Smart Home Security System Based on STM32

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Abstract: The Internet of Things (IoT) is developing at an explosive speed, and its impact on the world is becoming increasingly prominent. As a key trend in modern home life, smart home has become one of the core application scenarios of IoT technology, and the practical application of relevant technologies in the smart home field has achieved initial results.

With the continuous maturity of the application of IoT technology in smart home systems, aiming at the potential security risks existing in current smart home systems (such as the demand for real-time monitoring of residential environments) and the limitations of existing home security systems, this paper designs a highly networked smart home security system based on IoT. The system takes the detection, interception and alarm of unauthorized access as its core objectives, and its hardware architecture includes two nodes with CC2530 chip as the main control: one is the coordinator node, which is responsible for network establishment, maintenance and data interaction with the PC terminal; the other is the terminal device node, which undertakes the task of controlling various functional modules and transmits the collected data to the coordinator. The functional modules equipped in the system mainly include a temperature and humidity collection module, a smoke detection module, a relay module and a human body infrared sensor module.

This paper conducts research on the IoT-based home security system, not only analyzing its working principles from the theoretical perspective, but also building a simple home environment security monitoring system from the hardware perspective.

Keywords: System of Smart Home Internet of Things Smart House Security sensor network

1. INTRODUCTION

A smart home takes a residence as the platform. It integrates facilities related to home life by utilizing integrated wiring technology, network communication technology, security prevention technology, automatic control technology, and audio-visual technology. This integration builds an efficient management system for residential facilities and daily household affairs, enhancing the security, convenience, comfort, and aesthetics of the home while ensuring an eco-friendly and energy-saving living environment [1]. Smart home is also known as an intelligent residence. Generally speaking, it is a networked and intelligent home control system that integrates an automatic control system, a computer network system, and network communication technology[2]. A smart home enables users to manage household devices through more convenient means. For instance, users can control home devices via in-home touch screens, wireless remote controls, phones, the Internet, or voice recognition. They can even execute scenario-based operations to realize linkage among multiple devices. On the other hand, various devices within a smart home can communicate with each other and operate interactively according to different states without requiring user instructions, thereby providing users with the highest level of efficiency, convenience, comfort, and security[3].

A smart home system is a comprehensive system that integrates technologies including integrated wiring technology, network communication technology, security prevention technology, automatic control technology, and audio-visual technology, as well as devices related to home life[4]. Due to the differences in technical standards and protocols adopted by smart homes, most smart home systems use integrated wiring. However, a few systems may not adopt this technology—power line carrier communication is one such alternative. Regardless of the case, there must be corresponding network communication technology to complete the required signal transmission tasks. Therefore, network communication technology is one of the key technologies in smart home integration. Security prevention technology is indispensable in smart home systems and is widely applied in areas such as visual intercom (both within residential complexes and households), home monitoring, home anti-theft alarms, and community all-in-one cards for household-related services[5]. Automatic control technology is also essential for smart home systems; it is extensively used in smart home control centers and automatic control modules for home devices, playing a crucial role in the scientific management of household energy and the schedule-based management of home devices. Audio-visual technology is vital for achieving the comfort and aesthetics of the home environment, and it is reflected in aspects such as centralized audio-visual distribution, background music, and home theaters .

2. OVERALL DESIGN OF THE SYSTEM

This design realizes real-time monitoring of the home environment by establishing a ZigBee wireless network. The ZigBee wireless network consists of one coordinator node and one terminal device, both of which are composed of development boards built with TI's CC2530 chips. These two development boards are identical; their different functions are achieved by burning different program codes during use[6].

The ZigBee technology adopted in this paper has the advantage of low power consumption—only two AA batteries can support operation for approximately 6 months to 2 years[7] . Therefore, there is no need to design a dedicated power module for power supply, which would be very inconvenient in use. Besides battery power supply, another method is to power the nodes with solar cells, which will not be introduced here. As shown in Figure 1.
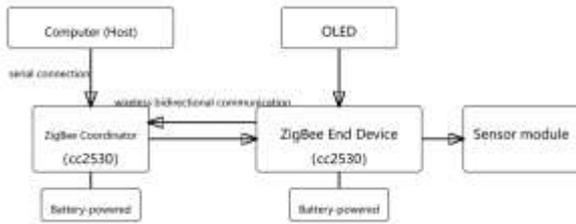
Figure.1 Overall System Framework

3. PROJECT DESIGN

3.1 CC2530 Chip Overview

The CC2530 is a true system-on-chip (SoC) solution designed for 2.4GHz IEEE 802.15.4, ZigBee, and RF4CE applications. It enables the establishment of robust network nodes at a very low total material cost. The CC2530 combines excellent performance of a leading RF transceiver with an industry-standard enhanced 8051 CPU, system-on-chip programmable flash memory, 8KB of RAM, and many other powerful features. The CC2530 is available in four different flash memory versions: CC2530F32/64/128/256, providing 32/64/128/256KB of flash memory, respectively. The CC2530 offers various operating modes, making it particularly suitable for systems with ultra-low power requirements. The short transition times between operating modes further ensure low power consumption[8].

The integrated modules within CC2530 can generally be classified into three types: modules related to the CPU and memory; modules related to peripherals, clock, and power management; and modules related to the radio[9].
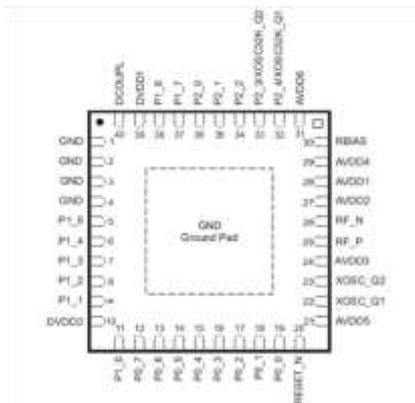

Figure. 2 Functional Pin

3.2 DS18B20 Temperature Sensor

The DS18B20 is a high-precision, digital-output 1-Wire digital temperature sensor that operates on the thermistor principle. It integrates a temperature-sensitive thermistor and an analog-to-digital converter (ADC) internally. When activated, the sensor converts the ambient temperature into a digital signal and transmits it to the main controller via the 1-Wire bus protocol[10]. Below is a detailed introduction to the DS18B20 temperature sensor and its performance parameters:

The DS18B20 temperature sensor is characterized by its wide range of application scenarios and excellent performance. It can work normally within an operating voltage range of 3V to 5.5V, ensuring stability and accuracy in measurements. Its temperature measurement range covers -55°C to +125°C, making it suitable for temperature monitoring in various thermal environments. Users can set different resolutions (ranging from 9-bit to 12-bit) as needed to meet the requirements of different application scenarios. Within the range of -10°C to +85°C, the DS18B20 achieves a measurement accuracy of ±0.5°C, guaranteeing high-precision measurements.

The DS18B20 outputs temperature data in digital signal form, simplifying the process of data processing and transmission. It uses the 1-Wire bus protocol for communication, requiring only one data line to complete both communication and power supply—this reduces connection costs and complexity. In addition, the DS18B20 is available in multiple package types, such as TO-92, TO-220, and SMD, to adapt to different application scenarios and installation requirements.

In terms of power consumption, the DS18B20 performs exceptionally well. Its low-power design makes it suitable for applications with strict power supply requirements. Meanwhile, the DS18B20 is equipped with a power-failure protection function, which can retain the set values of resolution and alarm temperature after a system power outage. Each DS18B20 has a unique 64-bit ROM code, allowing multiple DS18B20 devices to be connected to a single I/O port; these devices can be uniquely identified and controlled through ROM operation commands.

Figure.3 DS18B20 Temperature and Humidity Module Diagram

3.3 The Gas Sensor Module

For this experiment, it is necessary to detect gases present in the external environment, so two gas detection modules—MQ-2 and MQ-6—were selected for application.

Figure.4 Gas Sensor Module

The Gas Sensor module can detect multiple types of gases simultaneously, including flammable gases (such as natural gas and LPG) and smoke. It is suitable for use in households, industrial settings, safety monitoring, and other fields. This sensor has a sensitive response to gases and can detect the presence of gases at low concentrations. Additionally, the

MQ-2 module is equipped with both analog output and digital output, allowing for easy connection to micro controllers and convenient integration into various projects. Furthermore, the module features a robust design, making it suitable for long-term use and adaptable to a variety of environmental conditions.

4. SOFTWARE SYSTEM DESIGN

For software programming in this project, Keil uVision5 is mainly used, and its programming interface is shown in the figure. Keil uVision5 is an integrated development environment (IDE) primarily used for programming microcontrollers in embedded systems. It is also a comprehensive software suite that includes a source code editor, project manager, debugger, and other essential tools required for microcontroller development, debugging, and programming.

Developers can directly write C language programs in this IDE and compile them using the built-in compiler to generate programs that can run on the target hardware. Keil uVision5 also provides a source-level debugger, which can simulate various different MCU hardware platforms, helping developers perform real-time debugging during the development process.
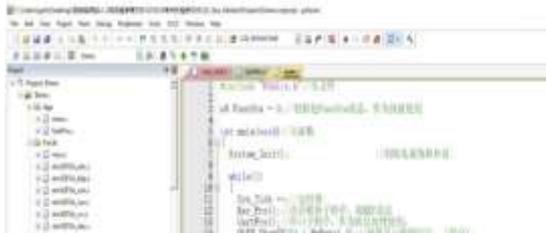

Figure.5 Software Development Tools

The ZigBee Management System is a software designed to manage and monitor wireless sensor network systems. Different models can be configured for various development projects. The functions of the ZigBee Management System used in this design include: detection of ambient temperature and humidity along with temperature/humidity trend curves; smoke detection function; and light control function. The interface of the ZigBee Management System is shown in Figure 6.

The ZigBee Management System serves as a host computer, enabling the control of home environments and household appliances. This allows for a clear understanding of the home environment and facilitates remote control of household appliances, thereby realizing home security functions.

Figure displays the interface when the management system is just opened. Once the wireless sensor network is established and all functional modules are operating normally, the interface shown in Figure 5.6 appears during data collection.

The operation steps are as follows: first, open the management system, locate the serial port and open it; then click the "Auto Update" button; finally, press the S1 key on the terminal device to upload data. At this point, the data collected by the functional modules will be displayed on the interface of the management system. In addition, when we press the "Turn Off All Lights" button on the management system, the table lamps in the home will be turned off.

Figure.6 Management System Monitoring Interface

5. System Implementation and Debugging

The wireless network designed in this paper comprises two nodes: a coordinator and an end device. The entire network is initiated and established by the coordinator, and its specific workflow as well as the operation mechanism of relevant modules are as follows:

In the phase of network establishment and node status feedback, after powering on the coordinator node, if its LED3 stays steadily on, it indicates the successful establishment of the network. Subsequently, when the end device node is powered on, its LED1 will be in a blinking state initially. Once the end device successfully joins the network, its LED3 will switch to a steady-on state, and the display screen will show "EndDevice:A9e3 Parent:0". In this information, "A9E3" represents the address of the end device, and "0" represents the address of its parent node (i.e., the coordinator).

In terms of handling abnormal network states, if the coordinator suddenly loses power and causes network interruption, both LED1 and LED3 of the end device will blink simultaneously, and the end device will continuously scan the surrounding environment to detect whether the network is restored. At this time, the display screen will show "Assoc cnf fail" to indicate that the end device has failed to join the network.

In addition, the working state of the smoke alarm module is closely linked to indoor air quality: when the indoor air quality is good, the LED light on the module remains off; when the smoke concentration is relatively high, the LED light of the module will turn on automatically, and the system will start the exhaust fan at the same time to expel harmful gases from the room to the outside. If the smoke concentration reaches an excessively high threshold, the LED light of the module will remain on, and the buzzer will start synchronously to trigger a smoke alarm.

To verify the function of the smoke alarm module, during the system testing phase, a lighter was used to release smoke to the smoke sensor, simulating a scenario where harmful gases exist. Through testing, this functional module can accurately respond to changes in smoke concentration, and all actions such as the on/off of the LED light, the start/stop of the exhaust fan, and the alarm of the buzzer meet the design expectations, with the function operating normally.
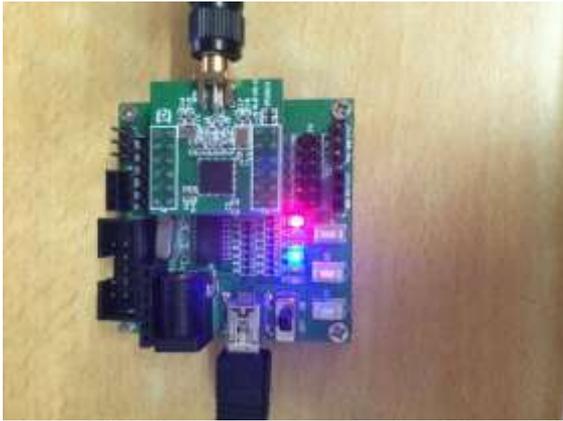
Figure. 7 Physical Test Result Diagram

6. Conclusion

To sum up, the smart home security system based on STM32 takes the high-performance and low-cost STM32 micro controller as its core, and effectively integrates various security sensing modules (such as human infrared sensing, door/window magnetic control, smoke detection, gas leakage monitoring, etc.), execution modules (such as sound and light alarms, smart door locks, remote linkage switches, etc.) and communication modules (such as Wi-Fi, Bluetooth or ZigBee). It builds an intelligent security system that integrates "real-time monitoring, abnormal early warning, remote control and historical traceability".

In terms of hardware design, the system makes full use of the multi-peripheral interface and low-power characteristics of STM32 to achieve accurate collection and efficient processing of multi-dimensional security status of the home environment. In terms of software design, modular programming is used to optimize the data transmission logic and alarm response mechanism. This ensures that when security risks such as illegal intrusion, fire hazards, and gas leakage occur, local sound and light alarms can be triggered quickly, and early warning information can be simultaneously pushed to users through terminals such as mobile phone APPs. Users can remotely check the on-site status or perform emergency operations (such as remotely closing gas valves, starting exhaust fans, etc.).

Through physical tests and scenario verification, the system operates stably and responds in a timely manner. It not only meets the core needs of home users for basic security, but also can be adapted to different house types and personalized scenarios through function expansion. It provides a practical and feasible implementation path for low-cost and high-reliability solutions in the field of smart home security, and has strong practical value and promotion potential.

7. REFERENCES

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