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# Design of Energy Consumption Meter

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***Abstract:*** *This paper proposes an energy consumption measurement system for high-power appliances, which integrates multiple key components such as displays, controllers, main control modules, main clock circuits, RTC clock circuits, SWD debugging interfaces, reset circuits, 485 modules, power modules, and power modules. Through the use of STM32 chips as the main control chip and OLED chips as the display chip, efficient and accurate energy consumption data collection and display are achieved. The system uses the main clock circuit and RTC clock circuit for timing to achieve batch acquisition, and performs power calculations through the reset circuit and power module, so as to obtain and analyze the energy consumption data of the appliance multiple times, providing an important basis for further energy consumption optimization.*

***Keywords:*** *energy consumption measurement; STM32 chip; clock circuit; power module*

## 1. Introduction

Against the backdrop of rapid technological development, the research and development of electronic and electrical equipment is becoming increasingly widespread. With increasing attention from all sectors of society to energy issues, energy conservation and emission reduction have become the focus of current social concern. For high-power appliances, the monitoring and optimization of their energy consumption are particularly important. Obtaining the energy consumption of corresponding electrical components through energy consumption detection and then achieving reasonable optimization of electrical components have become necessary links in research and development and production. For household appliances, detecting the power of electrical appliances for regular maintenance and replacement is visible. Therefore, the research and development of energy consumption detectors is of great significance for production and life.

A utility model in China has disclosed an energy consumption meter (CN204289927U), which includes a shell, multiple functional buttons, an electrical energy consumption unit, a microcomputer controller, a socket unit, and multiple functional indicator lights[1]. However, the above-mentioned energy consumption detector does not limit the specific circuit structure inside it, and in terms of corresponding technology, the above-mentioned energy consumption detector can only detect the energy consumption of small household appliances with low power, and cannot detect the energy consumption of high-power appliances[2-3]. Therefore, its practicality is not high. Developing a more practical energy consumption detector for high-power appliances is an urgent problem for technical personnel to solve.

## 2. Scheme Design

The energy consumption meter for high-power appliances proposed in this paper is composed of a display, controller, main control module, main clock circuit, RTC clock circuit, SWD debugging interface, reset circuit, 485 module, power module, and power module. The system selects the high-performance and low-cost STM32 chip as the main control chip, and the OLED chip as the display chip. Through the timing of the clock circuit and RTC clock circuit, it collects data in batches, and through the reset circuit and power module, it can calculate and obtain the power consumption in batches. Therefore, compared with previous energy consumption meters, this energy consumption meter can detect corresponding high-power appliances, thereby further improving the practicality of the corresponding energy consumption meter. The schematic diagram of the system design is shown in Figure 1.

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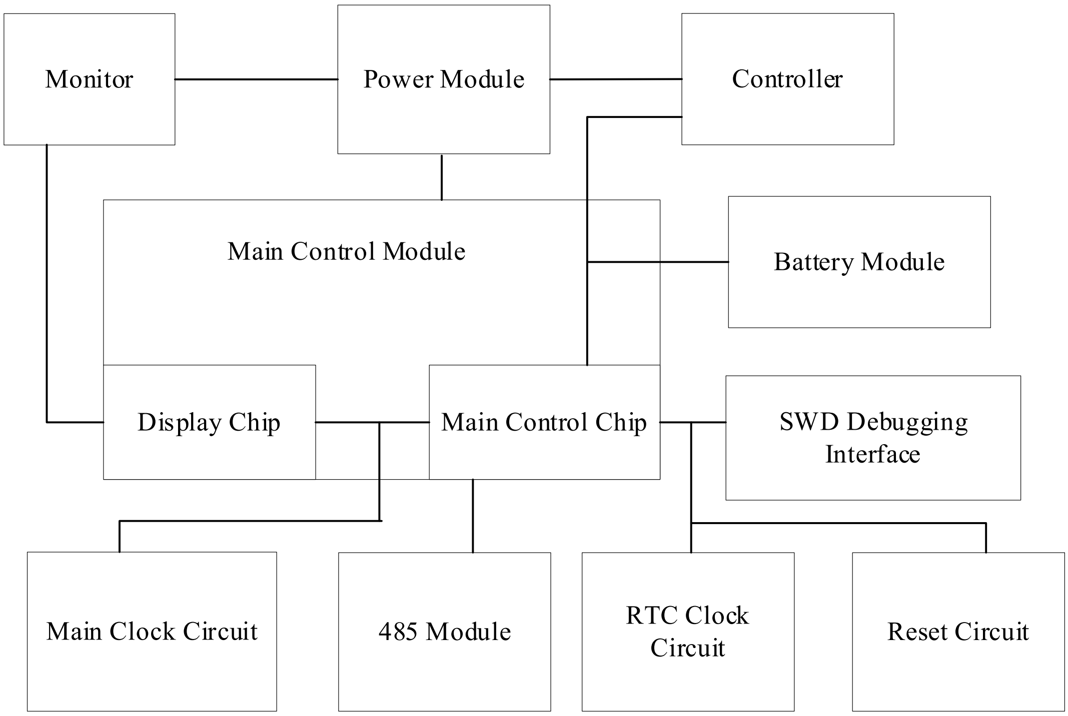


*Figure 1: Block Diagram of Energy Meter Principle*

## 3. System Hardware

### *3.1. PCB Design*

To achieve lightweightness of the system and high-speed signal transmission, the single-chip microcomputer is constructed using a PCB board. We used Altium Designer software for drawing. During the design process, we adopted a double-layer board design by separating the signal and power layers onto different layers, which can better manage signal integrity and power distribution, reducing cross-layer interference. The double-layer board design can better control differential impedance and single-ended impedance, as well as optimize the output of signal frequencies. In terms of PCB processing, we chose copper cladding treatment, placing the main devices on the top layer while laying out power lines and signal lines. The overall PCB diagram is shown in Figure 2.

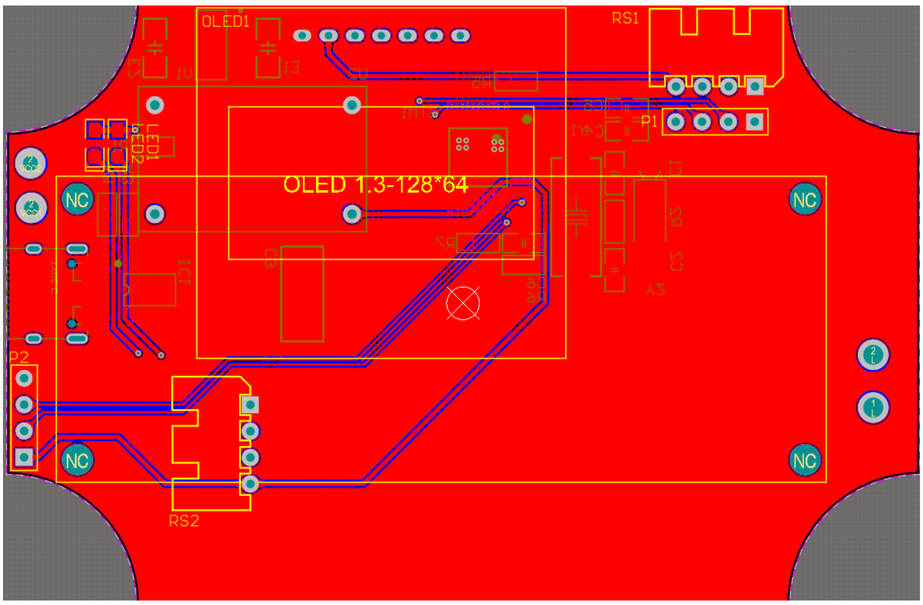


*Figure 2: PCB Design*

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### *3.2. Circuit Design of Each Module*

#### *3.2.1. Main Control Module*

The main control module includes the main control chip and the display chip. This system selects the STM32F103C8T6 chip as the control chip for the single-chip microcomputer[4]. The STM32F103C8T6 chip is rich in functions, with built-in communication controllers such as CAN controllers and serial ports, responsible for the control and management of the entire system, and realizing functions such as data collection, processing, storage, and transmission to meet the design requirements of the system. The control port is connected to the main control chip, and the display input port is connected to the display chip. The schematic diagram of the main control module is shown in Figure 3.

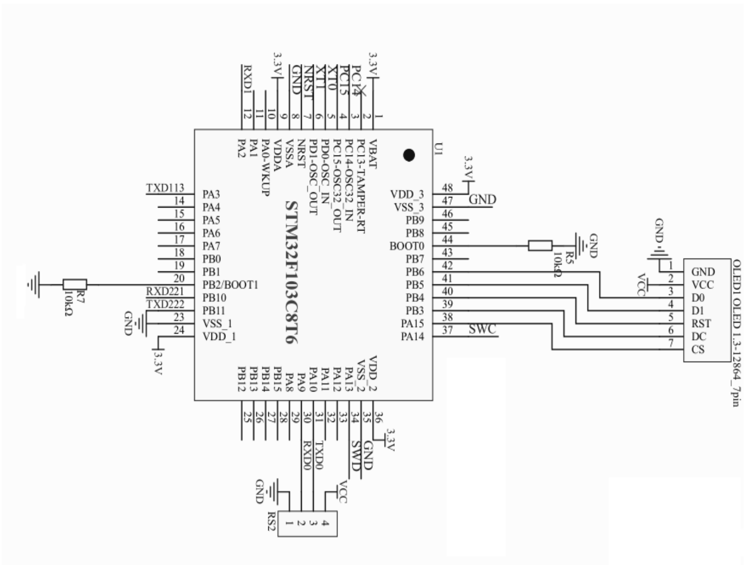


*Figure 3: The schematic diagram of the main control module*

#### *3.2.2. Power Module*

The power module includes a charging circuit and a power supply circuit. The charging module uses the IC-TP4056, which is a constant current/constant voltage linear charger for single-cell lithium-ion batteries[5]. The power supply module uses the AMS1117-3.3, which is a positive low-dropout voltage regulator with an output voltage of 3.3V. It converts 220V AC power into stable 3.3V DC power to provide electricity for the single-chip microcomputer and other modules. The schematic diagram of the power module is shown in Figure 4 and Figure 5.

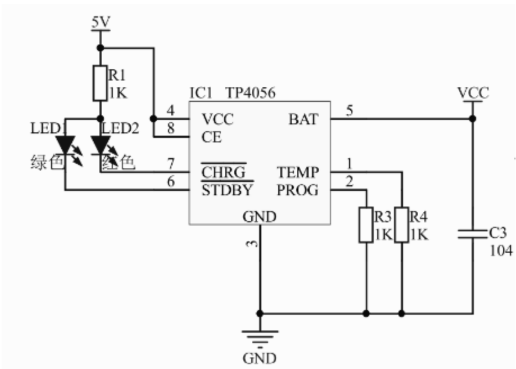


*Figure 4: Charging Circuit*

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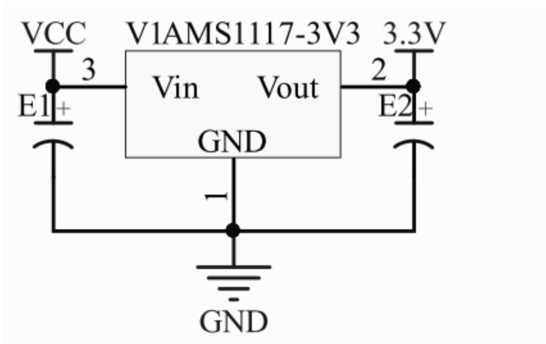


*Figure 5: Power Supply Circuit*

### 3.2.3. Battery Module

The system adopts the SUI-101A module, which can collect DC voltage and working current through voltage transformers and current transformers. The maximum measurable voltage of this system is 400V, and the maximum measurable current is 5A. The schematic diagram of the battery module is shown in Figure 6.

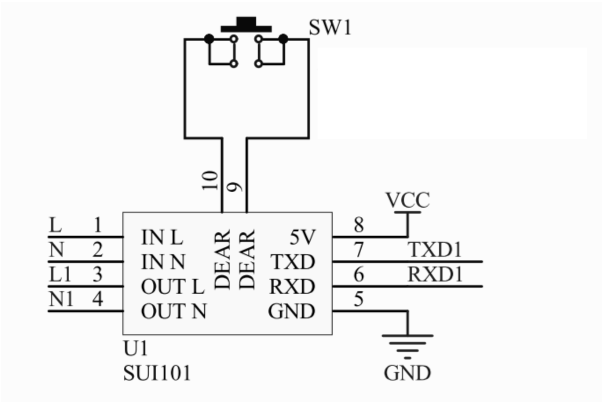


*Figure 6: The schematic diagram of the battery module*

### 3.2.4. Clock Module

a) Main Clock Circuit

The main clock circuit is one of the most important components in digital circuits, providing a reference clock signal for the entire digital system. The main clock circuit usually consists of components such as crystal oscillators, frequency dividers, and filters. The quality and stability of its output clock signal directly affect the performance of the digital system. The schematic diagram of the main clock circuit is shown in Figure 7.

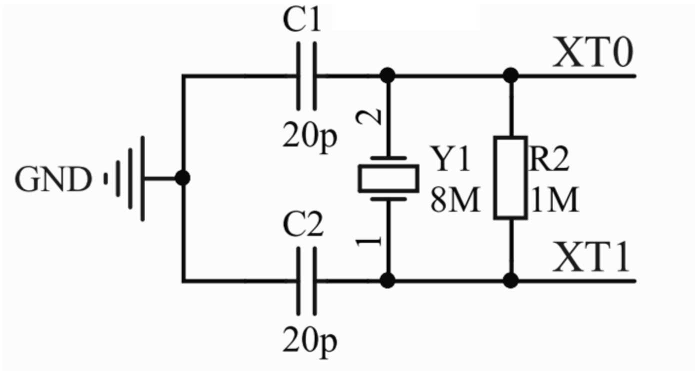


*Figure 7: The schematic diagram of the main clock circuit*

b) RTC Clock Circuit

The RTC (Real-Time Clock) clock circuit is a type of real-time clock circuit that provides accurate date and time information. The RTC typically generates a stable clock signal using a quartz crystal

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oscillator (or other high-precision oscillator) and implements time counting and display through components such as counters and registers. The schematic diagram of the RTC clock circuit is shown in Figure 8.

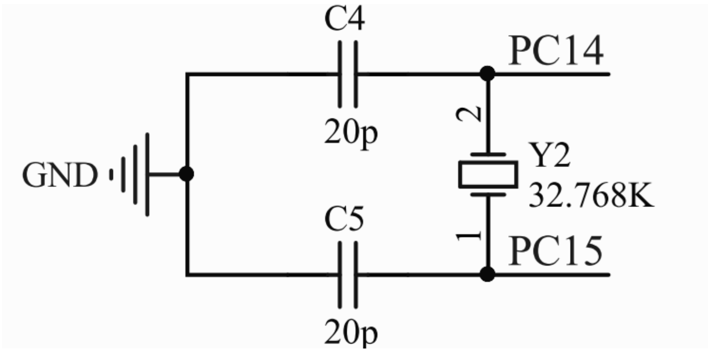


*Figure 8: The schematic diagram of the RTC clock circuit*

Timing is performed through the main clock circuit and the RTC clock circuit to enable batch data acquisition. Additionally, through the reset circuit and the battery module, multiple measurements of power consumption can be calculated in batches.

### *3.3. Hardware Interface Details*

#### *3.3.1. RS485 Interface*

The RS485 interface is a common serial communication interface standard that uses differential signal transmission, making it highly resistant to interference and capable of long-distance transmission. It is widely used in industrial automation, building security, smart homes, and other fields. In the RS485 bus, a master-slave communication mode is adopted, where one master device controls multiple slave devices. The master device initiates a data transmission request by sending a control signal, and the slave devices respond after receiving the request. Data transmission adopts a half-duplex mode, meaning that information can only be transmitted in one direction at the same time. Therefore, it is necessary to control the timing of data transmission and reception.

This system selects the TTL-to-485 module and writes the Modbus communication protocol to enable data communication with devices from different manufacturers in the industrial field. Through the 485 module, energy consumption data is remotely transmitted to the monitoring center, allowing users to monitor and analyze energy consumption data in real-time.

#### *3.3.2. SWD Debugging Interface*

SWD (Serial Wire Debug) is a serial debugging Interface that requires only two wires, SWCLK and SWDIO, which reduces the number of pins and the occupation of GPIO ports on the microcontroller. It is also more reliable in high-speed mode. This system adopts the SWD debugging interface to facilitate developers to debug and maintain the system, improving its reliability and stability.

### *3.4. Microcontroller Unit Design*

This system uses the KEIL software to develop the single-chip microcomputer. KEIL is a software development system that is compatible with the C language for single-chip microcomputers. It provides developers with a complete development solution including a C compiler, macro assembler, linker, library management, and simulation debugger[6]. Its easy-to-use integrated environment and powerful software debugging tools are beneficial for the development of this system. The system uses the STM32 standard library for development. The development of the single-chip microcomputer end mainly involves serial port modules, battery modules, etc.

### *3.5. Serial Port Module*

Using the standard library function library, the IO ports are first configured, with PA2 set as the serial port RXD push-pull multiplexed output and PA3 set as the serial port TXD pull-up input for communication with the battery module. Similarly, IO port PA9 is set as the RXD push-pull multiplexed output, and PA10 is set as the TXD pull-up input for communication with the TTL-to-485 module.

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Afterward, the four essential elements of the serial port are initialized, with the baud rate of the serial port set to 9600, 1 stop bit, 8 data bits, and no parity bit configured. Finally, the serial port's reception interrupt is programmed and configured so that when the serial port receives a frame of data, an interrupt is generated, ensuring that a complete frame of data can be received.

### *3.6. Battery Module*

The power module is responsible for collecting and calculating power consumption. By collecting and calculating in batches, accurate power data can be obtained. The SUI-101A processes the collected high voltage and high current through voltage transformers and current transformers to obtain voltage and current values that can be processed by the single-chip microcomputer. The single-chip microcomputer receives the voltage and current through the serial port and PA3 port, converts them into actual voltage and current values, and calculates the power consumption by multiplying them. After the calculation is completed, the power is displayed on the OLED screen.

## 4. Conclusions

This article designs an energy consumption meter for high-power electrical appliances, which achieves precise measurement and data analysis of energy consumption through multi-module collaboration and multiple batches of collection and power acquisition. The system has high integration, stability, and real-time performance, providing strong support for energy conservation and emission reduction. At the same time, the system also has remote communication functionality, facilitating real-time monitoring and analysis of energy consumption data.

## References

*[1] Ye Yuezheng. A energy consumption measuring device [P]. Zhejiang: CN204289927u, 2015-04-22.*
*[2] Niu Xing. Wireless sensor network node energy consumption measurement equipment design and realization [D]. Henan: Henan University, 2011.*
*[3] Liu Jiancai. Embedded equipment energy consumption measurement system based on machine learning calibration [J]. Information communication, 2020 (1): 75-77.*
*[4] Yang Hongbo, Zhu Lei, Zhang Bo, Waiting. STM32's W5500 Ethernet communication module quickly implement method [J]. Single-chip microcomputer and embedded system application, 2018,18 (8): 11-16.*
*[5] Cen Xunyi, Huang Xuerun, Li Jiahang, etc. The design of STM32-based smart storage car design [J]. Mechanical and electrical product development and innovation, 2023,36 (06): 40-43.*
*[6] Zhou Ming. The energy consumption measurement system of high-power LED lamp array is [J]. Computer measurement and control, 2018,26 (2): 13-16, 20.*