Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Design and implementation of energy consumption acquisition device based on ESP32

To cite this article: Kai Zhang and HongFang Lv 2022 *J. Phys.: Conf. Ser.* **2310** 012035

Design and implementation of energy consumption acquisition device based on ESP32

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Abstract—In recent years, due to the vigorous development of China's economy and society, the country's energy use is increasingly high, and the demand is very large. Effectively reducing power consumption while ensuring economic and social development has become a very important issue that the whole Chinese economy and society are concerned about. Based on this, a device energy consumption acquisition device is proposed in this paper. The hardware adopts ESP32 microprocessor as the core controller, and the current type current transformer is used to collect the voltage and current signal data of the device. Arduino software is used to design the acquisition program and output energy consumption data. Finally, the device is tested, and the results show that the device can collect energy consumption data of the equipment.

1. Introduction

With the shortage of energy supply in the world, the development of green building and building energy conservation has attracted great attention. In European and American countries and some developed countries, building energy accounts for about 40% of the total energy[1], and 60-70% of building energy consumption is used for building air conditioning and heating[2]. According to the data analysis of energy consumption and carbon emission in the whole life cycle of buildings in China in 2018, building energy consumption accounts for 46.5% of the total energy consumption in China[3]. In terms of building energy consumption, building operation energy consumption is the leading part of building energy consumption[4]. Energy consumption is generated through thermal power stations, in which the incineration of fossil fuels will produce CO_2 gas and cause greenhouse effect[5]. Under the background of increasingly serious energy supply and demand, advocacy of green building, energy conservation and emission reduction, etc.[6], research on energy conservation is of great and far-reaching significance.

2. Overall design and demand analysis of energy consumption acquisition device

2.1 Design Objectives of the Energy Collector

Using energy consumption acquisition device to collect energy consumption data of equipment in the factory plays a very important role in reducing power consumption, can reduce the power consumption of the factory, can effectively reduce the cost of factory production; The energy consumption collector is used to collect energy consumption of the equipment in the factory.

2.2 Overall design of energy consumption acquisition device

This collection device adopts the modular design idea, carries on the overall planning, designs the realization step by step. The acquisition device consists of four parts: control processor module, acquisition module, communication module and infrared module. The current transformer module is connected with the control processor module, and the signal measured by the current transformer is input to the processor module for analysis and processing. Infrared control module is the follow-up research and improvement. The communication module can upload energy consumption data.

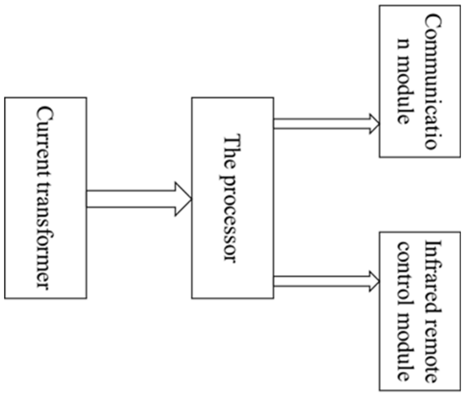

Fig.1 Schematic diagram of the energy consumption collector

3. Hardware design of energy consumption acquisition device

3.1 Control the selection of processor modules

ESP32 chips are widely used in different applications due to their advantages of stability, versatility and reliability, ultra-low power consumption, and ability to adapt to different power requirements. ESP32 is currently the industry's leading highly integrated Wi-Fi and Bluetooth solution.

After comparing STM32 chips similar to ESP32, as shown in Table 1, it can be concluded that ESP32 is superior to STM32 in terms of main frequency, flash size and ADC channel, and STM32 has many more pins than ESP32. However, due to the small number of peripherals in this system, the demand for pins is also not high. In terms of price, the ESP32 is cheaper.

Table 1 Comparison between STM32 and ESP32

Chip	frequency	flash	pin	power supply voltage	ADC	price
STM32F103R8T6	72MHZ	128KB	80	2V-3.6V	2 * 12 bit	28
Lexin ESP32	240MHZ	4MB	38	2.2V-3.6V	18 * 12 bit	25

Therefore, after comprehensive consideration, the system adopts ESP32 as the main control chip, which is convenient for the realization of functions and cost saving.

3.2 Collection Module

In the design of the energy consumption acquisition device, the current-type current transformer is selected as the main component of the acquisition module. The typical application circuit of the current-type current transformer is shown in Fig.2.

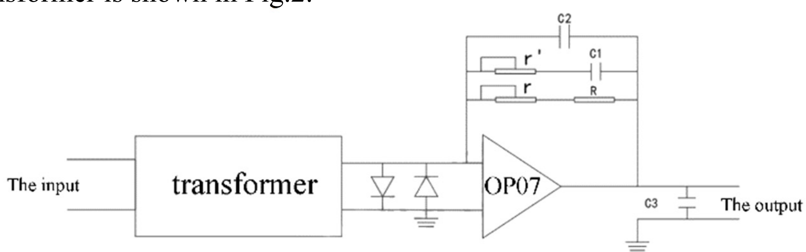

Fig.2 Circuit diagram of current type ct in typical application

The specific working principle is that the bus is connected with the bus through the first turn of the reserved channel. Input a rated high current level (such as 10A), the secondary stage (secondary side) will reflect a small voltage level (such as 5mA), by adjusting the feedback resistor R, with the operation amplifier (OP07) amplifier amplification, from the current output terminal can automatically obtain the maximum voltage output system can require.

However, in this energy consumption acquisition device design, THE current transformer I choose is ZHT903-D, which directly outputs voltage signals. The specification parameters are 10A/3.33V, and it can be directly connected with ESP32 processor. The ESP32 microprocessor chip comes with A 12-bit A\D conversion function that can directly convert analog to digital quantities.

3.3 Design of infrared module and communication module

The design of the infrared module is to take into account that the energy consumption acquisition device can be further improved in the future. It can control the operation of the equipment through the infrared function while carrying out the energy consumption.

The communication module is designed to take into account the uploading and storage of equipment data and information in the later research, and to facilitate the further improvement of the energy consumption acquisition device in the later research. In this design, the energy consumption acquisition device upload energy consumption data to the cloud server database through MQTT protocol, without hardware design.

4. Software design of energy consumption acquisition device

4.1 Software process design

Firstly, the program is started, the microcontroller is powered on and reset, the data initialization management of ADC, GPIO and other modules is completed, the baud rate data initialization value of serial port is set to 115200b/s, and AD sampling is started. The software program flow chart is shown in Fig.3.

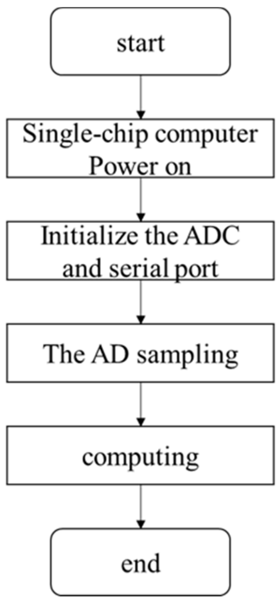

Fig.3 Flowchart of software programs

4.2 Software Configuration

4.2.1 Software Selection

In the design of the energy consumption acquisition device, I chose to use Arduino software to design and develop the program.

Developed by a European research organization in the winter of 2005, Arduino is a simple, flexible, hands-on, open source electronic prototyping tool. It can use many sensors to learn about its surroundings, and react and manipulate the natural environment by manipulating lamps, motors or other mechanical devices. Programs can be written using Arduino's programming language, compiled into binary format, and then burned to the microcontroller; It also provides development applications on Windows, Macintosh-OS and Linux.

4.2.2 Serial Port Configuration

In this design, 34 pin port of ESP32 is used to connect with the positive pole of the current transformer. The current transformer selected is a direct output voltage signal, which can be directly connected with the ESP32 processor. ESP32 chip comes with 12-bit A\D conversion, which can convert analog to digital quantities and write programs using Arduino software.

First, configure the GPIO port, which is ADC1_CH6. Then set the GPIO port to the AD module input mode. Finally, set the baud rate of the serial port to 115200 B /s. The setting procedure is as follows.

```
ESP32AnalogRead adc.        // Declare an ADC object and set the module address
Int analogPin = 34;             // Define input pins
Void setup (void)
{PinMode (analogPin, INPUT);                 // Define the input mode
Serial. The begin (115200);                 / / baud rate
Delay (1000);}
```

4.3 Energy consumption acquisition program design

ADC conversion is the conversion of the input analog voltage to a digital value. The ADC conversion result provided by the ADC driver APIs is the raw data. In single-channel read mode, the resolution of the ESP32 ADC's original results is 12 bits. The voltage is calculated from the original results of the ADC by the following formula.

$$Vout=Dout*Vmax/Dmax \tag{1}$$

Vout is the digital output result and represents the voltage. Dout is the reading result of ADC original digital; Vmax is the maximum measurable input analog voltage; Dmax is the maximum value of the output ADC original digital read result, which is 4095 in single-read mode.

The following describes some energy consumption collection procedures.

```
Void loop (void)
{adc0 = analogRead(analogPin);         // Read the numerical value of pin 34
float Voltage = 3.3/4095*adc0;       // Convert digital values to analog voltage values
Electric = (10*(3.3/4095*adc0))/3.33;         // Calculate the current
Power = Voltage*3*220;                              // Calculate the power
// Serial port displays data
Serial. Print (" AIN0: ");Serial. Print (adc0);Serial. Print (" ");Serial. Print (" \ tVoltage: ");
Serial. Print (Voltage, 3);Serial. Print (" V ");Serial. Print (" \ tElectric: ");Serial. Print (Electric, 3);
Serial. Print (" A ");Serial. Print (" \ tPower: ");Serial. Print (Power, 3);Serial. Print (" W ");
Serial. Println ();Delay (1000);}
```

4.4 Uploading Data to the Cloud Server

The collected energy consumption data is uploaded to the cloud server through MQTT protocol to complete data communication and storage.

4.4.1 Cloud platform construction

Set up the MQTT server

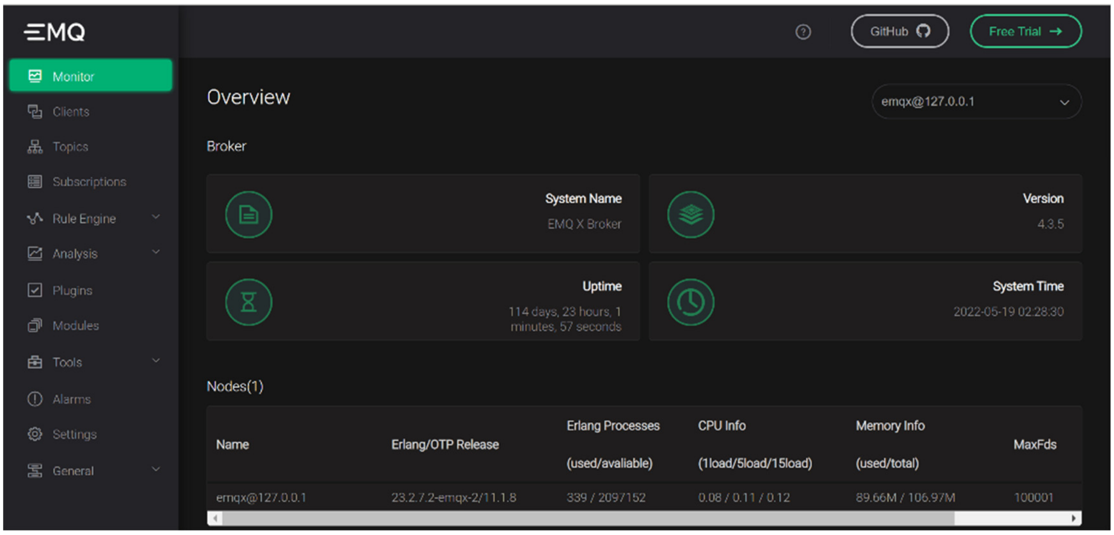

Fig.4 EMQ platform

To use MQTT service, port 1883 used by MQTT must be released in the security group of cloud server. Meanwhile, EMQ has a management console Dashboard with port 18083, which can be accessed through IP:18083 after the release

Test the MQTT server and connect to the test tool on the EMQ platform page

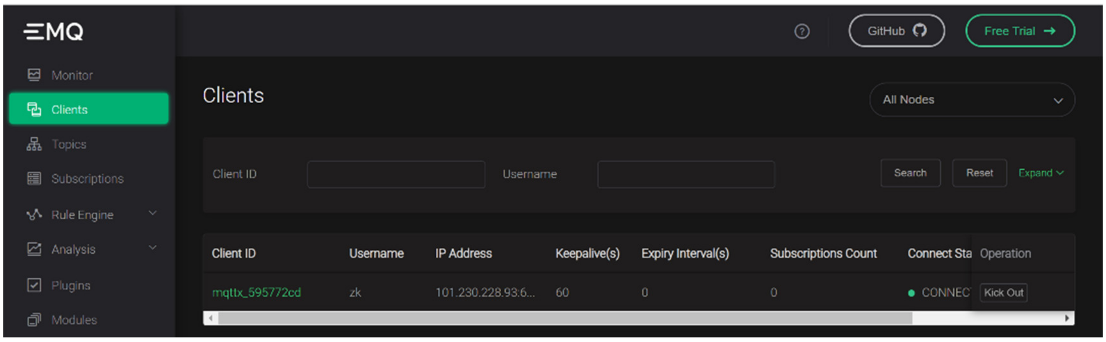

Fig.5 EMQ Platform page the client is connected

Send messages to the server through MQTT test tool, which can also be seen in the console, indicating that the server is set up and ready to use.

4.4.2 Creating and uploading a database

Navicat 15 for MySQL is used to connect to the database, design and modify the established database, and upload the energy consumption data to the cloud server through MQTT protocol.

5. Test and implementation of energy consumption acquisition device

In the test of energy consumption acquisition device, the desktop heating pad is selected as the measurement device object, and the information of voltage, current and power through the serial port of Arduino software is displayed.

5.1 Physical Connection

Using a desktop heating pad as a load device, the read data is displayed through the Arduino serial port

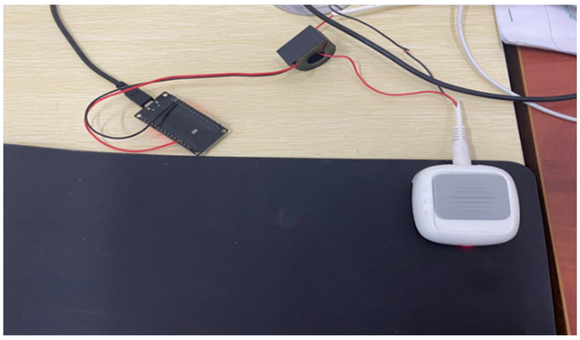

Fig.6 Physical device connection

5.2 Data Output

The read data is displayed through the Arduino serial port.

```
15:11:28.461 -> AIN0: 1094    Voltage: 0.882 V    Electric: 2.647 A    Power: 63.476 W
15:11:29.488 -> AIN0: 1121    Voltage: 0.903 V    Electric: 2.713 A    Power: 65.043 W
15:11:30.483 -> AIN0: 1148    Voltage: 0.925 V    Electric: 2.778 A    Power: 66.609 W
15:11:31.478 -> AIN0: 1163    Voltage: 0.937 V    Electric: 2.814 A    Power: 67.480 W
15:11:32.473 -> AIN0: 1154    Voltage: 0.930 V    Electric: 2.793 A    Power: 66.957 W
15:11:33.468 -> AIN0: 1136    Voltage: 0.915 V    Electric: 2.749 A    Power: 65.913 W
15:11:34.462 -> AIN0: 1093    Voltage: 0.881 V    Electric: 2.645 A    Power: 63.418 W
15:11:35.461 -> AIN0: 1040    Voltage: 0.838 V    Electric: 2.517 A    Power: 60.343 W
15:11:36.454 -> AIN0: 1008    Voltage: 0.812 V    Electric: 2.439 A    Power: 58.486 W
15:11:37.460 -> AIN0: 992     Voltage: 0.799 V    Electric: 2.401 A    Power: 57.558 W
15:11:38.475 -> AIN0: 992     Voltage: 0.799 V    Electric: 2.401 A    Power: 57.558 W
```

Fig.7 Serial port data output

5.3 Data Comparison

The measured data is compared with the equipment parameters


```
Power: 63.476 W
Power: 65.043 W
Power: 66.609 W
Power: 67.480 W
Power: 66.957 W
Power: 65.913 W
Power: 63.418 W
Power: 60.343 W
Power: 58.486 W
Power: 57.558 W
Power: 57.558 W
```

Fig.8 Data comparison

6. Conclusion

An equipment energy consumption acquisition device is designed and developed, through the current transformer and the core processor, ESP32 collecting electricity equipment load current and voltage signal, and then after analog-to-digital conversion, digital signal energy acquisition, and ESP32 processor to achieve the connection, implements the intelligent hardware module initialization data installation, and also for a variety of data acquisition program The communication interface programming is designed to complete the energy consumption collection of the equipment. At the same time, it is also found that when using the current transformer, the minimum measuring equipment of 30W is needed, and the accuracy of the current transformer can be greatly improved by detecting equipment of 1KW and above.

Acknowledgments
I would like to thank my teachers, classmates and research groups for their help and care for me, for their careful guidance and suggestions, so that I can finish this article.

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