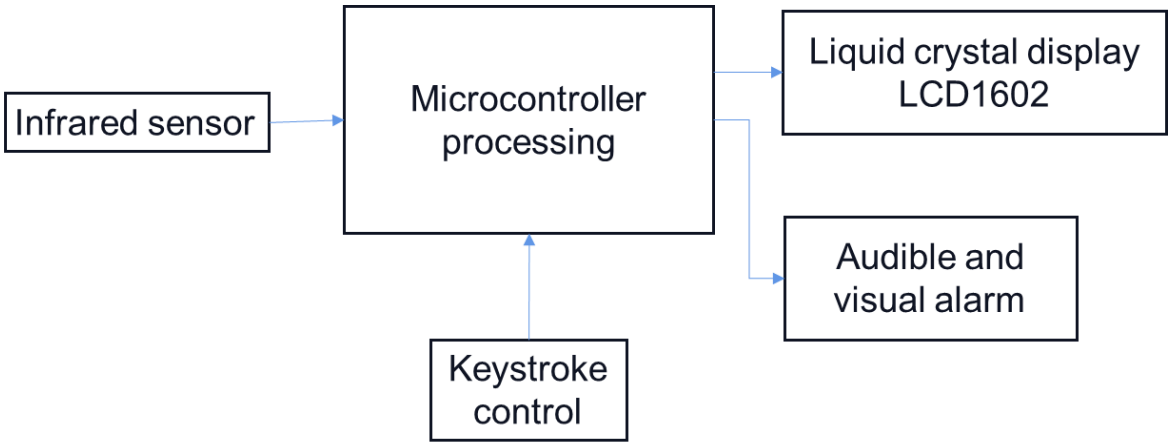

Figure 2. Anti-theft function design scheme.

The operation process of the anti-theft function is as follows: First, initialize the microcontroller. Second, detect the signal input of the pyroelectric infrared sensor. If the input signal is generated, the audible and visual alarm works. In addition, in order to save power, increase service life, and ensure that the alarm works normally the next time the sensor generates an input signal, the alarm is set to stop automatically after 10s.

3. Hardware Circuit Design

3.1. Microcontroller AT89C52

Microcontroller is an integrated circuit chip containing a microcomputer system, which is widely used in intelligent electronic devices due to its small size, light weight and low cost. In the fire protection and anti-theft system, the microcomputer is used as a control module to accept, process, and send signals to achieve fire protection and anti-theft functions. After considering the functions, cost, service life and other factors, this design adopts microcomputer AT89C52.AT89C52 is an 8-bit general-purpose microprocessor with 8k bytes rewritable flash memory and 32 programmable I/O ports, which meets the functional realization of the design [2]. At the same time, AT89C52 has an idle mode and a power-down mode, which can help the system created in this paper run normally over the long term while also effectively reducing power usage. The physical diagram and the pin diagram of Microcontroller AT89C52 are as follows figure 3.

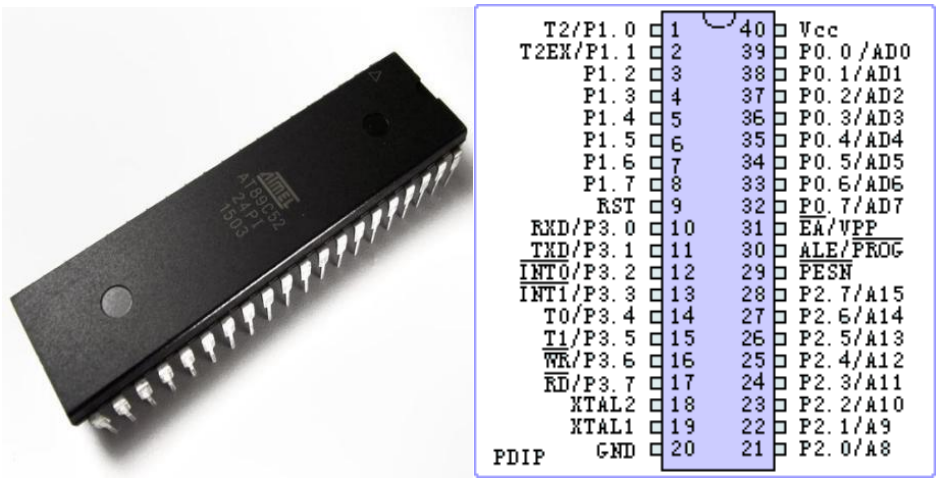

Figure 3. Physical and pin diagram of microcontroller AT89C52.

Microcontroller minimum system refers to a system capable of working on a microcontroller composed of the most basic components that drive a microcontroller. The minimum system of microcontroller AT89C52 includes three parts: microcontroller, crystal oscillator circuit, and reset circuit. Its minimum system circuit diagram is as follows figure 4.

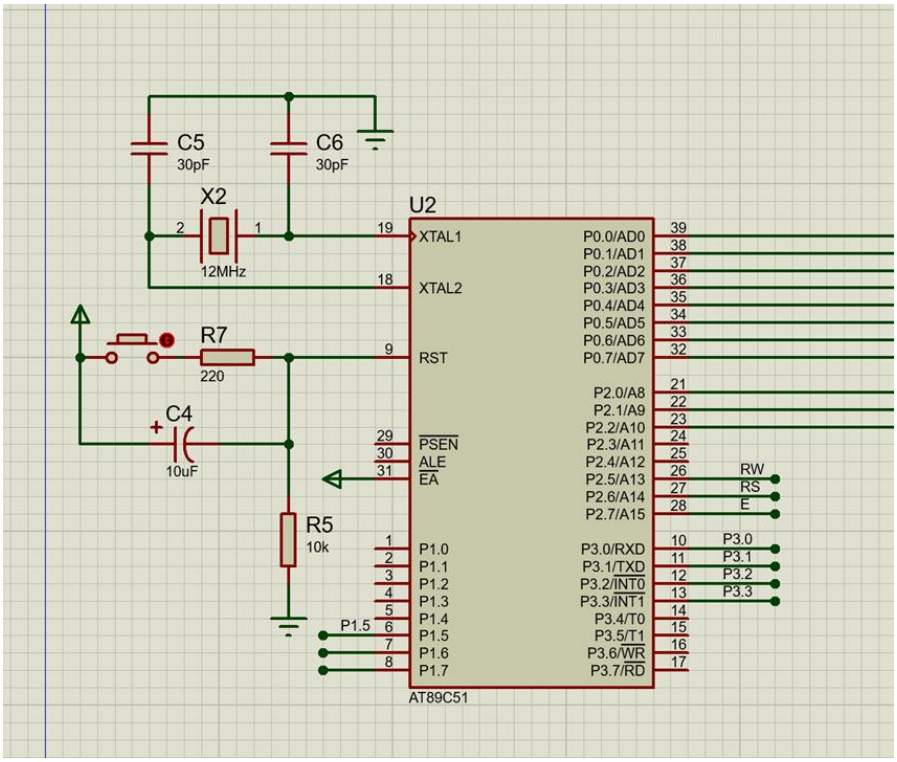

Figure 4. Circuit diagram of microcomputer minimum system.

A crystal oscillator, which produces precise and stable single-frequency oscillation by utilizing a crystal that can convert mechanical and electrical energy in a resonant condition, provides basic clock signals for the system, and makes the system equipment work stably. Microcontroller systems have crystal oscillators. Typical crystal oscillators take 11.0592MHz. In order to make the serial port baud rate setting simpler, here select the capacitor with a capacitance value of 22pf.

Reset circuit can restore the circuit to the starting state, and the program in the microcontroller will also run from the beginning, which is helpful for the system which is affected by environmental interference and so on. The 51 microcontrollers can be reset by connecting a high level at the RST pin for 2 microseconds, which is very simple and convenient [3]. In addition, due to the non-automatic forgetting of the flash memory inside the microcontroller, all devices must be in the starting state through the reset circuit before each use of the system.

3.2. Fire prevention sub-function hardware circuit

The fire prevention function of this design mainly includes the detection of smoke concentration and temperature, using smoke sensor MQ-2, digital-to-analogy conversion device ADC0832, and temperature sensor DS18B20 respectively.

3.2.1. Smoke Sensor MQ-2

Smoke sensors are sensors that can sense most of fine particles. Considering factors such as the service life, accuracy, and cost of the sensor, the design in this paper adopts smoke sensor MQ-2. Smoke sensor MQ-2 uses a gas-sensitive material of SnO2, which has low conductivity in clean air. However, if the number of combustible gases in the air grows, the conductivity of the sensor will alter and its value will rise, so the concentration of combustible gases in the environment can be detected. Smoke sensor MQ-2 has many advantages, such as high sensitivity, fast response, simple driving circuit, and two output modes of analog and digital signals. The specific parameters are as follows: the operating environment temperature is -10 °C ~ +50 °C, humidity ≤ 85%RH [4]. The working response time is less than 10s. The working power is small, only 0.7W. Smoke sensor MQ-2 is shown below figure 5.

Figure 5. Physical diagram of smoke sensor MQ-2.

3.2.2. ADC0832

Analog-to-digital converter is a circuit that transforms analog signals into digital ones, referred to as A/D converter. This paper uses ADC0832 analog-to-digital conversion chip with 8-bit resolution which supports dual-channel A/D conversion. Thanks to its compact design, high level of interoperability, and great price performance, it is widely used and has a high penetration rate. ADC0832 is powered by 5V power supply, operates at 250 KHz and has a short conversion time of 32μs [5]. And the general power consumption is only 15mW, low power consumption, easy to work for a long time. The working temperature is -40 °C ~ +85 °C whose range is large, which is conducive to working in different environments. The circuit connection diagram of ADC0832 chip is as follows figure 6.

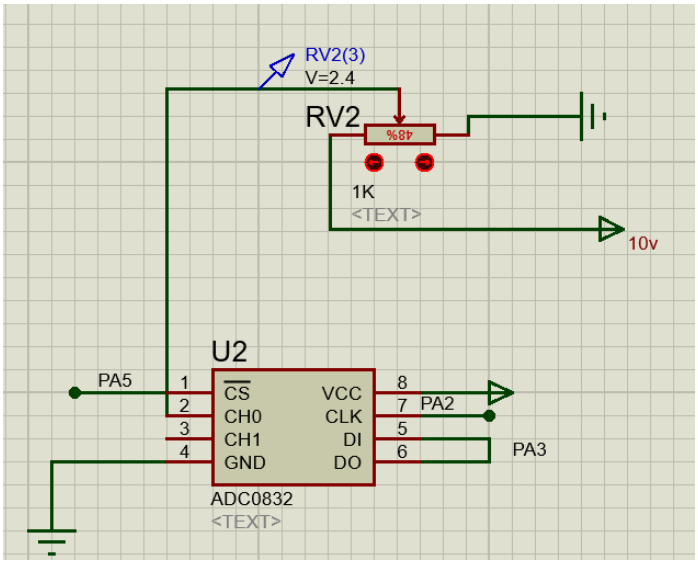

Figure 6. Circuit diagram of ADC0832.

3.2.3. Temperature sensor DS18B20

Temperature sensor is a sensor that can detect temperature and provide a signal based on it. Considering the ability of anti-interference, cost of the sensor and other factors, the design in this paper uses digital temperature sensor DS18B20, which has many advantages such as high accuracy, robust anti-interference capabilities, tiny size, convenient wiring, etc., and is widely used in many occasions. In addition, it outputs a digital signal, and therefore it is convenient for the microcontroller to directly read the digital amount. The physical diagram and the pin diagram of Temperature Sensor DS18B20 are as follows figure 7.

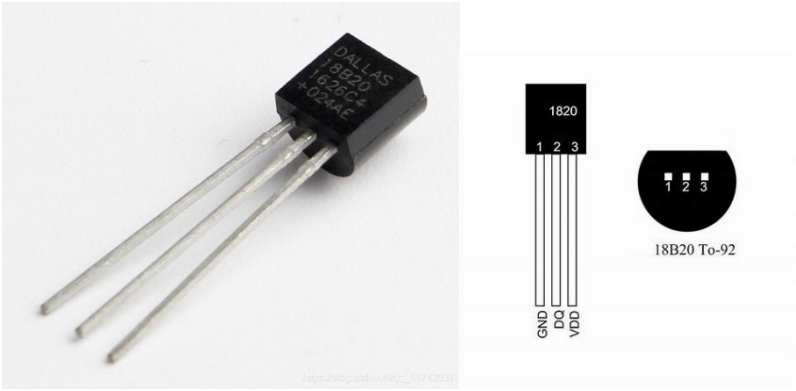

Figure 7. Physical and pin diagram of DS18B20.

DS18B20 has a unique single-wire interface mode, which only needs one line port to achieve two-way communication when connected with the microcontroller, and the connection is simple and convenient. At the same time, its wide temperature measuring range, which is between -55 °C and +125 °C, and good temperature measurement accuracy meet the requirements of this design, and the delay time during temperature conversion is only 750ms [6]. At the same time, DS18B20 has a negative voltage characteristic. If the power supply polarity is reversed, the chip cannot work properly but will not be burned, increasing the fault tolerance rate when connecting the circuit, and also easy to check errors. The circuit diagram of DS18B20 is as follows figure 8.

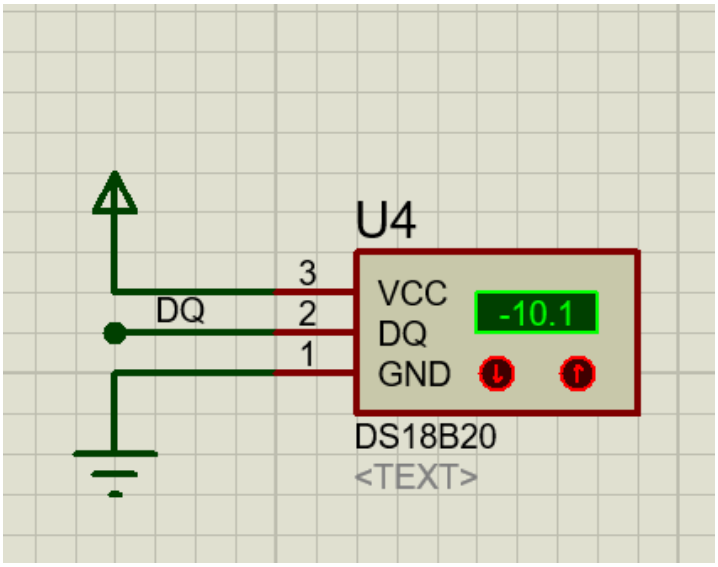

Figure 8. Circuit connection diagram of DS18B20.

For the temperature measurement in the fire protection monitoring system, the temperature measurement range and resolution can fully meet the requirements.

3.3. Anti-theft sub-function hardware circuit

Like other objects, the human body radiates energy to the surrounding area, and its wavelength belongs to the infrared region. The human infrared sensor detects the infrared ray released by the

human and produces a switch signal to identify a moving human body, which is widely used in visitor notification, anti-theft warning and so on.

Pyroelectric infrared sensors mainly use detection elements made of high pyroelectric coefficient materials such as lithium tantalate and triethylene sulfate. To lessen the interference brought on by the sensor's own temperature increase, two detecting elements are often fitted and coupled in series with reverse polarity. When infrared light is caught, the detection element turns it into a weak voltage signal. In order to make the output signal suitable for use, a field effect transistor is installed in the probe, and the signal is amplified and then output outward. At the same time, in order to make the detector more sensitive and the detection range wider, a Fresnel lens is installed in front of the detector. Additionally, in order to avoid interference from other signals detected, a filter is installed on the top of the sensor, and only infrared photons with wavelengths that match the human body's infrared radiation wave can get through. The composition of the pyroelectric infrared sensor system is as follows figure 9.

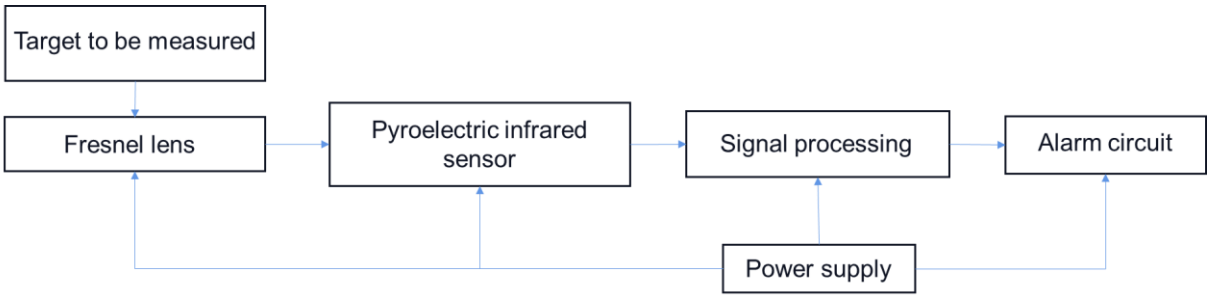

Figure 9. Block diagram of pyroelectric infrared sensor system.

The working circuit principle of the pyroelectric infrared sensor is shown in the following figure. In order to achieve the stability of the operating voltage, a filter circuit is used, and the filter circuit is formed by capacitors and resistors at the power supply end. The output of a stable signal at the output is same as the operating voltage, adopting a filter circuitry. When a human intrusion occurs, the weak voltage signal generated by the pyroelectric infrared sensor will be stably output in the form of a high potential through the amplification circuit and filter circuit, as shown in figure 10 [7].

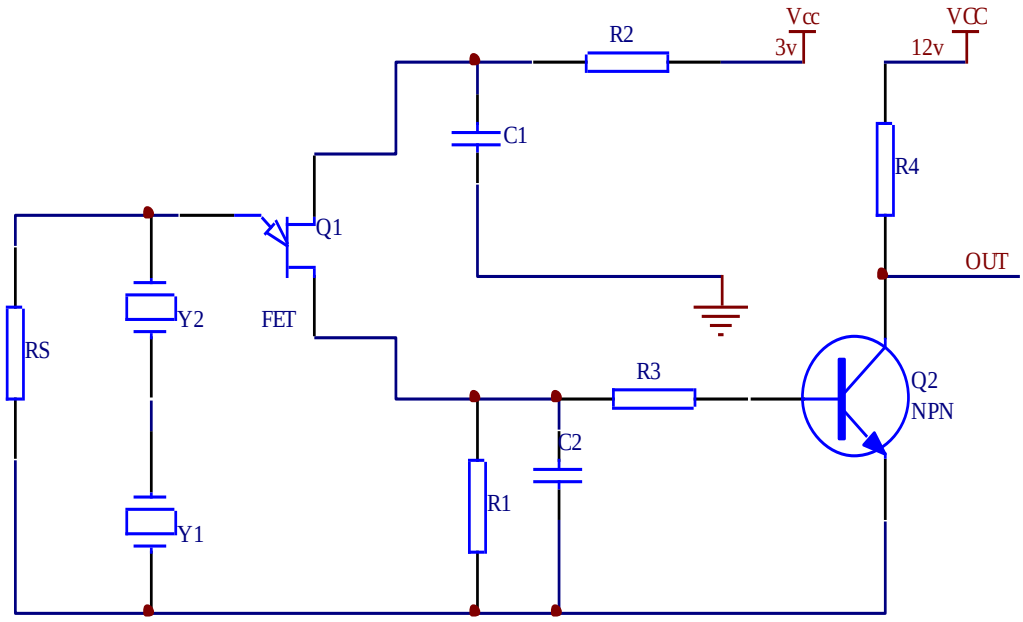

Figure 10. Schematic diagram of pyroelectric infrared sensor.

The pyroelectric infrared sensor used in this paper does not produce any type of radiation itself, and has a small size, small power consumption, and a long service time. At the same time, it has excellent anti-interference performance, such as anti-small animal interference, anti-electromagnetic interference of mobile phones, etc., which enhances the sensor's accuracy. And the detection range is

wide. The horizontal angle is 90 ~ 140 degrees. The vertical angle is 15 ~ 30 degrees, and the detection distance can reach 15 meters. The physical figure of the pyroelectric infrared sensor used is as follows figure 11.

Figure 11. Physical diagram of pyroelectric infrared sensor.

3.4. Monitor LCD1602

For the display module of this design, it is mainly used to display the set temperature information and alarm information, and the information content is simple and less. Considering the resolution, screen size, cost and other factors, the design in this paper adopts the display LCD1602, which has a display capacity of 16X2 characters, including a reset circuit, and the best working voltage is 5.0V, with less power consumption, low cost, long service life and other advantages. LCD1602 provides control commands for various functions such as screen clearing and character flickering, and contains 192 5X7 dot matrix character generators (CRGOM) and 8 User-definable 5X7 dot matrix character generator (CRGAM) [8]. The physical diagram and the pin diagram of display LCD1602 is shown in figure 12 below.

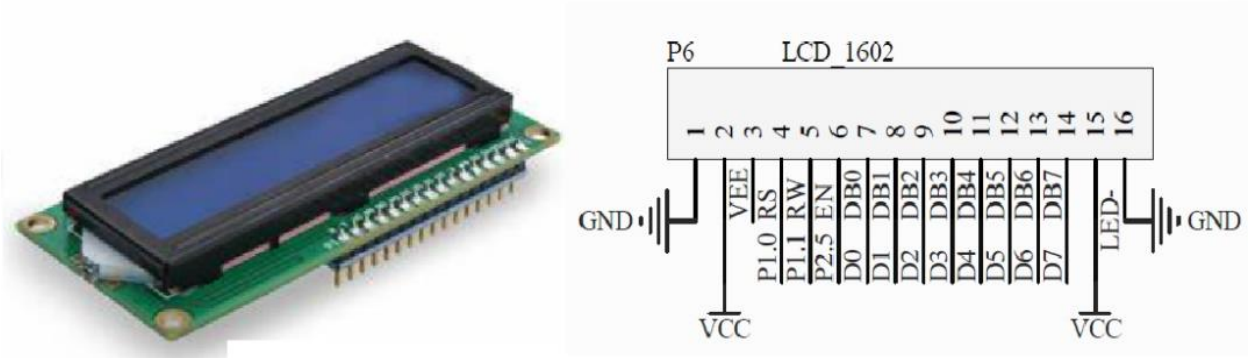

Figure 12. Physical and pin diagram of LCD1602.

3.5. Alarm circuit

The alarm module of this design contains two parts of sound and light, adopting a buzzer and a LED bulb.

Buzzer is an electronic component that converts an electrical signal into an acoustic signal, can emit a fixed frequency of sound, which is widely used in alarms, electronic toys, computer industry and other electroacoustic industries. Most buzzers are powered by DC voltage. The buzzer works in the mode of direct drive of PWM outlet or the mode of I/O port timing flip level drive [9]. This design uses an active buzzer with simple structure which is driven by a high voltage change generated by the microcontroller.

A solid-state semiconductor device called an LED bulb may convert electrical energy directly into visual light. Compared with traditional lighting products, LED bulbs have great advantages in terms of luminescence principle, energy saving, and environmental protection, so they are widely used. At the same time, LED bulbs also have the characteristics of long life, continuous use for 100,000 hours, and high efficiency [10]. This paper uses an LED bulb as a light alarm module. The figure 14 displays the alarm circuit.

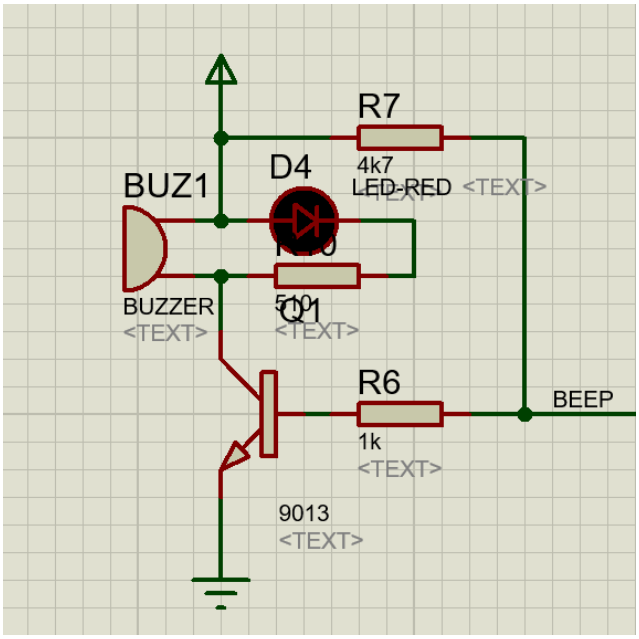

Figure 13. Alarm circuit.

3.6. Key circuit

The principle of the button circuit is to judge the key action by the output voltage. When the key is pressed, the key circuit outputs a low voltage. When the key is released, the key circuit outputs a high voltage. The microcontroller determines the key state by receiving the read voltage relative to the high and low.

Due to the jitter of artificial pressing and the jitter caused by the active contact hitting the fixed contact, the output signal of the microcontroller will be affected, bringing errors to the work of the system [11]. The method of setting the delay is used, in which the output voltage of the key is read independently before and after the delay, to eliminate the impact of this inaccuracy. If both values are low, the key is in the pressed state, and if the two values are different, it is judged that there is an interference signal. The hardware circuit of the button is shown in the figure 15.

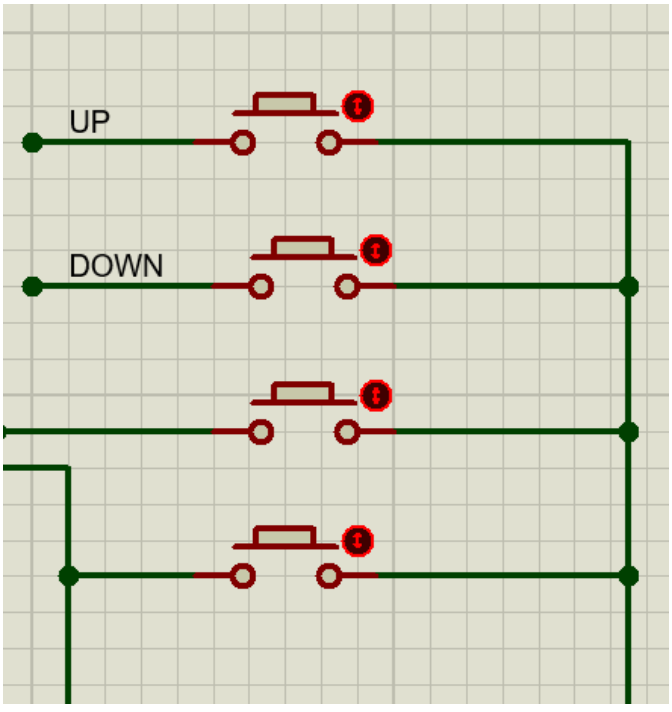

Figure 14. Key circuit.

4. System Software Design

4.1. System main program design

In order to meet the normal use of each function, as well as the microcontroller to control each function, the code writing and conversion part of this design uses Keil software. Keli C51 is produced by Keil Software in the United States, which is a widely used and acclaimed 51 series compatible microcontroller C language software development system, with many advantages, such as comprehensive function, complete structure, and high code readability and low maintenance costs [12]. In this paper, the C code file edited in Keil5 is converted into the standard Hex file for the microcomputer to read.

In order to make the structure of each part of the program clear and easy to understand, each function is programmed separately, and then through the main program for comprehensive collation. Each sub-function is fire prevention function, anti-theft function and liquid crystal display function. At the same time, the subroutines of each function are written separately, which is conducive to the later error correction and maintenance. The following figure 16 is the primary program flow chart.

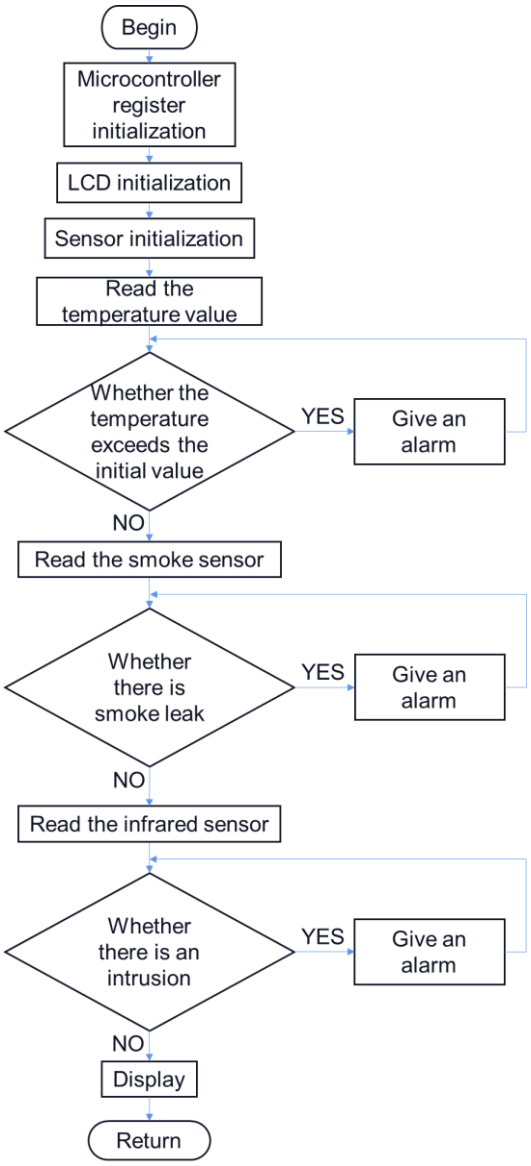

Figure 15. Primary program flow chart.

The operation process is as follows: First, initialize the microcontroller, sensor and LCD display. Second, when the gas, temperature or pyroelectric infrared sensor detection value is abnormal, the audible and visual alarm works to alert the user to a fire or theft. The main program of this design

takes the microcomputer as the main body, and the overall function operation procedure is as depicted in the above image, and the function is comprehensive and the structure is clear and complete.

4.2. Fire prevention function subroutine

The fire prevention function designed in this paper is mainly achieved by detecting the two values of smoke concentration and temperature, and its flow chart is depicted in the figure 17 below. First, initialize the smoke sensor and temperature sensor. Second, check to see if the temperature and smoke concentration data are higher than the predetermined levels. Finally, compare the value with the set value. If it is greater than or equal to the set value, the audible and visual alarm works immediately. Otherwise, determine whether the key is pressed. The function of the buttons in this design is to set the limit of smoke concentration and temperature, that is, to set the corresponding alarm values to achieve fire prevention function. At the same time, the existence of the key function makes the applicable scope and scene of this design wider, and enhances the practicality.

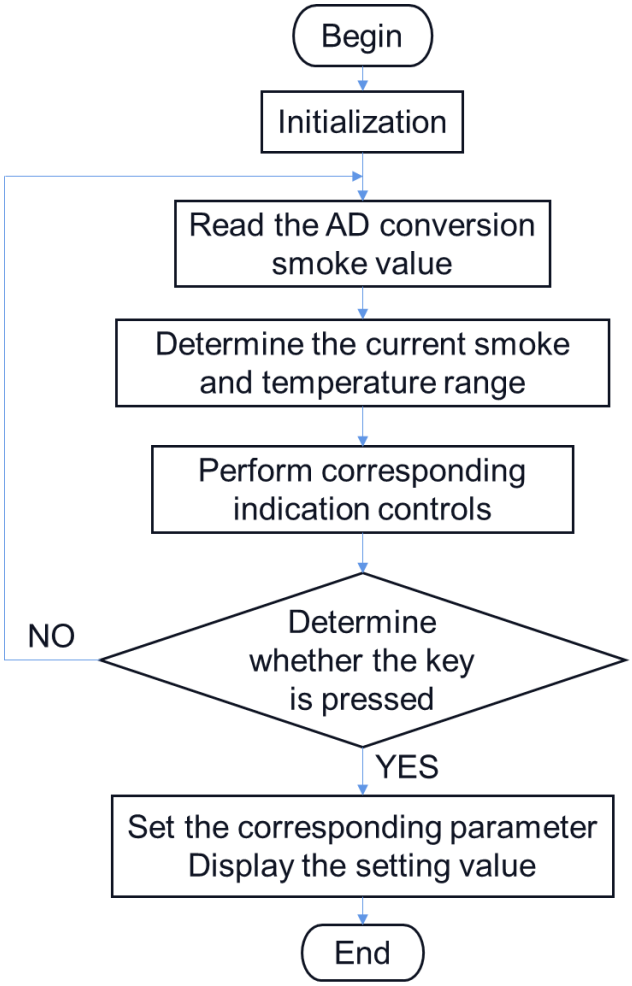

Figure 16. Fire protection function flow chart.

4.3. Anti-theft function subroutine

The realization of the anti-theft function designed in this paper is mainly by detecting the small change signal of the pyroelectric infrared sensor, and the following graphic figure 18 depicts its flow chart. First, initialize the microcontroller. Secondly, detect whether the pyroelectric infrared sensor has an input signal. If there is an input signal, the audible and visual alarm works immediately to achieve anti-theft function. In addition, in order to save power, increase the service life, and ensure that the alarm works normally the next time the sensor generates an input signal, the alarm is set to stop automatically after 10s. At the same time, this setting can also greatly reduce the impact of the system due to false alarms on the normal life and rest of the user.

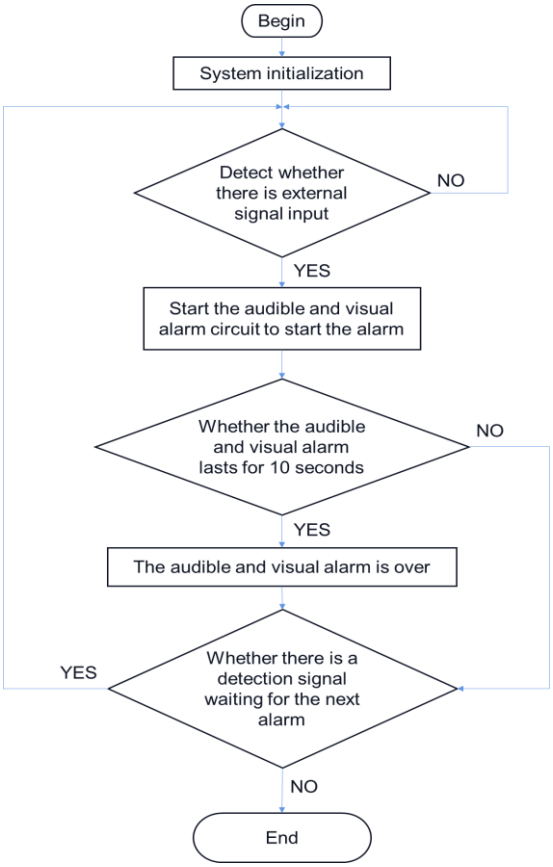

Figure 17. Anti-theft function flow chart.

4.4. Liquid crystal display subroutine

The following figure 19 illustrates the flow chart for the liquid crystal display module developed in this paper, which is primarily utilized to display the configured smoke concentration and temperature values. First, the position of the liquid crystal display needs to be determined. Second, considering that LCD display mode for strings or numbers is that when the position of the first character or number is determined, subsequent characters or numbers are automatically displayed one after another, so when displaying characters or numbers only one placement is required at the beginning. For example, the display of the string "world". When the position of the first letter "w" is determined and displayed, "o", "r", "l" is displayed one by one, and the display task for this string is not completed until the letter "d" is displayed.

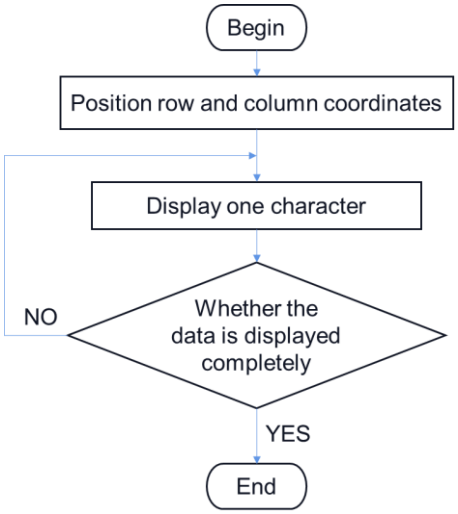

Figure 18. Liquid crystal display flow chart.

5. System Test

In order to realize the control of the microcontroller and the corresponding device modules, the design uses Keli C51 software to write and convert the code. And in this paper, the C code file edited in Keil5 is converted into the standard Hex file for the microcomputer to read.

According to the process of the design scheme, the anti-theft function and the fire prevention function are independent of each other and do not affect each other, so the two parts of code are written respectively. The code program is then entered and compiled. During the compilation process, some problems such as undefined variables, code syntax errors, format errors, etc. were encountered, and the target code that can achieve the normal execution of each function was generated after correction.

For the hardware test, in order to make the circuit structure clear, easy to analyse, check errors, and improve, the hardware circuit was first simulated and debugged to facilitate the subsequent construction of the real circuit. The system simulation circuit diagram is as follows figure 20.

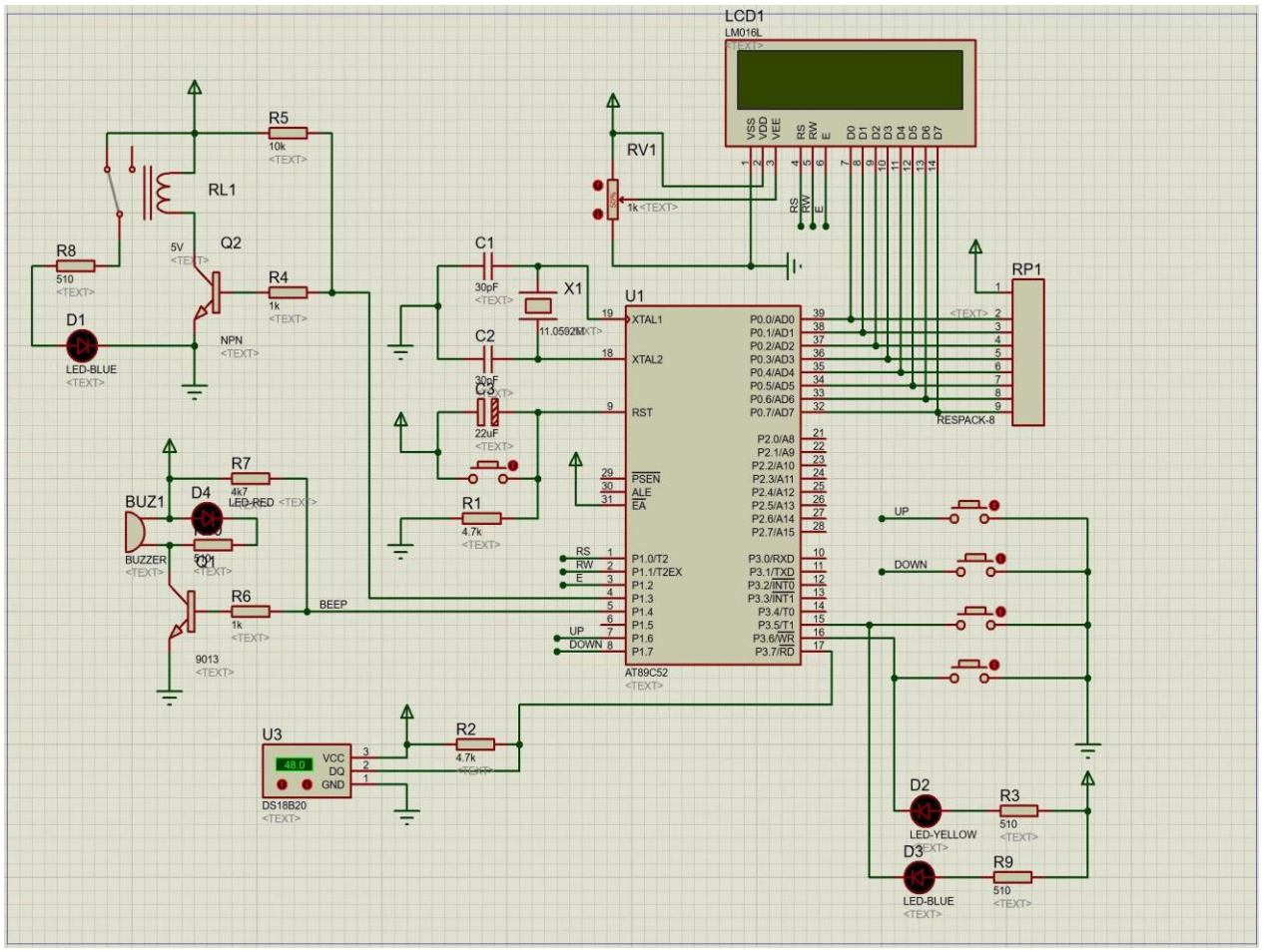

Figure 19. System circuit.

The system is working normally as shown in Figure 21, at this time the temperature monitoring is running normally. The LED display shows that the real-time temperature has not exceeded the limit temperature. The smoke sensor and the pyroelectric human infrared sensor have not detected an abnormal signal, and the buzzer has not emitted a sound. When the pyroelectric human infrared sensor detects an abnormal signal and there is a theft, as shown in Figure 22, the blue LED light in the lower right corner of the figure is lit, and the buzzer makes a sound. When the temperature sensor detects that the temperature is higher than the defined temperature, the buzzer alarms, as shown in Figure 23. When the smoke concentration detected by the smoke sensor exceeds the safe value, as shown in Figure 24, the buzzer alarms, and the yellow LED light in the lower right corner of the figure is lit.

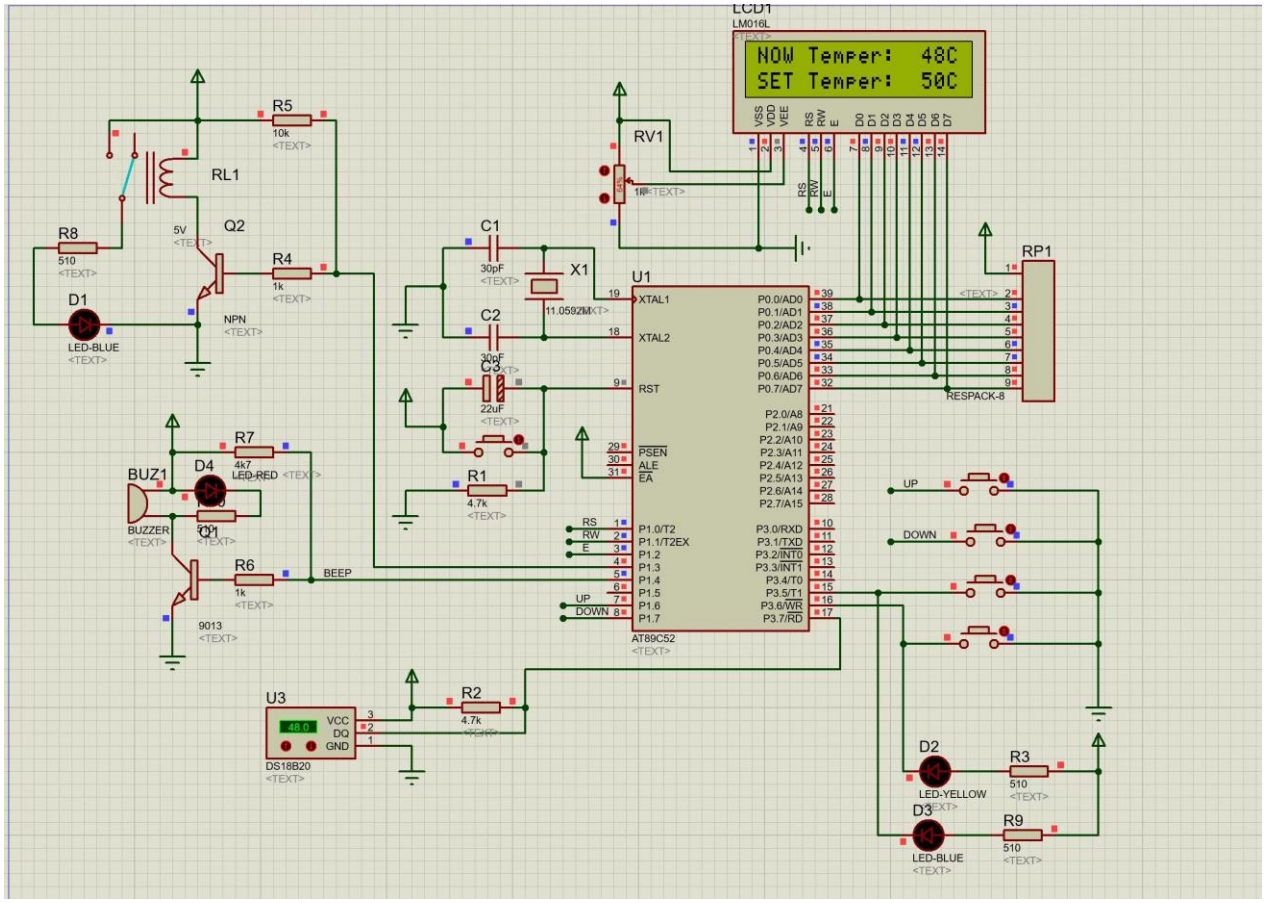

Figure 20. Normal operation of the system.

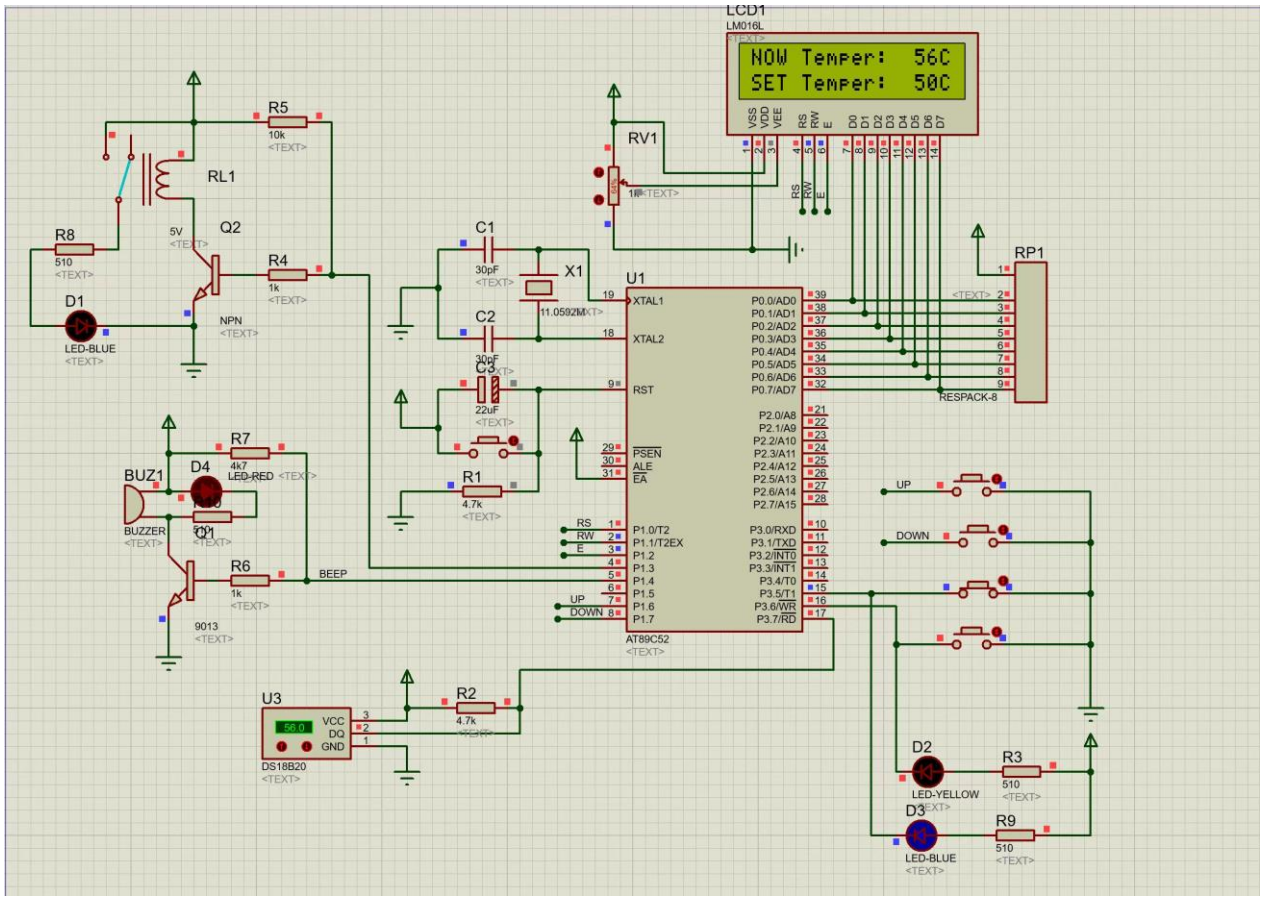

Figure 21. System state diagram in the case of theft.

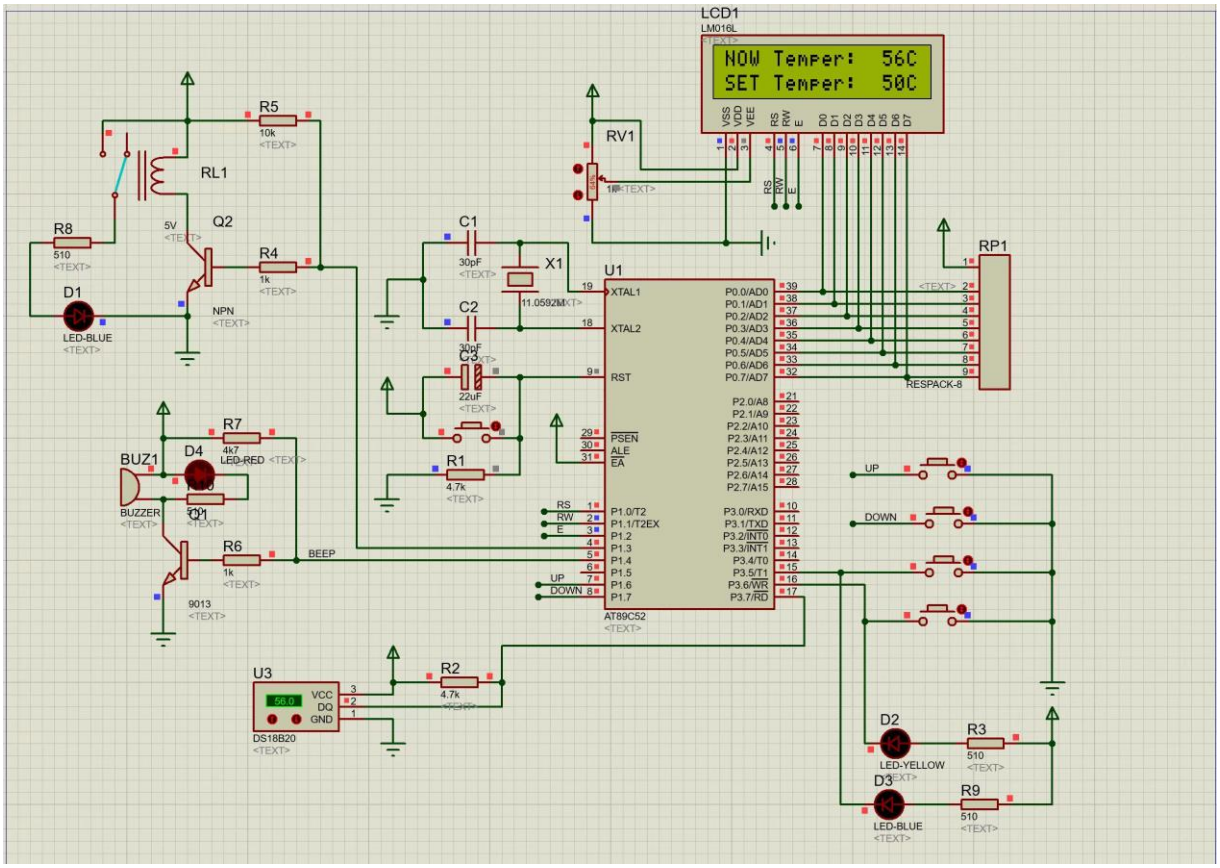

Figure 22. System state diagram in the case of temperature exceeding the limit.

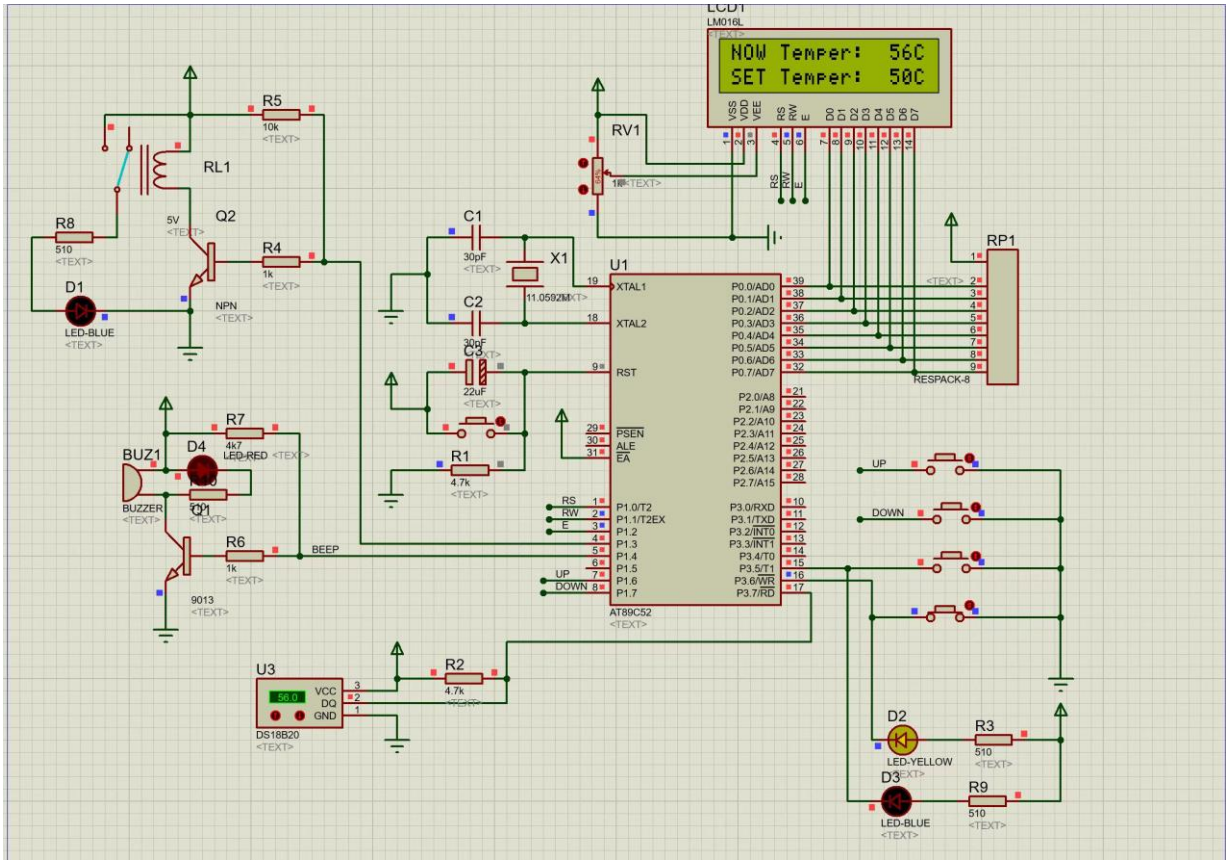

Figure 23. System state diagram in the case of smoke concentration exceeding the limit.

In the construction and debugging of the simulation circuit, some problems were encountered. For example, alarm circuit cannot automatically alarm and the key does not work. After analysis and

correction, the simulation program can run normally, all expected functions can be successfully realized.

6. Conclusion

By analysing the requirements of fire prevention and anti-theft integrated alarms, this paper designs a fire prevention and anti-theft system with a microcomputer as the core, including single-chip AT89C52, smoke sensor MQ-2, temperature sensor DS18B20, pyroelectric infrared sensor, analogy-to-digital conversion chip ADC0832, display LCD1602, a buzzer and other equipment, composed of sensor detection module, minimum system module, key control module, LCD display module and alarm module, so as to achieve fire prevention and anti-theft two sub-functions. Through the simulation and testing of the system circuit by software, the system runs well and the functions can work normally. The functions of fire prevention and theft prevention can be realized, which verifies the feasibility of the design in this paper.

This design integrates the fire prevention function and anti-theft function and makes up for the lack of alarms on the market which are difficult to expand functions and whose function is single. Additionally, it supports the growth of the alarm sector and significantly contributes to the protection of people's lives and property, which is beneficial to social security and stability.

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