ISSN: 2710-0588

Intelligent Smoke Alarm Based on Microcontroller

Zhengwei Song*, Ziliang Liu, Yinghui Li, Lanhe Yang, Runhao Chen

School of Information Engineering, Henan University of Science and Technology, Luoyang, China

*Corresponding author email: 382446574@qq.com

Abstract

The urbanization process is unstoppable, with towering high-rise buildings emerging one after another. In this rapidly developing era, urban buildings continue to rise, and the safety hazards and fire problems of high-rise buildings in cities have not been well solved. Intelligent smoke alarms based on microcontrollers have significant practical significance. Design a real-time fire detection system based on STM32 microcontroller as the microcontroller core, combined with temperature, smoke, and flame sensors to detect various environmental values in real time, providing early warning for fire incidents. By connecting the various communication pins of the sensor through a microcontroller, the signals collected by the sensor are received. The program then quantifies and processes the raw signal data to drive the OLED display screen to display real-time values and alarm status. Applying IoT communication technology, the system is equipped with a WiFi communication module, which can connect to a network cloud server and send data to the cloud server for relay, and then remotely send it to the mobile APP for display, making it convenient for users to check the fire alarm situation in a timely manner. When a fire occurs, the buzzer will be driven for alarm reminder, and the mobile APP can also remotely obtain the alarm prompt, improving the efficiency of fire warning. After on-site practical testing, this system can effectively solve the problem of high-rise building fires.

Keywords

STM32 single chip microcomputer; Sensors; WiFi module; Mobile app.

1. Introduction

1.1. Research Background

The accelerated urbanization process has rendered high-rise building fires a significant threat to public life and property safety[1]. Under the pressures of modern lifestyles, residents often overlook fire hazards, resulting in ineffective emergency responses during fire outbreaks[2]. Statistical data reveal that China experiences over 110,000 fire-related incidents annually, causing thousands of casualties and substantial economic losses[3][4]. Despite ongoing governmental efforts to enhance firefighting infrastructure, conventional rescue methods frequently fail to contain fire spread due to delayed response times[5]. The increasing diversity of building materials further amplifies fire propagation rates and toxic gas emissions, underscoring the critical demand for early warning systems and preventive measures[6].

1.2. Current Research Status (Domestic and International)

Advancements in Internet of Things (IoT) technology have catalyzed innovations in intelligent fire alarm systems. Contemporary systems utilize WiFi connectivity to integrate with residential networks, enabling remote alerts via mobile applications[7]. Combined with miniaturized, low-power sensors, these systems markedly improve response efficiency and monitoring accuracy. Internationally, Siemens pioneered research on high-rise building fire alarms in the 1970s, though early iterations suffered from bulkiness and high costs[8]. In contrast, China achieved rapid progress through IoT adoption despite a later start. Current domestically developed systems integrate high-performance sensors, wireless communication modules, and cost-efficiency, establishing a robust market framework[9].

1.3. Research Significance

Intelligent fire alarm systems synergize IoT and mobile internet technologies, transcending spatial limitations inherent in traditional monitoring approaches. They enable real-time hazard detection and instant emergency notifications. Beyond mitigating fire-induced casualties and property damage, these systems optimize labor resources through automated monitoring, adapting to the complexities of modern living environments[10]. Their implementation holds practical significance for enhancing household electrical safety and refining urban disaster prevention frameworks, positioning them as a cornerstone for smart city development and residential safety innovation[11].

2. Design Overview

2.1. Requirements Analysis

1. Use the STM32 microcontroller as the control core of the system;

2. Use a temperature sensor to collect temperature in real time;

3. Use a smoke sensor to collect smoke concentration in real time;

4. Use a flame sensor to monitor the flame situation in real time;

5. When a flame, high temperature, or high smoke concentration is detected, the buzzer will sound an alarm;

6. The display will show the temperature, smoke concentration, flame status, and respective alarm reminders in real time;

7. Use a WiFi module to send data to a mobile phone APP via a cloud server for remote display and alarm.

2.2. Overall System Design

The system hardware is mainly divided into five parts. The first part is power stabilization, with the system powered at 5V and stabilized to 3.3V to supply the microcontroller and display and other hardware components. The second part is the microcontroller main control, which serves as the control core of the system. The third part is the sensors, including the temperature sensor, flame sensor, and smoke sensor to monitor real-time fire conditions. The fourth part is the OLED display, used to show real-time fire monitoring information. The fifth part is the reminder module, which connects to the internet cloud server to achieve remote data communication with the mobile phone APP. The overall system design is shown in Figure 2-1.

3. Hardware Circuit Design

3.1. STM32 Microcontroller Minimum System Circuit Design

The STM32 microcontroller core system exhibits exceptional stability and high operational speed, attributes derived from its robust 5V voltage tolerance across all I/O pins. To ensure reliable system functionality, stable activation of the external high-speed crystal oscillator (HSE) is essential, as it provides synchronized clock signals for program execution. The system incorporates dual reset mechanisms: an automatic reset circuit initializes the microcontroller upon power-up, while a manual reset circuit facilitates device reinitialization during development and maintenance phases. The manual reset function generates a low-level signal via a tactile switch, triggering hardware and software resets. Upon completion of the reset operation, the MCU executes the program stored in its flash memory based on the configured boot options. The schematic diagram of the STM32 minimum system circuit is illustrated in Figure 3-1.

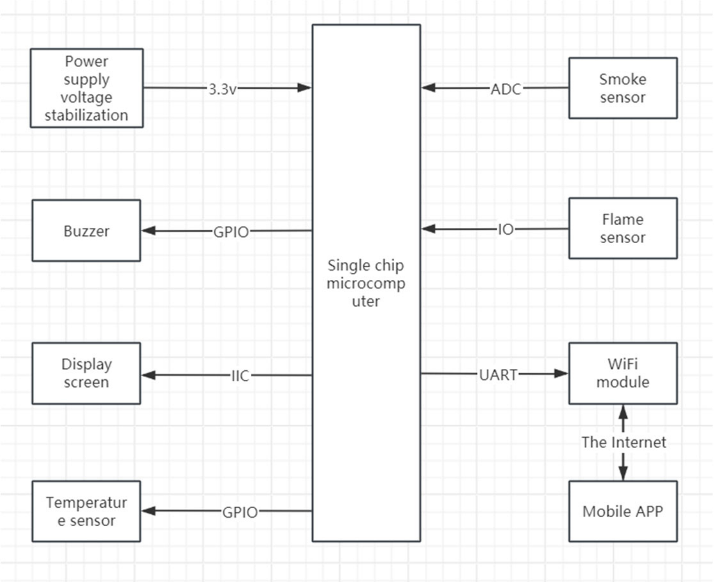

Figure 2-1. Overall Framework Diagram of System Hardware

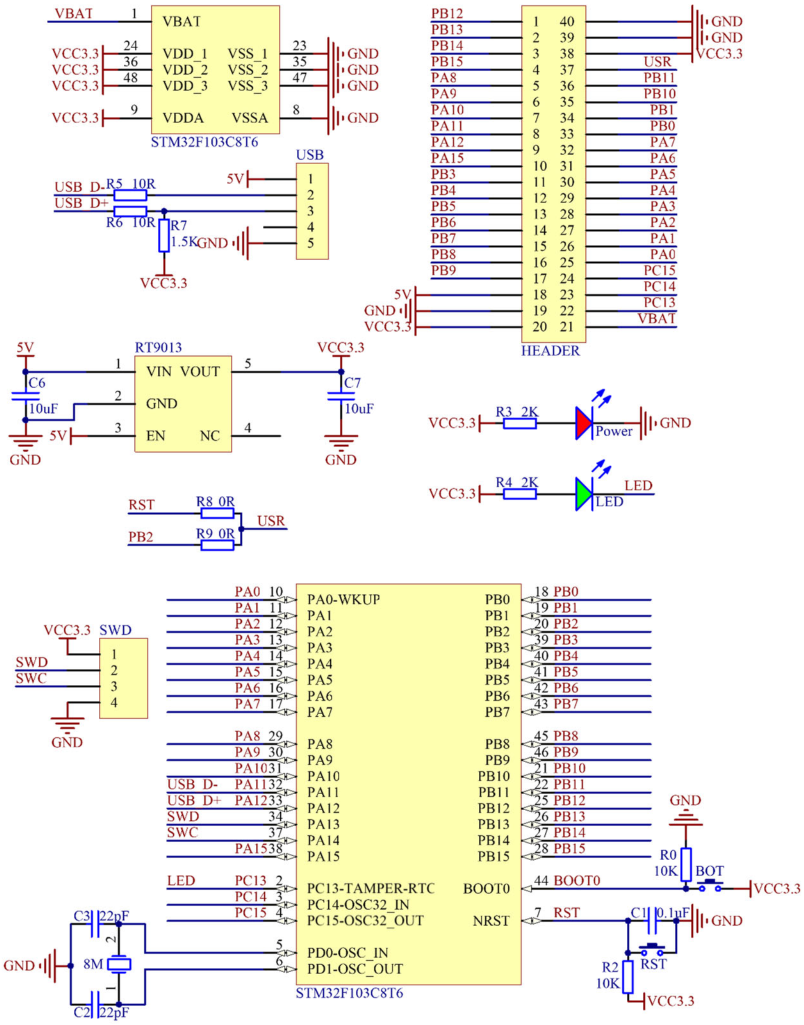

Figure 3-1. Single-Chip Microcomputer Minimum System

ISSN: 2710-0588

3.2. WiFi Module Circuit

Stable power supply to the ESP module is critical for ensuring communication reliability. A decoupling capacitor (C8) is connected in parallel at the power input to suppress electromagnetic interference (EMI) generated during WiFi operation, thereby preventing signal disruption. Pins 1 and 5 are connected to the 3.3V power rail and ground (GND), respectively. The UART interface utilizes W-TX (PA9) and W-RX (PA10) to establish serial communication with the microcontroller unit (MCU). This integrated module combines WiFi-to-serial conversion with an embedded full TCP/IP protocol stack, enabling remote data interaction between the device and a mobile APP through AT command control. Its low-power consumption and wide-temperature operability (-40°C to 125°C) ensure stable operation under harsh environmental conditions. The circuit design is illustrated in Figure 3-2.

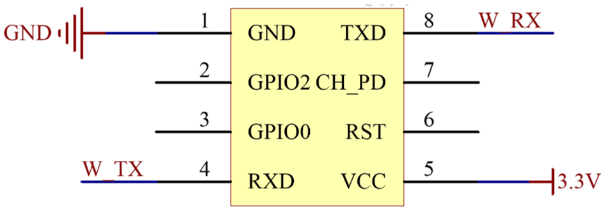

Figure 3-2. WiFi Module

3.3. OLED Display Module Interface Circuit Design

The OLED display module achieves data communication via the I^{2}C bus, with its SCL (clock) and SDA (data) pins directly interfaced to the microcontroller unit (MCU). This self-emissive technology eliminates the need for backlight components, ensuring high efficiency and stable operation. The integrated modular design avoids challenges associated with bare-screen soldering while enhancing system reliability. As illustrated in Figure 3-3, the interface circuit employs the I^{2}C protocol for command transmission, enabling the MCU to drive the display and achieve intuitive visualization of design data.

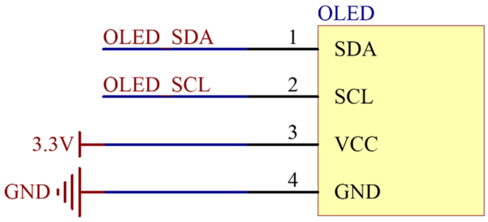

Figure 3-3. OLED Display Module Interface Circuit

3.4. MQ2 Smoke Sensor Circuit

The MQ135 sensor is employed for hazardous gas detection, where its gas-sensitive resistor exhibits a high impedance state in clean air and undergoes linear resistance reduction upon exposure to harmful gases. The analog output pin (VCC 5V) transmits concentration signals, while the DO pin provides digital outputs. For smoke detection, the MQ2 sensor modulates its resistance based on smoke concentration, forming a voltage divider circuit through series connection with a fixed resistor (10kΩ ±1%). The resultant voltage variation is acquired by the microcontroller's ADC (12-bit resolution) and converted into smoke concentration values via linearization algorithms. Both sensor modules feature standardized interfaces with signal conditioning circuits, including EMI filtering (100nF decoupling capacitors) and output buffering (LM358 operational amplifiers). The interface circuits for these gas/smoke detection modules are illustrated in Figure 3-4.

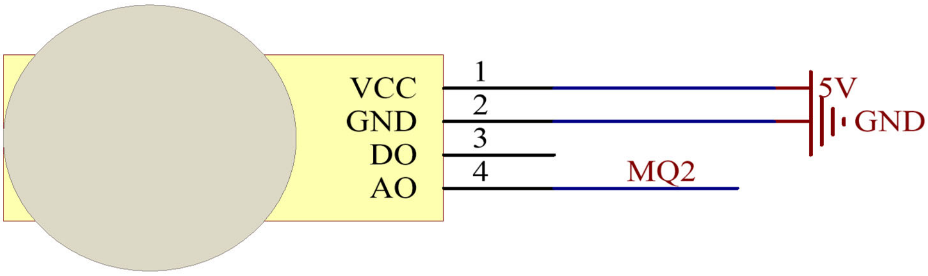

Figure 3-4. Smoke Concentration Sensor Module Interface Circuit

3.5. Design of DS18B20 Temperature Measurement Circuit

The DS18B20 digital temperature sensor is selected for temperature detection due to its compact size, integrated measurement chip, high precision (±0.5°C), and strong anti-interference capability. Among its three pins, pins 1 and 3 are connected to a 3.3V power supply, while pin 2 serves as the single-wire data port. A 10kΩ pull-up resistor is externally connected between pin 2 and 3.3V to ensure a default high logic level, enabling communication with the microcontroller unit (MCU) and temperature acquisition through high-low level transitions. The sensor circuit, supporting a temperature range of -55°C to +125°C with 12-bit resolution, is illustrated in Figure 3-5.

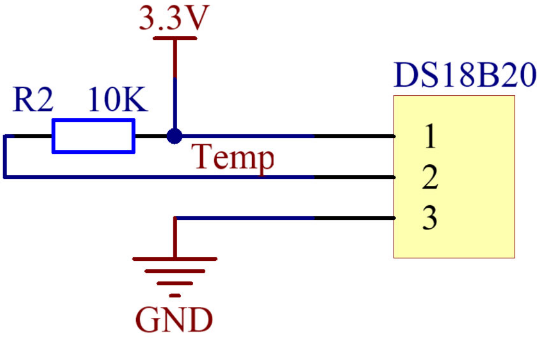

Figure 3-5. DS18B20 Temperature Measurement Circuit

3.6. Flame Sensor Detection Circuit

The flame sensor requires strict 5V power supply, with pins 1 and 2 connected to the power source, and pin 3 (DO) outputting a digital signal. Its internal modulation-demodulation circuit detects flames by identifying specific infrared wavelengths (typically 760–1100 nm). However, ambient light containing similar infrared spectral components (e.g., sunlight or incandescent lighting) may induce false positives. The sensor interface circuit, supporting a detection range of 0.5–3.0 meters with 60° viewing angle, is shown in Figure 3-6.

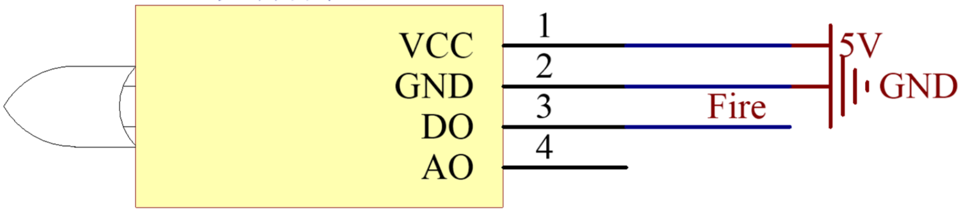

Figure 3-6. Flame Sensor Module Interface Circuit

3.7. Alarm Circuit Design

The alarm system triggers buzzer activation through preset thresholds, enhancing operational utility. The circuit comprises a transistor (e.g., NPN 2N3904), current-limiting resistor (1kΩ), and piezoelectric buzzer (5V/20mA). The transistor amplifies drive current to prevent microcontroller I/O pin overload, with its base connected to the MCU via the resistor. When the MCU outputs a high logic level (3.3V), the transistor conducts, enabling buzzer actuation; a low logic level (0V) cuts off the transistor, silencing the alarm. This configuration ensures dual functionality: current amplification ($\beta>100$) and current limitation ($I_c<100mA$), achieving stable single-signal control while protecting MCU hardware. The alarm circuit schematic is shown in Figure 3.7.

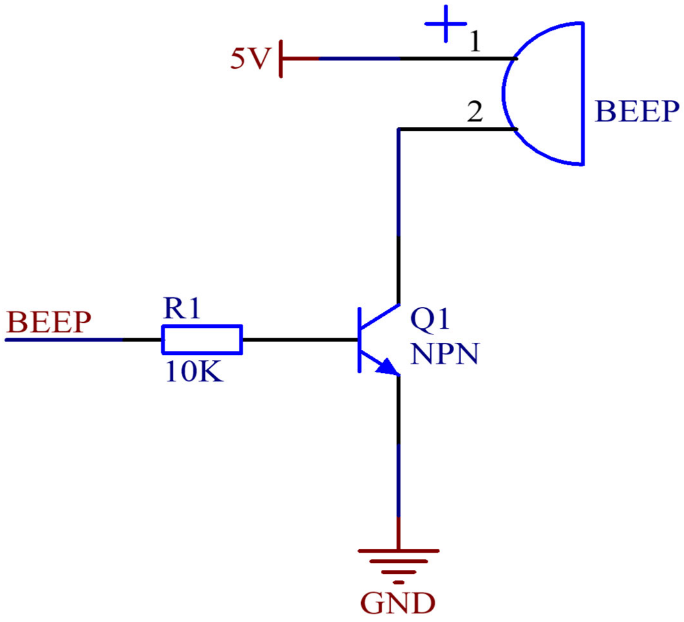

Figure 3-7. Buzzer Alarm Circuit Diagram

4. System Software Design

4.1. Main program flow

After the fire alarm system is powered, the MCU will automatically reset, and then the program will locate and run to the main function. After entering the main function, the initialization operation will be carried out first to initialize ADC interface, GPIO interface, WiFi interface and OLED interface, and after the initialization, wait for the WiFi module to connect to the WiFi router. After the router is connected successfully, it will enter the while(1) main cycle, cycle to detect the smoke concentration, temperature and flame status and display it in real time through the OLED display screen, then determine whether there is a fire. If the smoke or temperature exceeds the threshold, or the flame sensor is triggered, the buzzer will be driven to sound the alarm, and then determine whether the APP has received the instruction to set the threshold. If yes, the analytic instruction acquisition threshold is saved in the MCU Flash, and finally the data and alarm signal are sent to the mobile APP remotely through the WiFi module for display.

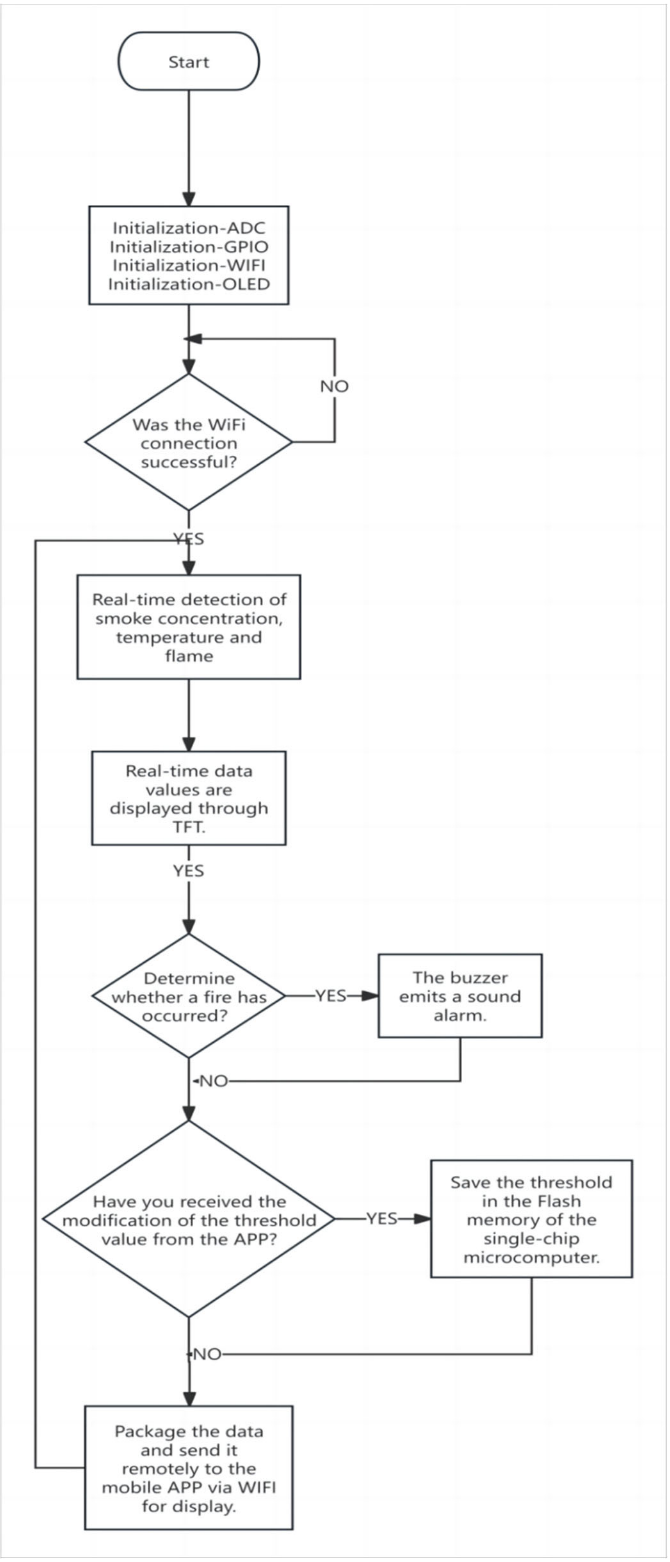

Figure 4-1. Main Program Flowchart

5. System Debugging and Analysis

5.1. Hardware Debugging

5.1.1. Communication Module Debugging

The wifi signal stability determines whether communication quality, wifi communication depends on the signal strength, the ambient radio interference and the power supply stability in the environment, the most easy problem is that the power supply and wifi module need the current of 500ma, so the current is required, so the current is required, so the supply current is needed, otherwise the wifi transmission and data error will be caused by the transmission of the wifi. The wifi module debugging diagram is shown in figure 5-4.

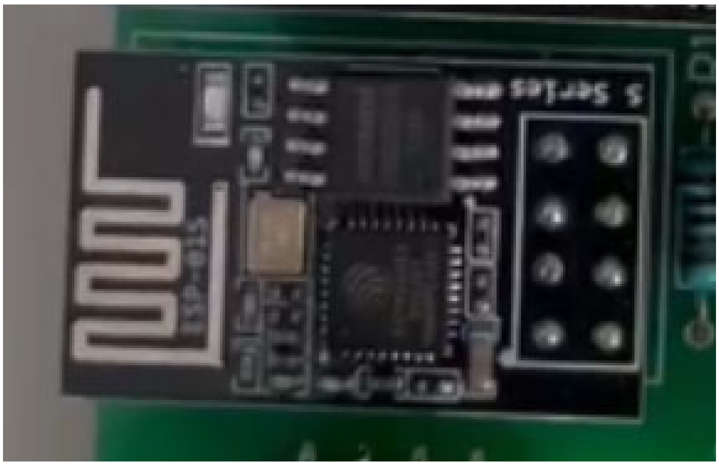

Figure 5-4. Physical diagram of the WiFi module

5.1.2. Sensor Module Debugging

The debugging of the sensor is mainly for the adjustment of the flame sensor and MQ2 sensor, and the temperature sensor can check whether the power supply is normal. The smoke sensor and flame sensor can measure the voltage of the output pin of the module through a multimeter. The AO pin of the smoke sensor will output different voltages according to different concentrations of smoke. If this effect is achieved, it indicates that the smoke sensor is working normally. When the flame sensor detects the flame, the pin output voltage is low, and the flame voltage is high when it is not detected. If this effect is achieved, it indicates that the flame sensor is working normally.

6. Conclusions

This design completes the development of intelligent smoke alarm based on single chip microcomputer, and realizes the function of smoke detection and buzzer alarm through sensor selection, circuit welding, hardware and software cooperation. The system runs stably. The test shows that it can quickly respond to smoke and trigger local sound and light alarm. At the same time, it supports remote status monitoring by mobile phone APP, which has practical application value. Subsequent optimization direction:

1. The extension SMS alarm functions improve the response time;
2. Increasing water valve linkage fire module system integrity;
3. The optimization of environment adaptability to expand application scenario.

Acknowledgements

This work was supported by Undergraduate Training Program for Innovation and Entrepreneurship of Henan University of Science and Technology (No. 2024144).

References

[1] Xu, L. P. (2016). Survival of the Smartest in Intelligent Home Appliances. Shanghai Informatization, (4), 42–45.

[2] Ma, Y. (2013). Design and Application of Smart Sockets in Energy Conservation for Universities. Bulletin of Science and Technology, (9), 102–105.

[3] Zhou, C. Y., & Wang, T. (2015). Market Analysis of Switch and Socket Industry in China. China Economist, (6), 265–266.

[4] Chen, X. J. (2015). Development and Trends of the Smart Home Industry. World Electronic Components, (7), 41.

[5] Feng, J. F. (2017). Role of IoT in Manufacturing Informatization. In Yunnan Mechanical Engineering Society (Ed.), 2017 Annual Conference Proceedings of Yunnan Mechanical Engineering Society (p. 4). Kunming: Yunnan Mechanical Engineering Society.

[6] Cheng, D. Z., & Shen, Y. (2017). Dilemmas and Prospects of Smart Homes. Intelligent Buildings and Smart Cities, (2), 10–18.

[7] Chen, H. (2017). Design of IoT-based Smart Home Security System. Value Engineering, (8), 67–69.

[8] Zhang, W. X. (2017). Human-Computer Interactive Smart Home Security System Design. China New Technologies and Products, (4), 129–130.

[9] Alibaba Cloud Plans to Provide Computing and AI for "New Manufacturing". (2016). Internet World, (12), 89.

[10] Chen, L., Gao, H. L., & Zhou, L. (2015). Application of Embedded Servers in Smart Home Systems. Computer Measurement & Control, (5), 1758–1761.

[11] Qing, Y. (2017). Review of Smart Home Development and Key Technologies. Software Guide, (1), 180–182.