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A Remote Program Control Method for Wireless Communication Devices that is Highly Reliable

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ABSTRACT: The rapid development of industrial automation systems has led to the need for robust frameworks for seamless communication and control. This paper proposes a highly reliable remote program control framework tailored for the dairy industry, utilizing a highly reliable remote program control method (HRRPCM) for ESP32 devices. This framework addresses the need for reliable and efficient remote programming, enabling users to update the firmware of ESP32-based devices without physical access. The framework incorporates pressure and temperature sensors to monitor critical parameters in dairy processing, ensuring optimal conditions for production. The proposed system uses a secure and scalable mechanism to ensure the integrity and authenticity of firmware updates. The ESP32 wireless communication module establishes a stable and responsive link between dairy industrial automation devices and a central control unit. The framework provides a user-friendly interface for remote program control, allowing users to manage and update device functionality effortlessly. Key features include fault-tolerant protocols, encryption mechanisms, and real-time status feedback. The framework's effectiveness is validated through experimental results demonstrating its reliability, security, and efficiency. The findings demonstrate the potential for seamless integration into existing dairy industrial automation setups, contributing to a more adaptable and user-friendly smart industrial environment.

KEYWORDS: Industrial Automation, Remote Program Control, ESP32 Devices, Firmware Updates, Security Mechanisms

I. INTRODUCTION

In the rapidly evolving environment of the Internet of Things (IoT) and remote device management, the High Remote Program Control Method stands out as a cutting-edge solution for seamless and efficient control of ESP32-based devices. This method leverages wireless communication technologies to enable remote programming and updates, providing unparalleled flexibility and convenience in managing devices deployed in various environments. The ESP32, a powerful and versatile microcontroller, serves as the cornerstone of this method. Developed by Espressif Systems, the ESP32 combines Wi-Fi and Bluetooth functionalities, making it a perfect choice for applications that need wireless connectivity. The Arduino IDE, a popular open-source development platform, enhances the accessibility of the ESP32 by simplifying the programming process and enabling a vast community of developers to contribute to its ecosystem.

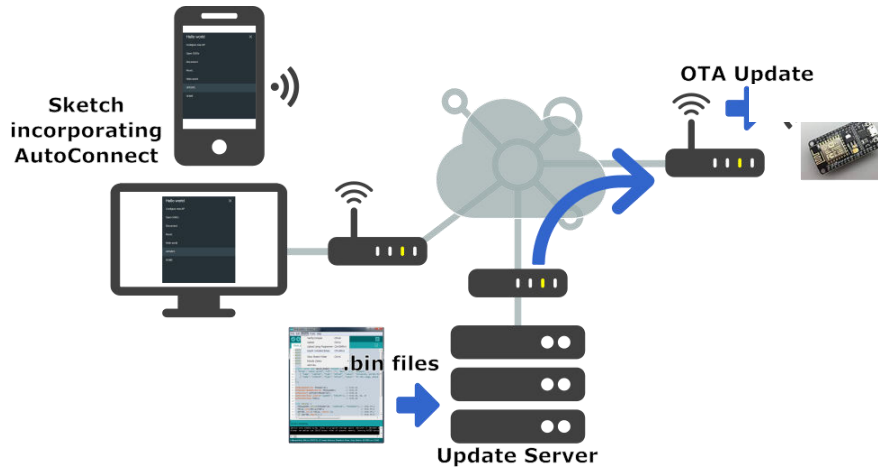


Figure 1. Auto Connect Configuration Update of ESP 32

The HighRemote Program Control Method is its utilization of a Web Updater, allowing users to remotely update firmware and modify device functionality without physical access. This is particularly advantageous for scenarios where devices are deployed in remote locations or are challenging to reach, as it reduces the need for manual interventions and on-site programming. The wireless communication device, in this context, acts as the bridge between the ESP32 and the remote programming interface. This device facilitates bidirectional communication, enabling users to send commands to the ESP32 and receive real-time feedback. The wireless communication aspect adds a layer of flexibility, making it possible to control and monitor devices from virtually anywhere with an internet connection.

Through the combination of the ESP32, Arduino IDE, and Web Updater, the HighRemote Program Control Method empowers developers and system administrators to streamline the management of IoT devices, enhance system reliability, and reduce downtime. This innovative approach to remote programming not only simplifies the development process but also opens up new possibilities for applications in home automation, industrial control, and other fields where remote device management is crucial. As we delve deeper into the details of this method, its features, and its implementation, it is clear that High Remote is leading the way in modern IoT solutions, continuously expanding the possibilities in wireless device control.

1.1 Objective

- To address the need for robust frameworks for seamless communication and control in industrial automation systems.
- To propose a highly reliable remote program control framework utilizing the HRRPCM updates for ESP32 devices.
- To ensure the integrity and authenticity of firmware updates through a secure and scalable mechanism.
- To provide a user-friendly interface for effortless management and update of device functionality via remote program control.
- To validate the framework's reliability, security, and efficiency through experimental results, demonstrating its potential for integration into existing industrial automation setups.

II. LITERATURE SURVEY

The literature review explores the design aspects of the Intelligent Reflecting Surface (IRS) in future wireless networks. It introduces the IRS's fundamental concepts, reconfigurability, performance metrics, and joint optimization of phase control and transmission control. The review also discusses emerging use cases and practical challenges, highlighting the need for continued exploration in the realm of IRS-assisted wireless networks beyond 5G communications [1].

The comprehensive analysis of wireless networks centers on 6G and future advancements, emphasizing crucial enabling technologies like THz band operation, intelligent communication environments, artificial intelligence, and large-scale network automation. The study provides detailed use cases and discusses recent advancements and open

problems. It also explores early-stage technologies like NanoThings, BioNanoThings, and quantum communications, aiming to provide insights into operational intricacies and challenges associated with each technology, fostering a deeper understanding of wireless communication networks [2].

The paper introduces the digital version of information metasurfaces (IMs) in wireless communications, focusing on their applications in controlling electromagnetic waves. IMs use digital codes to represent meta-atoms and control electromagnetic responses. Real-time programmable control of EM waves is achieved by integrating IMs with FPGAs. The paper presents basic concepts, programmable features [3].

The paper introduces a controller for multiple IoT devices that utilizes Amazon Web Services (AWS), ESP32 modules, and the C# programming language. Enables centralized management and monitoring of IoT devices through a user-friendly interface. The AWS IoT Core manages IoT devices, while ESP32 modules facilitate data transmission. The C# application serves as the master controller, while ESP32 devices function as clients. The comprehensive example showcases the significance of AWS, ESP32, and C# programming languages in IoT device development [4].

IBM is focusing on fundamental requirements for developing systems within the Industrial Internet of Things (IIoT). The study explores various components and technologies such as low-level programming of microcontrollers, real-time operating systems, low-power wireless communication technologies, the MQTT application layer protocol, and specialized cloud services including Artik Cloud, IBM Cloud, and Intel Cloud. Additionally, it offers guidelines for choosing appropriate hardware and software, as well as a practical prototype implementation [5].

The study focuses on developing a remote monitoring system using the ESP32-CAM microcontroller for fire detection. The system uses sensors like the AM312 PIR sensor for motion detection and the KY-026 fire sensor for fire detection. The MC-38 magnet sensor monitors door status. The ESP32-CAM reads data from these sensors and transmits it to a remote server. The system's performance was validated with a 100% success rate in capturing images and sending notifications, demonstrating advanced microcontroller and sensor technology [6].

STEMMA is integrating IoT technologies into the educational process for mechatronics students through a hands-on approach. The methodology involves an introductory IoT course and project-based learning, using interfaces like Grove, STEMMA QT, or Qwiic. Students acquire hands-on experience in microcontroller operations, Students gain practical experience in operating microcontrollers, creating printed circuit boards, mastering 3D design, and delving into IoT technology. The approach fosters active learning and provides students with essential skills for the job market [7].

Wearable communication (WC) technology has been developed to facilitate video streaming and data transfer in both indoor and outdoor environments. A 2.4 GHz WC prototype was tested for its performance, capturing data and transmitting it via an access point to a server or receiver station. The device maintained stable connections and high-quality video transmission up to 17 meters from the access point. Various technical aspects including the extent of coverage, lighting circumstances, and camera quality were taken into account to ensure the best possible performance. The technology shows promise in fields like smart textiles, sports monitoring, and e-health systems [8].

Analytical calculations and physical modeling were used to verify the feasibility of using phase-pulse modulation of linear-frequency-modulated (LFM) signals for transmitting control commands. The study involved determining temporal changes in voltage, visualizing data variations, and monitoring the performance of a wireless modem. The results confirmed the operational viability of using phase-pulse modulation for LFM signals in wireless control systems, even in intentional interference environments. Modern microcontrollers successfully handled the optimal processing required for the modulation technique [9].

The study explores the physical tracking in IoT applications, focusing on ESP32 devices. The method involves calculating distance using Received Signal Strength Indicator (RSSI) values to determine if devices are within a predefined coverage area. The results show negligible error rates, attributed to environmental influences like magnetic fields. Future research will explore detecting moving devices and using Bluetooth Low Energy (BLE) and Wi-Fi communication technologies for enhanced accuracy and reliability [10].

The integration of technology into daily life is transforming devices and daily life. High-speed Internet allows real-time access and monitoring of devices from various devices. The hardware implementation of a Home Automation system utilizes Arduino Mega 2560 and ESP32 development boards. The Wi-Fi network allows two-way communication, enabling real-time monitoring of temperature, humidity, and garage door status. Future improvements include receiving fire alarm notifications, adding security notifications, using ePaper displays, and charging the power bank during off-peak hours [11].

The concurrent surge in devices and IoT devices has led to the development of new communication technologies, such as the Cellular Internet of Things (C-IoT). However, C-IoT faces coverage outages in specific regions, making it challenging for handovers. A cost-effective, easily deployable, and manageable network infrastructure is being developed using device-to-device communication using LoRa and LoRaWAN [12].

The research introduces a novel communication framework utilizing Long Range (LoRa) technology to enable secure bidirectional communication for remote robot control and monitoring. The protocol, an extension of the LoRaWAN standard, aims to create a robust connection between a central station and robots without necessitating network infrastructure. By employing cryptographic techniques, the system ensures data security and integrity. Practical validation on a Pioneer-3DX robot illustrates the viability of the approach in remote environments [13].

Mount Merapi in Indonesia has implemented an innovative lava flood detection system with IoT support. The system employs a customized automatic rain gauge and a new vibration sensor. Utilizing a Kalman filter, it accurately measures earthquake vibrations at both high and medium intensities. Its primary purpose is disaster management, facilitating timely communication to alert stakeholders for evacuation and inform residents. The system underwent rigorous testing in laboratory experiments, comprising an IoT server and two client stations situated upstream and downstream of Mount Merapi. Leveraging WhatsApp and SMS technologies, it dispatches lava flood warnings promptly. These warnings are relayed to the Disaster Risk Reduction Forum (FPRB) and disseminated via the Community Communication Radio (CCR). The comprehensive approach aims to enhance resilience against natural calamities, particularly cold lava flood incidents [14].

Rapid advancement of global industrialization has led to a focus on industrial modernization, addressing issues with traditional control methods. A novel industrial automation control system is being explored using ZigBee wireless communication technology. The study demonstrates the effectiveness of the proposed system in a pharmaceutical factory, demonstrating superior performance compared to wired transmission systems. The operational temperatures of the system are reduced, and it boasts an impressive maximum transmission distance of 40 meters while maintaining a minimal packet loss rate. ZigBee's short-range wireless sensor network technology enables efficient two-way communication with minimal power usage, modest data rates, and affordability. This makes ZigBee an ideal complement to existing technologies such as Wi-Fi, promising notable advancements in industrial applications [15].

A flexible 5G communication control strategy is proposed to address traffic floods and improve network traffic flow. The model uses 5G quality of service and the Mobile Application Network (MANET) to provide cost and convenience. The CHAOS algorithm is customized for network traffic flow boards, allowing dynamic injection of traffic from 1 MB to 10 MB. Adaptive 5G routing is proposed for multimedia applications, aiming to reduce extra network traffic and achieve higher-bitrate network traffic segments. The approach minimizes traffic overflow and considers future routing limitations [16].

The research introduced an innovative multifunctional IP instrument system leveraging remote wireless communication technology, providing exceptional data acquisition precision alongside compact dimensions, portability, adaptability, and a wide range of capabilities. The system incorporates a high-precision data acquisition circuit with an impressively low noise floor of 0.29 μV , resulting in a significant 5-fold enhancement in acquisition accuracy. The transmitter component boasts a maximum output power of 6 kW, facilitating the transmission of stepped waves and rectangular waves across various frequencies and duty cycles. Through a wireless communication protocol, users can seamlessly control the instrument via an Android mobile application developed in Java, thereby optimizing real-time imaging efficiency and instrument intelligence [17].

NodeMCU is a crucial component in load automation and surveillance systems, minimizing power and resource consumption. The ESP-32 CAM module plays a central role in load automation and intelligent garden watering

systems. The Blynk app is used for real-time monitoring. The system is powered by a five-volt DC supply, supporting NodeMCU, ESP32 CAM, and the relay board. The Blynk app allows global control of loads, and the system integrates automation, surveillance, and smart garden watering through a single interface [18].

Arduino serves as a highly adaptable instrument for facilitating data transmission within microgrids, facilitating the integration of numerous sensors with LoRa transceivers to gather data from diverse units. The setup prioritizes secondary communication among the local controllers of dispersed generation units and the central controller, fostering efficient low-bandwidth communication. The information captured by these sensors is relayed to the LoRa gateway, functioning as the focal point for monitoring the system. To bolster communication security, a private server employing Node-Red is employed. Through rigorous testing, the system has proven its efficacy, boasting a data delivery rate exceeding 90% over a distance of 4 km, successfully accomplishing one-way data transfer within a grid monitoring framework [19].

The Arduino Uno microcontrollers are used as central controllers in a wireless real-time home automation system. The system offers two operational modes: manually-automated, allowing users to remotely control appliances via Wi-Fi, and self-automated, allowing controllers to monitor and control appliances based on signals from sensors. The Arduino Uno is flexible, inexpensive, and easy to use, connecting to computers via USB and communicating using a standard serial protocol. The design of the system is straightforward, affordable, and adaptable, positioning it as a viable option for the future of smart homes [20].

III. PROPOSED METHODOLOGY

The suggested system presents a robust method for remotely controlling programs on wireless communication devices, with a focus on the ESP32 microcontroller. The primary objective is to enable wireless data transfer and reprogramming of the ESP32 microcontroller using a URL over the air. Additionally, the system aims to facilitate the control of dairy industrial automation devices. To further enhance its capabilities in a dairy industrial context, the system integrates pressure sensors to monitor the amount of milk in storage silos, preventing overfilling and ensuring proper storage conditions. Temperature sensors are also employed to monitor and control the pasteurization temperature, ensuring milk is heated sufficiently to kill harmful bacteria.

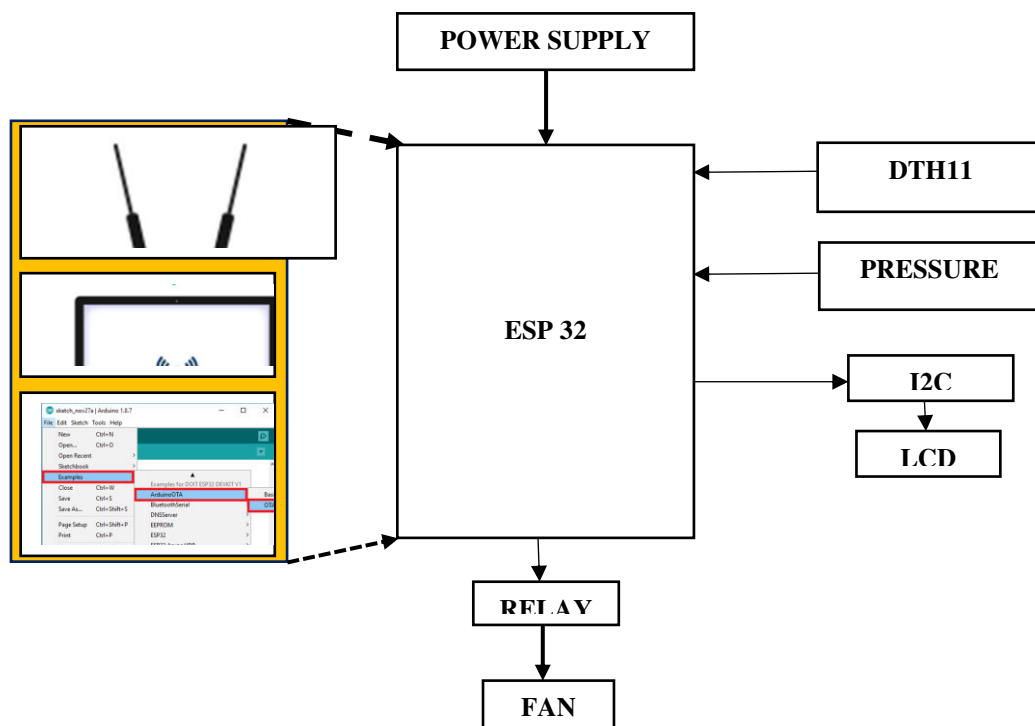


Figure 2. Robust Remote Program Control Technique for Wireless Communication Devices as ESP 32

The wireless programming method through a URL is highlighted as both easy and affordable. This indicates a user-friendly approach that minimizes complexities in the reprogramming process. The wireless programming method through a URL is highlighted as both easy and affordable. This indicates a user-friendly approach that minimizes complexities in the reprogramming process. The system's documentation works when both the ESP32 and the browser are on the same local network. This ensures that OTA programming is viable in situations where the ESP32 boards are not easily accessible physically. The first sketch needs to be uploaded via the serial port and should contain the code for creating the highly reliable remote program control method (HRRPCM) Web Updater. This establishes the foundation for subsequent OTA updates.

A notable limitation of the highly reliable remote program control method (HRRPCM) Web Updater is the need to add HRRPCM code to every sketch to enable future HRRPCM updates. Failure to include HRRPCM routines in a sketch makes it impossible to access the web server for over-the-air updates. The proposed system offers a robust solution for remote programming and control of ESP32 microcontrollers and industrial automation devices. By leveraging HRRPCM programming through a URL, the system prioritizes convenience and accessibility. However, the requirement to embed HRRPCM code in every sketch could be seen as a minor drawback, necessitating careful consideration during the development process to ensure seamless over-the-air updates. Overall, the system offers a robust solution for remote programming and control of ESP32 microcontrollers and dairy industrial automation devices, prioritizing convenience and accessibility while also addressing specific needs in the dairy industry.

3.1 Hardware Components

A. Power supply

A power supply converts energy to power electrical loads. It can switch between energy types, like mechanical, solar, or electrical. In AC-powered supplies, a chopper adjusts voltage, while in DC, a rectifier turns alternating voltage into pulsating direct voltage. Filtering components like capacitors and resistors reduces pulsations, but some residual ripple may remain, occurring at mains frequency or double it depending on the rectification type.

B. ESP 32 Controller

The ESP32, developed by Espressif Systems, is a powerful microcontroller widely used in electronics and IoT projects. It improves upon its predecessor, the ESP8266, with a dual-core processor for multitasking and efficiency. Integrated Wi-Fi and Bluetooth make it ideal for various applications like home automation and industrial setups. It offers GPIO pins, SPI, I2C, and UART for connecting sensors and components. Energy efficiency features extend battery life, while security measures like secure boot and cryptographic functions enhance system safety. Supported by a range of development environments and libraries, the ESP32 is a popular choice for diverse projects, from simple DIY to complex IoT setups.



Figure 3. ESP 32 controller

C. Relay

A relay acts like an electronic switch, controlled by an electrical signal rather than manual operation. It's made up of parts like an electromagnet, movable contacts, and springs. When an electrical current flows through the coil, it creates a magnetic field that pulls the contacts, either closing or opening the circuit. Relays come in different types, like electromechanical and solid-state. They're used in various applications, from controlling lights to safeguarding electrical systems. Relays are classified based on their configurations and can be found in many forms, serving diverse purposes in different industries.

D. Fan

A 12V cooling fan operates on 12-volt DC power and is crucial for dissipating heat in various electronics and systems. It's compatible with batteries, adapters, or power supplies. Used widely in electronics, automotive, and appliances, these fans vary in size and bearing types, affecting factors like durability, noise, and cost. Airflow and static pressure are key metrics, with lower noise levels preferred. Regular maintenance ensures longevity, as dust buildup can hinder performance.



Figure 4. Cooling Fan

E. Voltage Regulator

A bridge rectifier is a common configuration in electronic power supply circuits, converting AC input into DC. It comprises four diodes, D1, D2, D3, and D4. The bridge rectifier rectifies negative half-cycles of the AC input, ensuring positive output voltage. However, the output still contains AC components and ripple, requiring an RC filter to reduce voltage.



Figure 5. Voltage Regulator

F. Temperature Sensor

The DHT family, including the DHT11 sensor, is a popular and versatile digital temperature and humidity sensor for environmental monitoring. Manufactured by Aosong, it offers real-time temperature readings and humidity readings, making it suitable for applications like weather stations and industrial monitoring. However, some users may opt for the DHT22 for increased accuracy and a broader temperature range.

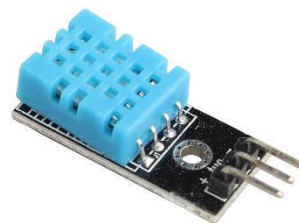


Figure 6. Temperature Sensor

G. Pressure Sensor

Bosch Sensortec's BMP180 is a high-precision, low-power barometric pressure sensor with an SPI interface, ideal for applications like weather forecasting and altitude measurement. It measures atmospheric pressure and temperature, offering accurate readings and low power consumption, making it suitable for long-term use in power-sensitive environments.

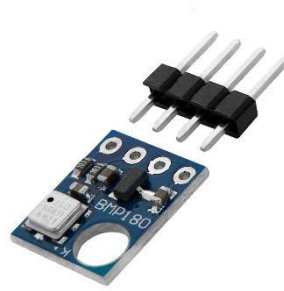


Figure 7. Pressure Sensor

3.2 Software Description

ARDUINO IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform application for Windows, macOS, and Linux designed for writing and uploading programs to Arduino-compatible boards. Written in C and C++, it features a user-friendly interface suitable for both beginners and advanced users. The IDE includes a code editor with syntax highlighting, automatic indentation, and brace matching. Programs, known as sketches, are saved with the `.ino` extension. It supports various Arduino boards via the Board Manager and provides extensive libraries through the Library Manager. Additionally, it has a built-in serial monitor for debugging and allows one-click compilation and upload of sketches. The IDE includes numerous example sketches and supports advanced features like custom libraries, integration with other tools, advanced debugging options, and a command-line interface (CLI). Overall, the Arduino IDE is a versatile and powerful tool for Arduino board development.

IV. RESULT AND DISCUSSION

The Arduino IDE and Web Updater have been successfully implemented for over-the-air (highly reliable remote program control method (HRRPCM)) programming on the ESP32, enabling users to update firmware wirelessly without the need for physical connections. This approach is particularly beneficial for IoT applications and embedded systems, as it eliminates the need for physical access to the ESP32 module, making it ideal for remote or hard-to-reach locations. The HRRPCM capability supports simultaneous updates across multiple ESP32 devices, ensuring efficient firmware delivery to a fleet of devices. The Arduino IDE provides a user-friendly interface, allowing both novice and experienced users to upload and manage firmware updates effortlessly. The Web Updater HRRPCM feature facilitates remote updates, allowing users to deploy changes without direct physical access to the ESP32 module. This results in a robust and efficient HRRPCM programming solution for ESP32 devices, eliminating the need for USB connections or manual interventions.

The HRRPCM programming solution offers several advantages, including convenience, accessibility, scalability, a user-friendly interface, security, and flexibility. The implementation employs encryption and authentication mechanisms to safeguard the firmware update process from potential unauthorized access or tampering. The combination of Arduino IDE and Web Updater HRRPCM offers flexibility, allowing developers to choose between local and remote update methods based on specific project requirements. The HRRPCM mechanism simplifies everyday tasks like controlling fans, lights, pressure and temperature sensor enhancing user experience and scalability of ESP32-based solutions in various industrial automation setups.

V. CONCLUSION

The proposed method concludes that highly reliable remote program control method (HRRPCM) over air programming is a revolutionary approach in dairy industrial automation, particularly for controlling fans, lights, pressure and temperature sensor using ESP32 microcontrollers through the Arduino IDE and Web Updater. This method simplifies firmware updates and adds convenience and flexibility to dairy industrial automation systems. Users can update and enhance device functionality without physical access, making it valuable in hard-to-reach locations or complex networks. The Arduino IDE and Web Updater combination further simplify the programming process, making it accessible to a broader audience, including those with limited technical expertise. Highly reliable remote program control method (HRRPCM) programming aligns with the evolving in smart dairy, promoting adaptability and ease of management. It contributes to device efficiency and opens up possibilities for future improvements and feature additions. The combination of highly reliable remote program control method (HRRPCM) programming, ESP32 microcontrollers, and Arduino IDE with Web Updater enhances user experience in dairy industrial automation and symbolizes the evolution of smart living solutions. This combination empowers individuals to create dynamic, upgradable, and responsive smart environment in a new era of convenience and innovation in dairy industrial control.

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