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Design of a High-Reliability Dual-Mode Communication Infrared Security System

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Abstract: This paper introduces a dual-mode communication infrared security system based on microcontroller technology, utilizing both active and passive infrared detectors for intrusion detection. The microcontroller processes and controls data to ensure accurate detection and effective alarm functions. Upon detecting an intrusion, the sensor transmits a signal to the microcontroller, which processes the data and uses software algorithms to confirm the intrusion, thereby triggering audible alarms, visual alerts, and real-time notifications to the user's mobile phone. Experiments demonstrate that this security system can accurately detect intrusions and promptly trigger alarms. Compared to traditional systems, this design provides timely communication, allowing users to take immediate action. It offers diverse alarm functionalities, fully utilizing different modules to ensure accurate and timely notifications in various environments, enhancing both practicality and reliability.
Keywords: Security alarm; Microcontroller; Infrared sensor; Alarm control; Communication module

1. INTRODUCTION

With the advancement of society and technology, the demand for improved living standards has made security a critical concern. Theft prevention is not only essential for protecting property and personal safety but also crucial for maintaining social stability and harmony. Infrared security alarms, as a common and highly effective security device, are widely used in homes, offices, shopping malls, and other settings. They play a critical role in prevention and awareness, enhancing security consciousness.

This paper presents the design of a high-reliability, dual-mode communication infrared security alarm system. The goal is to utilize a microcontroller to manage the operation of the infrared security system, providing a highly integrated, stable, and expandable solution to support everyday security needs.

Traditional alarm systems often suffer from slow response times, high false alarm rates, and challenges in real-time monitoring. In contrast, microcontrollers offer high precision, versatility, stable operation, and low power consumption, making them ideal for embedded security applications. In recent years, microcontrollers have been increasingly applied in intelligent alarm systems [5].

This design uses the STM32F103C8T6 microcontroller as the central processing unit, integrating infrared sensors for signal acquisition, detection, and processing. It combines audible and visual alarms for a more impactful alert system. Upon triggering, alarm notifications are sent to the user's mobile phone via WIFI and GSM modules, ensuring timely alerts for appropriate responses.

2. SYSTEM OVERALL DESIGN

This paper proposes an infrared anti-theft alarm system based on the STM32 microcontroller. The system consists of the STM32 microcontroller, active infrared sensors, passive infrared sensors, a WIFI module, a GSM module, a buzzer, LED lights, and a virtual platform. As a smart device, the system not only features automatic alarm functionality but also incorporates WIFI serial communication and GSM remote communication capabilities. Through the integration of multiple modules, the system forms a complete anti-theft solution. The overall system block diagram is shown in the figure.

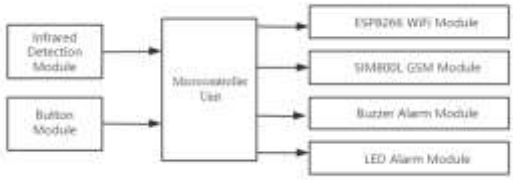

Figure. 1 System Block Diagram

3. HARDWARE DESIGN

3.1 Microcontroller Minimum System

A high-performance microcontroller is selected as the controller, characterized by high precision, low power consumption, and fast response, enabling rapid processing of sensor data and real-time control. This system uses the STM32F103C8T6 microcontroller, a 32-bit microcontroller from STMicroelectronics based on the ARM Cortex-M3 core. It is a mainstream model in the STM32F1 series and is widely used due to its stable performance, abundant resources, and low cost[2]. The minimum system circuit of the microcontroller includes the microcontroller itself, a crystal oscillator, a reset circuit, and a power supply circuit[3].

3.2 Button Module

Users can configure the system into two modes based on their needs: arming mode and disarming mode. Pressing the button switches the system to “arming mode”; pressing it again switches to “disarming mode.” Users can freely change modes at any time according to their preferences.

3.3 Sound and Light Alarm Module

The buzzer alarm module and the LED light alarm module together form the sound and light alarm module. In an intelligent alarm system, sound and light alarms are crucial

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components that deliver visual and auditory feedback. These two types of alarms ensure effective alerting in various environments. The microcontroller, through a dedicated driver circuit, ensures effective control of this module. The microcontroller is preprogrammed with the operating modes of the LED light and buzzer, including LED brightness, blinking frequency, and duration, as well as the buzzer's pitch, volume, and duration[4]. When an alarm is triggered, the LED light and buzzer activate in a predefined pattern, not only attracting attention but also conveying additional information such as the level of emergency.

3.4 Wireless Communication Module

In this system, the wireless communication module consists of both a WIFI module and a GSM module, serving as the key components for enabling remote communication and data transmission. The alarm mode is configured with WIFI as the primary communication method and GSM as a backup. When a stable indoor WIFI connection is available, the system uses the ESP 8266 module to send alarm notifications to a mobile phone. If the WIFI connection is interrupted or tampered with, the system automatically switches to the SIM800L module to send alarm messages via SMS, thereby ensuring system reliability and making full use of both modules' advantages.

This system uses the ESP 8266 module as the core component of wireless communication. It is a high-performance, low-cost WIFI chip that supports three working modes (STA/AP/SATRAP). With its powerful WIFI capabilities and integrated microcontroller (MCU), the ESP 8266 can operate independently or act as a communication module in conjunction with a microcontroller. It is widely used in IoT devices, smart home systems, remote monitoring, and wireless sensor networks. In this anti-theft system, the WIFI module is connected to the microcontroller via serial communication. Specifically, the module's TX (transmit) pin is connected to the microcontroller's RX (receive) pin, and its RX (receive) pin is connected to the microcontroller's TX (transmit) pin, allowing data exchange between the microcontroller and the WIFI module via UART. The ESP 8266 publishes the acquired data to an MQTT server, which enables the mobile app to retrieve data at any time and detect intrusions.

The SIM800L module is also a core component of wireless communication. It is a compact GSM/GPRS module widely used for SMS messaging, voice calls, GPRS data transmission, and cost-effective IoT devices. Due to its small size, low power consumption, and affordability, it has become a popular choice for IoT and remote-control applications[5]. In this system, the SIM800L module is also connected to the microcontroller's UART pins via a serial interface.

To avoid pin conflicts with the WIFI module, a dual-UART hardware solution is adopted. The RX pin of the ESP 8266 is connected to the TX pin (PA 10) of the microcontroller, and its TX pin is connected to the RX pin (PA 9) of the microcontroller. The RX pin of the SIM800L is connected to the TX pin (PA 3) of the microcontroller, and its TX pin is connected to the RX pin (PA 2). This configuration allows the system to be simple and reliable without requiring additional switching circuits, while enabling it to handle both WIFI and GSM data effectively.

4. SOFTWARE DESIGN

When the device is powered on, the user must press the main power switch. At this point, the device performs initialization operations. To activate the anti-theft system, the user presses the "arming" button. Once an unauthorized intrusion occurs, the infrared sensor begins collecting data in real time and transmits it to the microcontroller for processing. The microcontroller analyzes the data and then transmits the processed results to various modules to trigger an alarm. The microcontroller activates the sound and light alarm module, where the buzzer emits a piercing sound and the LED light flashes brightly to alert others. At the same time, the alarm information is sent to the mobile app via the WIFI module, notifying the user of the intrusion in real time. Simultaneously, the GSM module sends the intrusion alert to the user's phone via SMS. Upon receiving the alert, the user can take immediate action to prevent property loss. Since the ESP 8266 module heavily relies on the WIFI network and may be affected by network fluctuations, an intelligent switching algorithm is designed. When network instability is detected, the system automatically switches to the GSM module for alarm transmission, effectively avoiding missed alerts. The system's operational flowchart is shown below.

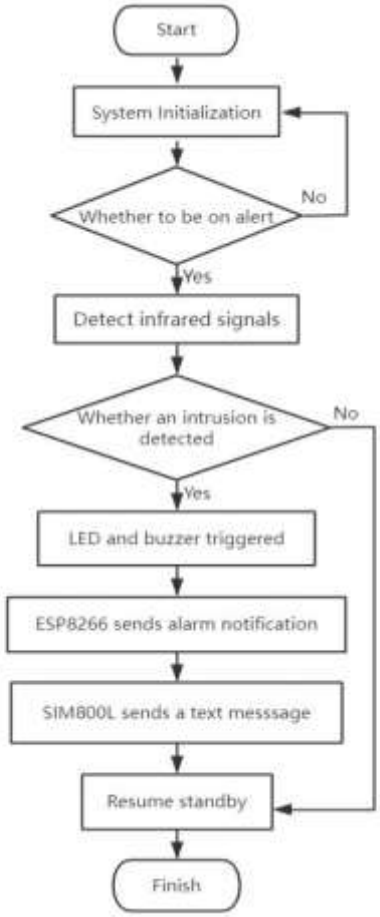

Figure 2. System Flowchart

5. CONCLUSION

The high-reliability dual-mode communication infrared security system designed in this study fully leverages the advantages of modern microcontroller technology, infrared sensing, and wireless communication to achieve intelligent

and efficient security protection. By combining active and passive infrared sensors, the system accurately detects intrusion events. The STM32F103C8T6 microcontroller is used as the core controller, ensuring high data processing efficiency and stable system operation. The integration of both Wi-Fi and GSM communication modules enhances the timeliness of alert notifications and improves the system's fault tolerance and communication reliability. Featuring sound and light alarms as well as remote message alerts, the system is suitable for a wide range of scenarios including homes, offices, and shops, providing users with real-time and comprehensive security protection. Experimental results confirm that the system is well-structured, functionally complete, and offers excellent practicality, scalability, and reliability, making it highly applicable for broader deployment. In the future, the system can be further enhanced by integrating AI-based image recognition and cloud platforms to achieve a more intelligent and advanced security management solution.

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