ISSN: 2414-1895 DOI: 10.6919/ICJE.202604_12(4).0051

# Design of Electronic Scale based on ESP32 Single-chip Microcomputer

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## Abstract

**This paper presents a smart electronic scale design scheme based on the ESP32 microcontroller. The solution integrates high-precision load cells, ESP32 microcontroller, display modules, and vibration motor technology to achieve intelligent weighing, data transmission, and processing capabilities. The paper elaborates on system architecture design, hardware implementation, and software development, followed by system assembly and testing. Experimental results demonstrate the high feasibility and practicality of this smart scale design. The developed solution offers advantages including high accuracy, user-friendly operation, comprehensive functionality, and strong scalability, effectively meeting diverse user requirements and enhancing quality of life.**

## Keywords

**ESP32; Smart Electronic Scale; High Precision; Intelligentization.**

## 1. Introduction

With the rapid advancement of technology and improved quality of life, smart products have become increasingly integrated into every aspect of daily life. As a precision measurement tool, smart electronic scales have emerged as indispensable companions in modern households, offering features like accuracy, speed, and user-friendly operation. Traditional electronic scales, however, typically only provide basic weighing capabilities and face limitations such as insufficient precision, cumbersome operation, and limited functionality[1].

This study employs the ESP32 microcontroller as the control core, utilizing high-precision sensors to enhance measurement accuracy and stability of electronic scales. By integrating human-machine interaction technology, the user interface is optimized for improved operational convenience. Communication with mobile devices enables remote data transmission, storage, and analysis capabilities, delivering comprehensive services to users[2]. The designed electronic scale features vibration motors that trigger alerts during overload detection. These innovations hold significant implications for elevating living standards, advancing smart living solutions, and fostering industry development in related sectors.

## 2. System Solution Design

This system employs an ESP32 microcontroller as its core control unit, integrating components such as an HX711 A/D conversion module, digital display, and vibration motor. The microcontroller processes digital signals to ensure accurate data handling and transmission[3]. Upon receiving control commands, the Bluetooth module displays key metrics like weight readings, providing users with

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intuitive data visualization. These modules collectively form a stable and efficient electronic weighing system framework. When weight exceeds the measurement range, the alarm module triggers vibration alerts, while the Bluetooth module facilitates parameter configuration for skinning and calibration processes[4].

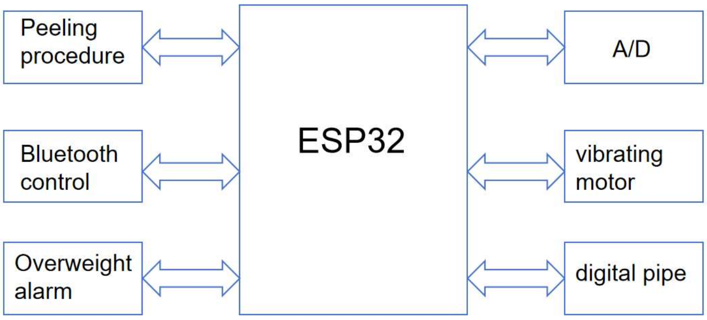


**Fig. 1** System design block diagram

## 2.1 Microcontroller

The ESP32 microcontroller integrates 2.4GHz dual-mode Wi-Fi and Bluetooth chips. Its Wi-Fi and Bluetooth capabilities support multiple protocols and standards including 802.11 b/g/n and Bluetooth Low Energy (BLE), enabling seamless connectivity to the internet and other Bluetooth devices[5]. Built with a 40nm process technology, this dual-core 32-bit MCU features a clock frequency of up to 230MHz and delivers 600DMIPS computing power, making it ideal for complex applications such as real-time data processing, image recognition, and speech recognition. Additionally, ESP32 supports various programming languages and development tools, providing developers with efficient customization capabilities[6].

## 2.2 HX711 Sensor

This study utilizes the 24-bit high-precision A/D converter HX711 chip, which features dual analog input channels and an integrated 128x gain programmable amplifier, making it an ideal high-precision measurement module. Fig. 2 shows the circuit diagram of the HX711 module. With proper wiring configuration, accurate transmission and processing of sensor data can be ensured.

Pin Description: The VCC and GND pins serve as the power input ports for the HX711 chip. The VCC pin connects to the positive power supply (3.3V), while the GND pin connects to ground (negative power). The DT pin is the data output port of the chip, delivering 24-bit data processed through A/D conversion. The SCK pin acts as the clock input port for the HX711 chip, controlling the A/D conversion clock signal.

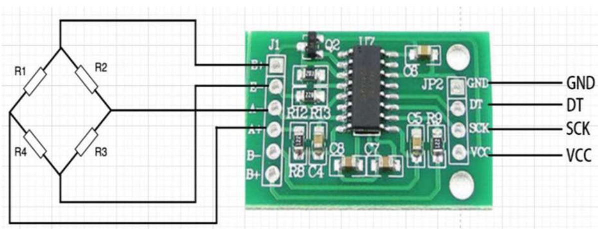


**Fig. 2** HX711 Module Circuit Diagram

## 2.3 Digital Tube Display Circuit

A digital display tube is an electronic device used for displaying numbers and other information, as shown in Fig. 3. Its structure typically includes a glass tube, an anode made of metal mesh, and multiple cathodes, most of which are designed in numerical shapes to clearly represent various digits.

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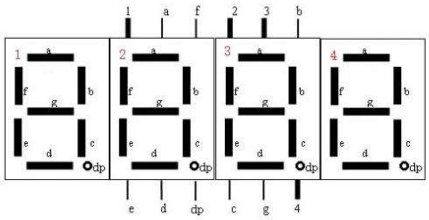


**Fig. 3** Digital tube circuit diagram

Digital tubes operate by controlling the on/off states of light-emitting diode (LED) units to display numbers or other information. In common anode digital tubes, a specific field lights up when its LED cathode is set to a low voltage level. Conversely, in common cathode digital tubes, the corresponding field illuminates when the LED anode reaches a high voltage level. These two types of digital tubes employ distinct voltage control mechanisms to achieve accurate number display and information presentation.

## 2.4 Vibration Motor

In this design, the vibration motor serves as an alert mechanism to notify users of the electronic scale's status. When the scale's weight exceeds its measurement range, the motor generates rhythmic vibrations to prompt users to check. This notification method **Fig. 4** Circuit diagram of vibration motorproves particularly effective in outdoor environments or quiet settings, minimizing disturbance from audible alerts. The system employs a rotor motor, as illustrated in Fig. 4.

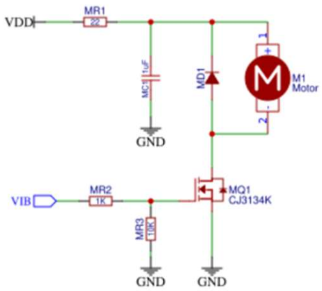


**Fig. 4** Circuit diagram of vibration motor

## 2.5 Design Bluetooth Data Output Interface


**Fig. 5** Bluetooth Control Page

The mobile phone serves as the output control terminal for the electronic scale to provide a more convenient and intelligent user experience. Specifically, Bluetooth technology is utilized to establish

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a wireless connection between the mobile phone and the electronic scale, enabling users to effortlessly operate various functions of the scale through an application on their mobile device. For details, refer to Fig. 5: Bluetooth Control Page.

## 3. Software Design

### 3.1 Main Program Design

The core functionality of electronic scales lies in weighing, with programming primarily aimed at ensuring measurement accuracy. However, given that pressure sensors lack self-calibration capabilities and cannot directly measure actual object weights, this course innovatively introduces a 50-gram reference weight for calibration through smartphone Bluetooth. To enhance weighing safety, a weight limit is set – once exceeded, the vibration motor activates immediately, emitting audible alerts and vibrations. For unit price adjustments, simply enter the desired value via unit price mode. These design elements collectively improve the practicality and user-friendliness of electronic scales.

Fig. 6 presents the main program flowchart, which processes various Bluetooth messages. Key functions include skinning, amount calculation, and normal status monitoring. The loop executes the following steps: First, the system receives Bluetooth messages and performs corresponding operations based on their content. For instance, receiving an "off" message or prolonged boot button press triggers program termination; detecting a "qupi" message initiates skinning operations; receiving an "Amountcalculation" message activates the amount calculation subroutine; identifying a "normal status" message or false calibration flag activates normal mode; while receiving a "jz" message or true calibration flag triggers calibration procedures. During each operational state, the program updates displayed weight values, transmits Bluetooth messages, and executes relevant actions.

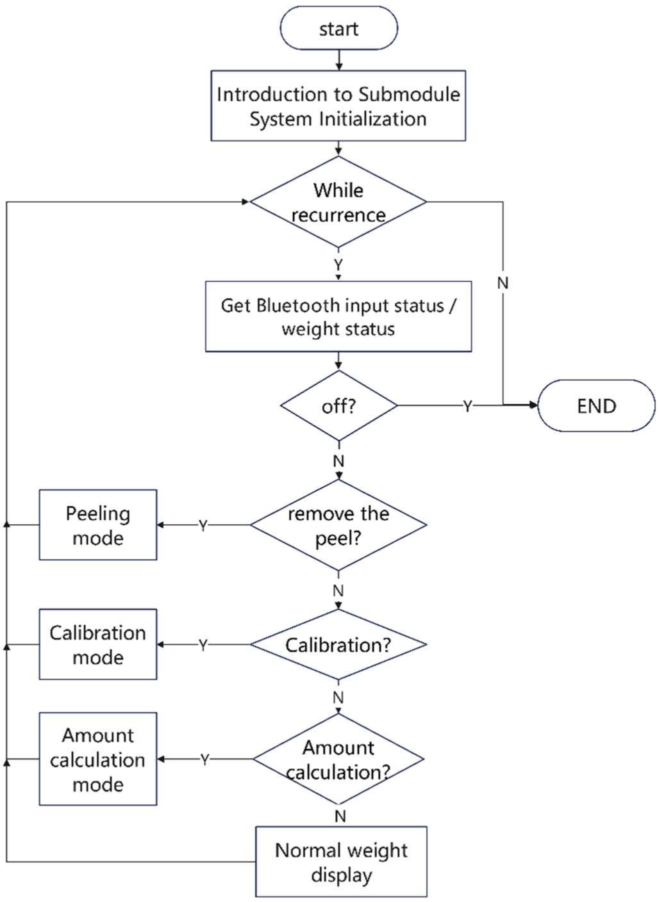


**Fig. 6** Main program flowchart

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## 4. System Debugging and Result Analysis

Launch the e-debugging app on your smartphone and connect to the microcontroller's Bluetooth. Connect to the ESP32BLE module shown in Fig. 7. Place a 50g standard calibration weight, and the electronic scale will display the result as shown in Fig. 8. To enter calibration mode, click the calibration button or press the Boot button on the microcontroller. After calibration, the Bluetooth interface will display the calibration results as shown in Fig. 9.


**Fig. 7** Bluetooth List

**Fig. 8** Display before calibration


**Fig. 9** Bluetooth display effect after calibration

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**Fig. 10** Calibration display

The electronic scale displays calibration results as shown in Fig. 10. Test results demonstrate that the scale's weight readings closely match the actual weights of standard weights, achieving the required design precision standards. This not only validates the scale's accuracy and reliability but also confirms its stability and dependable performance in practical applications. The test confirms the scale's capability to meet various high-precision weighing requirements, providing users with accurate measurement data. When the "Calculate Amount" function is activated, the scale not only identifies and records the object's actual weight but also calculates the total value using preset unit price information. This feature offers significant convenience, allowing users to instantly determine the total value of items during weighing. Whether for commercial transactions or daily use, this real-time amount calculation function effectively enhances efficiency and accuracy, as illustrated in Fig. 11's amount calculation interface. The calculation formula is as follows:

Total amount = Unit price (RMB/kg) * Weight (kg)


**Fig. 11** Calculation Amount Interface

After completing basic testing of the electronic scale, to further verify its measurement accuracy and sensitivity, experiments were conducted using everyday items. First, the actual weights were measured using calibrated standard electronic scales. The scale underwent four detailed tests, with each measurement taken three times and averaged to obtain final weight readings. Through a meticulously designed testing protocol, all measurement results were recorded and compiled into tabular data (Table 1). Designed to achieve ±1g accuracy, the scale demonstrated compliance with its specified precision standards across all three measurements following comparative analysis. These results not only validate the device's accuracy and reliability but also highlight its exceptional sensitivity and operational stability.

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**Table 1.** Measurement Data

| Numble | article | actual weight | Measured weight | D-value | Weight matching rate |
|---|---|---|---|---|---|
| 1 | 50g weight | 50 | 50.1 | -0.1 | 100.2% |
| 2 | 100g weight | 100 | 100.1 | -0.1 | 100.1% |
| 3 | 50g weight + 100g weight | 150 | 150.0 | 0 | 100% |
| 4 | Redmi K50 Ultra smartphone | 217.5 | 217.2 | 0.3 | 99.8% |

## 5. Conclusion

This paper provides a comprehensive analysis of the design process for a microcontroller-based smart electronic scale. Starting with theoretical foundations, we conduct an in-depth examination of the smart scale's operational principles. The study employs the high-performance, low-power ESP32 microcontroller as the core controller to ensure stable operation and energy efficiency. For hardware implementation, the HX711 high-precision sensor is selected to accurately capture weight measurements, leveraging its exceptional accuracy and stability to guarantee measurement reliability. To enhance user experience, the system integrates Bluetooth functionality and digital display modules for intuitive interface presentation. The software development focuses on functional requirements, implementing control programs that extend beyond basic weighing capabilities to incorporate intelligent features. Through Bluetooth technology, the scale enables real-time data transmission to mobile devices, facilitating remote monitoring and data management. This innovation not only broadens application scenarios but also delivers enhanced user convenience. Experimental validation confirms the microcontroller-based smart scale exhibits robust stability and measurement accuracy. Field tests indicate that the device offers intuitive operation and comprehensive functionality, effectively meeting diverse weighing requirements across various applications.

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