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Design of Lightweight, High Precision, Multi Scene Module Based on Narrowband Internet of Things

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Absrtact: At present, the number of active IoT devices worldwide has exceeded 16 billion, but existing devices generally suffer from problems such as large size, short battery life, low level of intelligence, and poor stability. In response to the limitations of traditional IoT terminals in terms of size, power consumption, and scene adaptability, this paper designs a lightweight IoT intelligent module based on STM32 microcontroller and Narrowband IoT (NB IoT). Environmental data is collected through temperature and humidity sensors, as well as light sensors, and processed through the STM32 microcontroller. With the low-power, wide coverage, and strong link characteristics of narrowband IoT modules, remote data reporting is achieved. The experimental verifi cation results show that the module has good performance and can accurately collect environmental data such as temperature and humidity. The module can be used in multiple scenarios such as bird tracking with good feedback.

Key words: Narrowband Internet of Things; STM32 Microcontroller; IoT Module; Lightweight

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Introduction

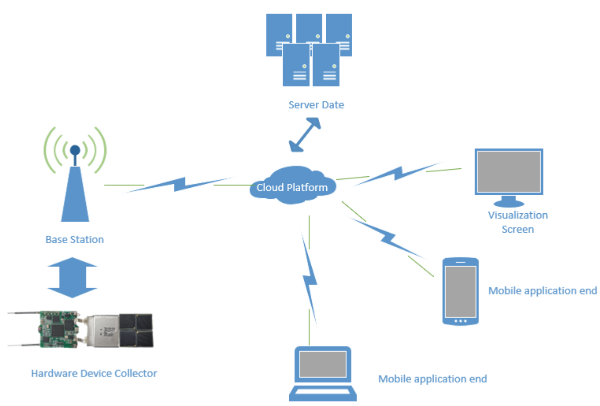
With the increasing demand for intelligent transformation in various industries, IoT terminals have become the main tool for achieving the Internet of Things. At present, traditional IoT terminal devices generally suffer from problems such as bulky size, high power consumption, and limited communication distance, which seriously restrict their application in mobile object monitoring and long-distance data transmission scenarios [1]. In recent years, with the development of low-power wide area network technology, a new solution has been provided for the miniaturization and intelligence of terminal devices. Through adaptive power management, wide area coverage capability has been achieved while ensuring ultra long battery life, signifi cantly expanding the application scope of IoT technology in complex environments [2].

The existing IoT modules mostly adopt communication technologies such as ZigBee, WiFi, GPS/GSM combination scheme, LoRa, etc. The GPS/GSM combination scheme has the problems of high power consumption and expensive operating costs, while LoRa is limited by complex networking. ZigBee and WiFi are not suitable for use in long-distance notifi cation scenarios due to their close communication distance[3]. Especially in outdoor scenarios without network coverage, device endurance and data transmission reliability become the core bottlenecks restricting long-term monitoring. Due to limitations in volume, weight, energy supply, and data transmission methods, traditional IoT terminal devices commonly suffer from low positioning accuracy, short battery life, and high data transmission delays[4]. This article designs a lightweight, multi scenario, high-precision IoT module based on STM32 and NB IoT technology. The system uses STM32 as the core control unit, combined with high-precision sensor matrices such as temperature and humidity sensors and light intensity sensors, to achieve multidimensional data acquisition.

1.Overall System Architecture

The system architecture consists of a perception layer, a network layer, a platform layer, and an application layer [4]. The perception layer adopts Cortex-M4 and Cortex-M0+dual core STM32WB55 multi-core processors, which manage nine axis sensors, environmental sensors, and positioning modules through SPI/I2C bus to achieve synchronous acquisition of motion trajectory and environmental parameters. The network layer adopts Bluetooth 5.0 and Cat-M1/NB IoT dual-mode communication, and establishes a dedicated APN channel through the China Telecom IoT platform. The platform layer is deployed on the Alibaba Cloud IoT platform. The application layer provides web and mobile visual interfaces, supporting geofencing settings and abnormal warning functions. The module system architecture is shown in Figure 1.

Figure 1 System Architecture Diagram

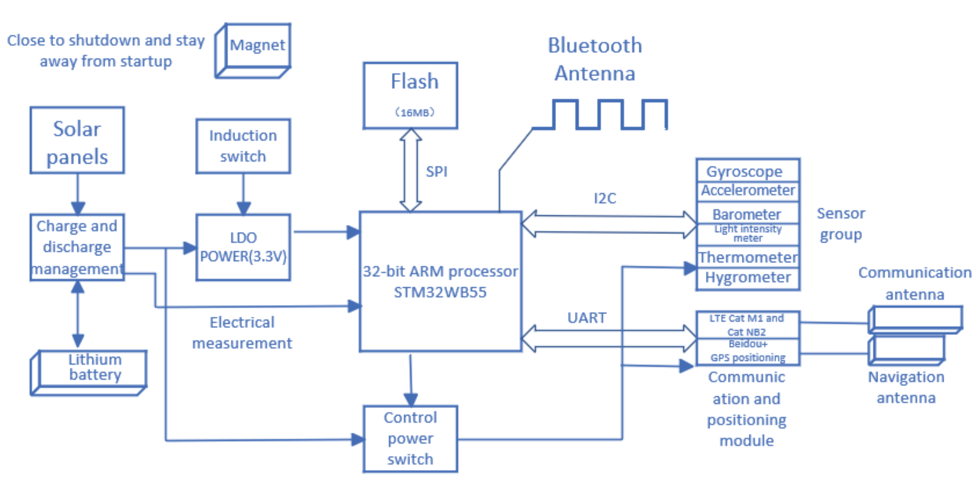


Next, the design and implementation process of the system will be detailed from the aspects of overall system design scheme, hardware circuit design, software program design, and system testing and verification. Validate and evaluate the performance and stability of the system through experiments.

2.Hardware Circuit Design

The system hardware circuit mainly includes STM32 core processing unit, power management unit, storage unit, sensor group, communication positioning module and antenna. The hardware circuit design fully considers the lightweight requirements, and surface mount components are used in the hardware selection stage. The hardware architecture of the system is shown in Figure 2.

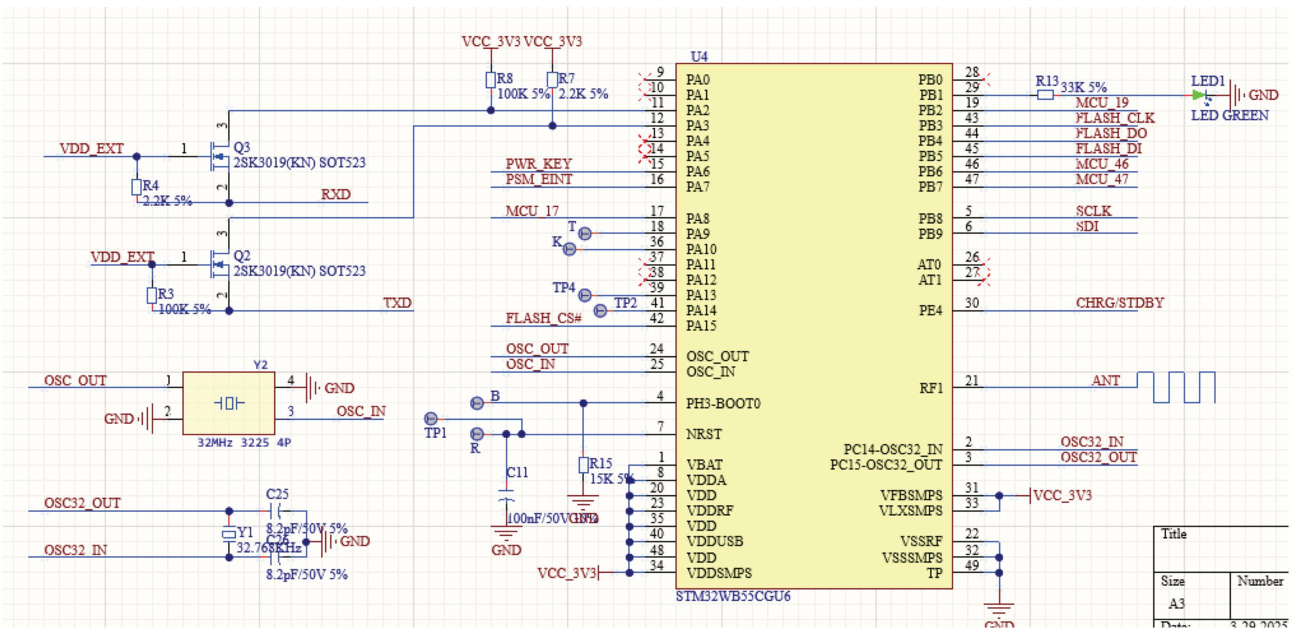
Figure 2 Hardware Architecture Diagram



2.1 Core Processing Unit

The core processing unit mainly undertakes the core tasks of data scheduling and protocol parsing. STM32 is a high-performance, low-cost, and low-power 32-bit microcontroller unit developed by STMicroelectronics based on the ARM Cortex-M core. It is widely used in smart homes, wearable devices, automotive electronics, medical equipment, and other fields. The module uses STM32WB55CGU6 dual core microcontroller, with Cortex-M4 core running at a frequency of 64MHz, responsible for the main program and wireless protocol stack processing; The Cortex-M0+coprocessor is dedicated to low-power task scheduling [5]. This chip integrates 16MB Flash and 128KB SRAM, and supports dual-mode communication of Bluetooth 5.2 and Zigbee 3.0. The STM32 minimum system includes power circuit, crystal oscillator circuit, reset circuit, etc. The circuit principle of the core processing unit is shown in Figure 3.

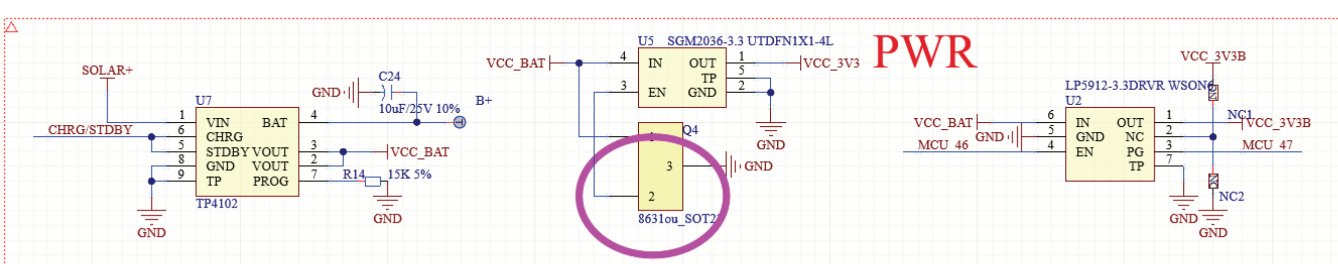
Figure 3 Schematic diagram of core processing unit circuit



2.2 Power Management Unit

The power management unit is the foundation for the stable operation of the system. The module charge and discharge management part adopts TP4102 chip, which supports a maximum charging current of 1A. Combined with UFX302020 solid-state lithium battery, it can suppress leakage current to below 1 μA in sleep mode. The LP5912 low dropout linear regulator provides a stable output of 3.3V, with a noise suppression ratio exceeding 60dB, significantly reducing the interference of power ripple on sensitive circuits. To solve the problem of module endurance, the system is connected to MSCM solar panels, which can output 4.5V voltage and 14.8mA current under lighting conditions, achieving adaptive collection and storage of environmental energy [6]. In order to reduce the size of the Hall element in the module, when the magnet is close to the module, the SGM2036 element's pin 3 enables the module to enter normal working state. The principle of the power circuit diagram is shown in Figure 4.

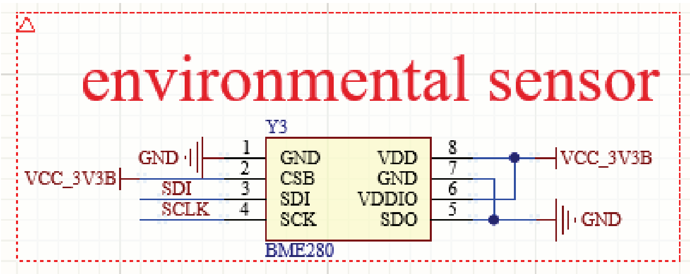
Figure 3 Schematic diagram of core processing unit circuit



2.3 Sensor Array

The sensor array design aims to fuse multi-source data. The environmental perception part adopts BME280 sensor, and its internal compensation algorithm effectively suppresses the temperature drift effect, which can synchronously obtain temperature, humidity, and air pressure parameters[7]. The motion state detection adopts the MPU9250 nine axis sensor, and the combination of accelerometer, gyroscope, and magnetometer can accurately analyze the three-dimensional spatial posture[8]. The ALS-DPDIC17-78C light intensity sensor provides wide range detection capability, and its I ² C digital interface and 10ms fast response feature ensure the real-time and accuracy of light data. The schematic diagram of the BME280 sensor circuit is shown in Figure 5.

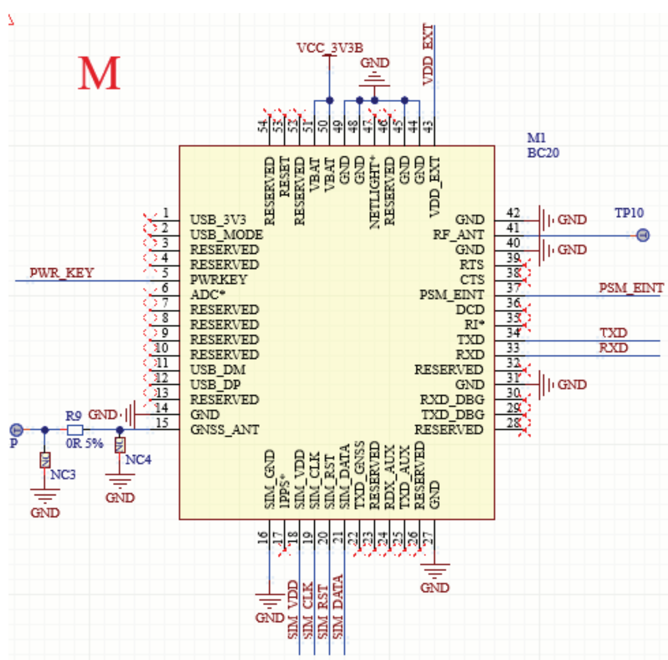
Figure 5 Schematic diagram of BME280 circuit



2.4 Wireless Communication Module

Wireless communication modules need to consider wide area connectivity and precise positioning requirements. The narrowband IoT chip adopts Shanghai Mobile Remote Communication BC20 module, which supports Cat M1/NB IoT dual-mode and B1/B3/B5/B8 multi frequency bands. The receiving sensitivity can reach -129dBm at a transmission power of 23dBm[8]. The positioning system adopts a dual-mode solution of Beidou III and GPS, combined with CA-G01 navigation antenna, which can achieve a positioning accuracy of 2.5 meters in open environments and shorten the cold start time to less than 35 seconds. The communication antenna adopts an inverted F-shaped ceramic design, with a size of only 5×3mm², and a radiation efficiency of over 48% in the 900MHz frequency band. At the same time, in order to minimize module size as much as possible, the module adopts ESIM technology, which enables seamless access to global operator networks without the need for physical card slots. The BC20 circuit schematic is shown in Figure 6.

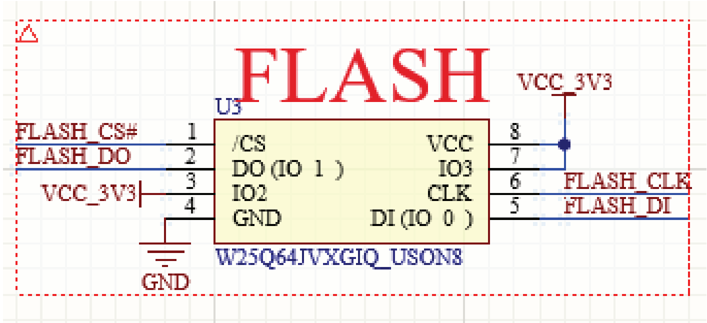
Figure 6 Schematic diagram of BC20 circuit



2.5 Storage Unit Design

The design of storage units focuses on considering data capacity and data security. The module storage unit adopts an external W25Q64JVXGIQ_SON8 to provide 16MB of storage space, supporting XIP mode and 128 bit AES encryption storage, with a data transfer rate of up to 100Mbps[9]. The circuit diagram of the storage unit is shown in Figure 7.

Figure 7 FLASH Electrical Schematic Diagram



3.Embedded software design

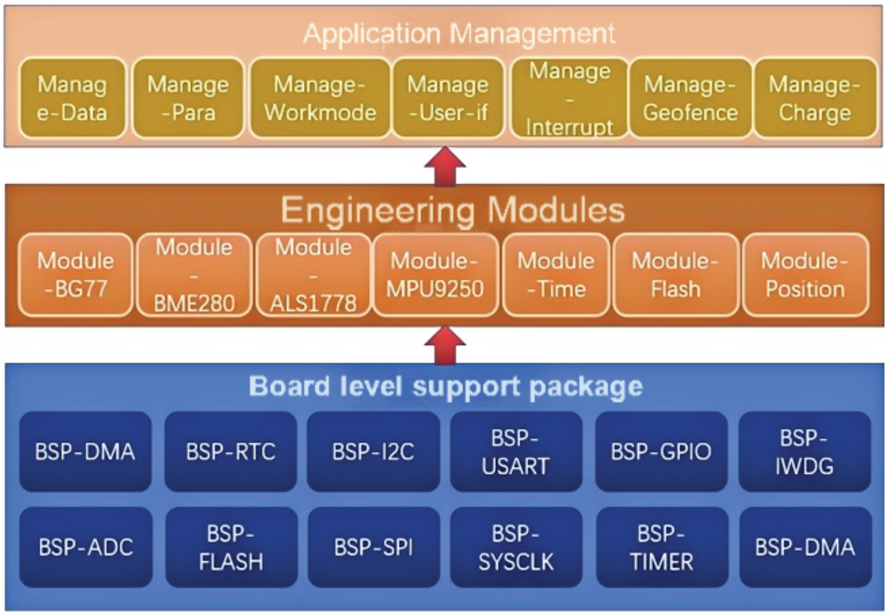
3.1 Development Environment Construction

The modular embedded software adopts a software architecture design that combines hierarchy and modularity. By using Keil MDK-ARM integrated development environment and STM32CubeMX configuration tool for project basic configuration, a full stack software solution was built from low-level hardware drivers to upper level application logic[10]. Keil MDK-ARM integrated development environment is an embedded system development tool specifically designed for ARM series microcontrollers. The software is easy to learn and use, with powerful features that can meet most embedded applications.

3.2 Embedded Software Architecture

At the overall architecture level, the system is divided into three levels: application management layer, functional module layer, and board level support package, as shown in Figure 8.

Figure 8 Embedded software design diagram



3.3 Main Program Design

After setting up the work environment, use C language to write embedded code, compile the code and burn it into the main control chip. The workflow of the module when it is powered on and running is mainly as follows:

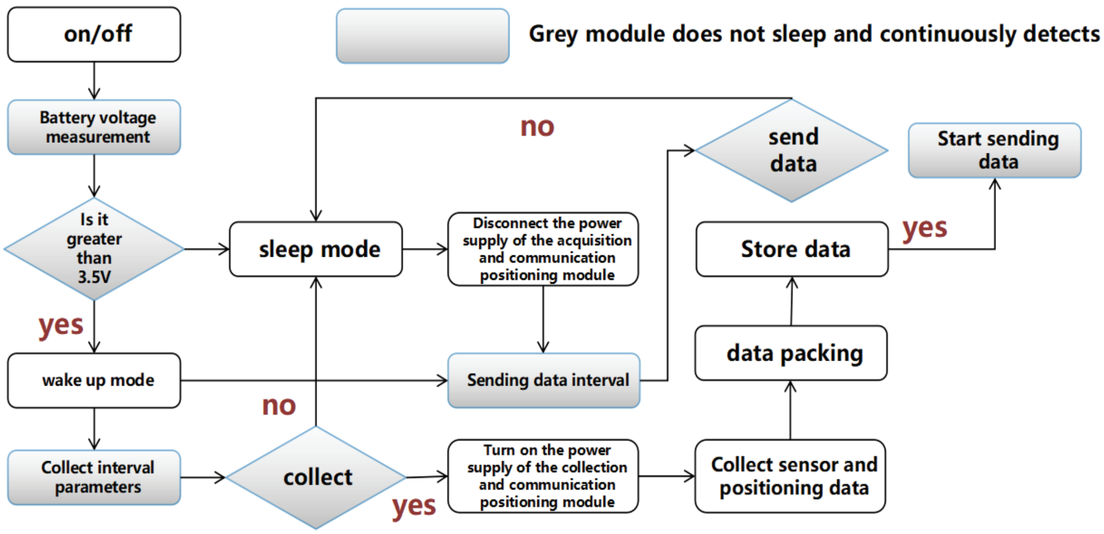
(1) Module embedded program initialization, initialization of system clock peripherals and external module initialization;

(2) Battery voltage measurement, voltage greater than 3.5V, normal operation; When the voltage is less than 3.5V, enter sleep mode;

(3) Collect data from temperature and humidity sensors, illuminance sensors, nine axis sensors, etc. at regular intervals. The default collection interval is 1 hour, and the time interval can be customized. The sensor data is transmitted to the microcontroller for analysis and processing;

(4) Determine whether the data transmission interval, data packaging, and data transmission are met;

Figure 9 Program flowchart

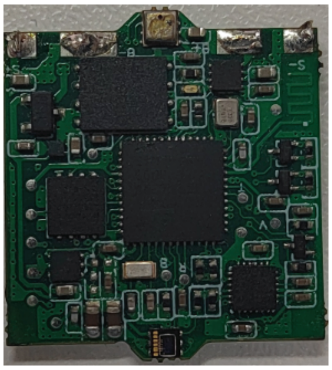


4.Experimental verification

4.1 Hardware physical display

The core hardware achievement of this study is a self-designed narrowband IoT module. The physical size of the module is 20mm × 20mm × 5mm, with a weight of only 7g. Through 3D printing of the packaging shell and IP67 protection design, it meets the deployment needs of complex scenarios such as outdoor and industrial environments. The physical display of the module is shown in Figure 10.

Figure 10 Physical display of module



4.2 Module software and hardware debugging

The core processing unit, power management unit, sensor array, wireless communication module, and storage unit of the system are soldered onto the PCB. Before powering on the module, the hardware soldering should be checked for short circuits, virtual soldering, and polarity according to the PCB design diagram. Perform programming and unit testing based on the schematic diagram to verify if the module hardware is functioning properly. According to the system functional requirements, complete the module embedded code programming, compile and burn it into the system.

4.3 Module Performance Testing

To verify the stability of module operation, perform module performance testing. The cloud platform for this test is Alibaba Cloud platform, and the test results show that the module voltage detection range covers 3.0-4.2V, accurately reflecting the charging and discharging characteristics of lithium batteries. The temperature and humidity sensor achieves accuracy of ± 0.3 ℃ and ± 3% RH within the range of -20~60 ℃ and 0-100% RH, respectively; The positioning accuracy is 3.5 meters; The atmospheric pressure detection module supports wide range measurement from 300-1100 hPa, adapting to diverse needs from low altitude plains to high-altitude areas. The experimental data validated the stability and environmental perception accuracy of the module, providing reliable support for multi scenario deployment.

5.Conclusion

This article is based on narrowband IoT and STM32 technology, and designs and implements a lightweight multi scene module. The module weighs 7g and has a volume of 2cm × 2cm × 0.5cm, which is an ultra micro volume. The system functions normally and meets the design requirements. The module can be widely used in ecological monitoring, smart cities and other fields, and has good application value.

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no

Conflict of Interests

The author(s)declare(s) that there is no conflict of interest regarding the publication of this paper.

References

[1] Li Huqun, Zhu Xiaomang, Wang Fang, Wu Feilong, Su Leilei Research and Implementation of Smart Campus IoT Door Lock System Based on NB IoT [J]. IoT Technology, 2025, 15 (07): 71-73+80.

[2] Li Xingli, Liu Dongxu, Gu Bingling, peaceful A new intelligent system for electric vehicle charging piles based on NB IoT technology [J]. Bonding, 2025, 52 (03): 146-149.

[3] Zhou Yuanju Design of Wireless Hydrological Monitoring System Based on NB IoT [J]. Internet of Things Technology, 2025, 15 (05): 9-11.

[4] Li Huqun, Zhu Xiaomang, Wang Fang, Wu Feilong, Su Leilei Research and Implementation of Smart Campus IoT Door Lock System Based on NB IoT [J]. IoT Technology, 2025, 15 (07): 71-73+80.

[5] Tang Yingjie, Chang Xiangxiang, Fan Changsheng Design of Kitchen Gas Security Monitoring and Alarm System Based on STM32 [J]. Instrument Technology, 2025, (02): 22-24.

[6] Chen Hongru, Fan Zai, Fan Changsheng Design of Automatic Water Flow Control System Based on STM32 [J]. Instrument Technology, 2025, (02): 38-40.

[7] Ma Qiufang Development of Thermal Control Billing Instrument Based on STM32 [J]. Instrument Technology, 2025, (02): 19-21.

[8] Chen Xiaodan, Li Haoyuan, Zeng Weichao, Lin Jiarui, Chen Xinxin, Zhang Min Research on Human Health Monitoring System Based on Ultra Wideband Radar Deep Learning [J]. Instrumentation Technology, 2025, (02): 58-62

[9] Liu Jie, Yuan Liangwei, and Yin Xuetao Design of Unmanned Self Balancing Bicycle Based on STM32. “Industrial Control Computer 38 03 (2025): 167-168.

[10] Jia Rongcong Design and Implementation of Vacuum Cleaning Robot Based on STM32. “Industrial Control Computer 38 03 (2025): 169-170.