ISSN: 2664-9640

Application Research of Remote Monitoring System for Electrical Appliances Identification Based on LoRa

Shiqiang Wang [1], Yanhua Xian [2]

[1]Handan Vocational College of Science and Technology, Handan 056046, China.

[2]College of Electronic Engineering, Guangxi Normal University, Guilin 541004, China.

Abstract

In view of the problem of more manpower and equipment wiring cost in the existing power monitoring system, the LoRa low-power long-distance communication is applied to the monitoring equipment of household appliances. The high-precision CS5463 chip is used to collect the voltage, current and power factor of the household appliance, and the information communication between the transmitting end and the receiving end is completed via the LoRa wireless transmission technology. A host computer is designed to display the collected data in real time on the computer. In addition, in order to control the high-power appliances, the K-nearest neighbor algorithm is used to identify the working status of electrical appliances running or stopping. The research of this system is of great significance for the intelligent management of electricity safety and the promotion of internet of Things technology.

Keywords

LoRa wireless; CS5463 chip; K-neighborhood algorithm; remote monitoring.

1. Introduction

With the increasing variety of high-power electrical appliances, such as fast heating, electric kettles, etc., higher requirements for electricity safety have been put forward. These heating appliances are used in student dormitories, which may cause fires due to improper use. The school's usual practice is to limit the total power consumption of each student dormitory, for example, when the power is greater than 500W, the power will be cut off. This practice is very unfriendly and will affect the simultaneous use of multiple computers by students. Therefore, it is necessary to adopt an effective monitoring method for electrical appliances.

The current communication methods of monitoring systems are mainly divided into wired and wireless Bluetooth monitoring[1], which have the defects of high erection cost and short transmission distance. The LoRa wireless communication technology using SX1278 chip can solve the problem that the signal of ordinary wireless communication technology cannot penetrate the floor in modern buildings, and SX1278 has low power consumption mode and sleep wake-up technology[2-6]. The communication method of this design uses LoRa low-power wireless devices to transmit data, and the communication distance can reach 10km without relay. In addition, in view of the problem of prohibiting the use of high-power electrical appliances in schools to ensure the safety of electricity use, the design has added an electrical appliance identification algorithm to detect the number of electrical appliances, identify which electrical appliances are working, and can send on-off signals to relays to control the power of the dormitory and power supply operation.

2. Overall System Design

The overall structure of the monitoring system designed in this design is shown in Figure 1. It mainly includes the collecting end and the receiving end. The data exchange adopts LoRa module for wireless transmission, and its communication interface is SPI, which is suitable for various development platforms. The data is collected in real time by the collecting end, and sent to the receiving end after the collecting is completed. When the collecting end receives the response code from the receiving end, the data transmission is successful. In Figure 1, the voltage and current acquisition module consists of a voltage and current transformer and CS5463. The collected information includes voltage, current, power, and power factor. The collected information is uploaded and the control command is issued through LoRa to complete the communication of the collected data. The core chip of the LoRa transceiver module is the SX1278 chip, and the control module is a relay. At the acquisition end, the microcontroller STM32F103 is responsible for the control of each module.

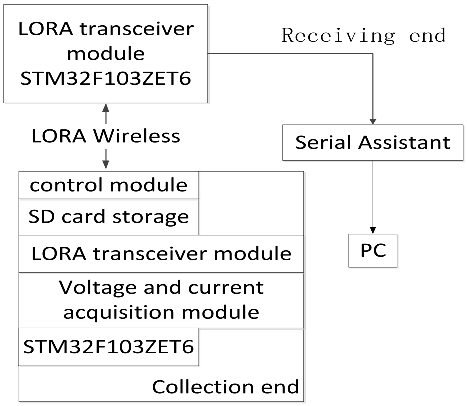

Figure 1 Overall structure of the system

3. System Hardware Design

3.1. Acquisition Circuit Design

CS5463 is an integrated power measurement chip. It communicates with the outside world through SPI. If it is connected to a reasonably designed peripheral circuit, it can accurately measure the instantaneous current and instantaneous voltage, and can calculate the apparent power, active power and reactive power. In this design, CS5463 and its peripheral circuits are shown in Figure 2.

Mainly include voltage measurement circuit (9-10 pins), current measurement circuit (15-16 pins), communication interface circuit (5-7, 19, 20, 23 pins), power supply circuit (11-14, 3, 4 pins) and crystal oscillator circuit (1, 24 pins). Among them, the crystal frequency of CS5463 is 4.096MHz.

The communication interface of CS5463 includes interrupt INT, reset REST and SPI communication interface. The acquisition circuit mainly reads data from the SPI interface of the CS5463. First, the CS5463 chip is initialized. After the initialization is successful, the corresponding registers of the CS5463 can be read to obtain the corresponding acquisition information, including voltage, current, power and power factor.

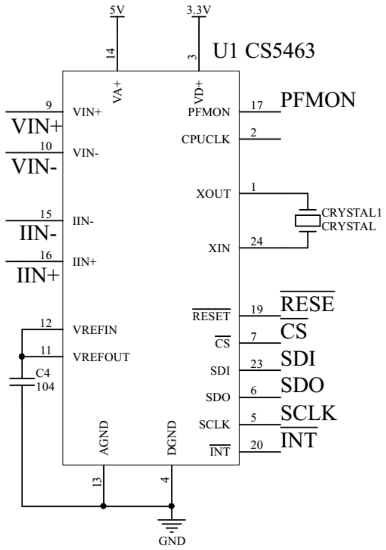

Figure 2 CS5463 pin definition schematic diagram

The voltage measurement circuit is shown in Figure 3, in which the terminal J2 is the access terminal for the voltage acquisition signal, the 1 and 2 ports of J2 are respectively connected to the neutral wire and the live wire at both ends of the electrical appliance, T1 is the voltage transformer ZMPT101B, and the capacitors C1 and C5 are Two filter capacitors, resistor R11 is a 110Ω precision resistor, R3 and R4 are 1kΩ, R7 and R8 are 470Ω, the positive half-wave of the voltage is input through R11, R3 and R8, and the negative half-wave is input by R11, R4 and R8 Input the collected voltage into the CS5463 chip.

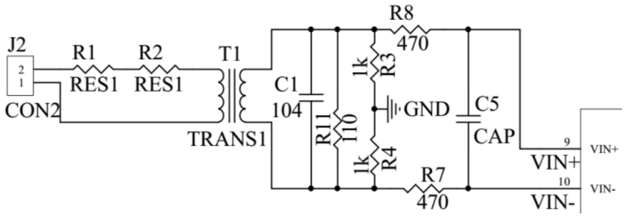

Figure 3 Voltage measurement circuit

The current measurement circuit is shown in Figure 4. Among them, T2 is the current transformer ZMCT103C, T2 is used to collect the current of the electrical appliance, C2 and C6 are filter capacitors, the function of the resistor is to convert the current signal of the current transformer into a voltage signal of the corresponding proportion, and input the 15 and 16 tubes of CS5463. pin, PFMON is connected to pin 17 of CS5463.

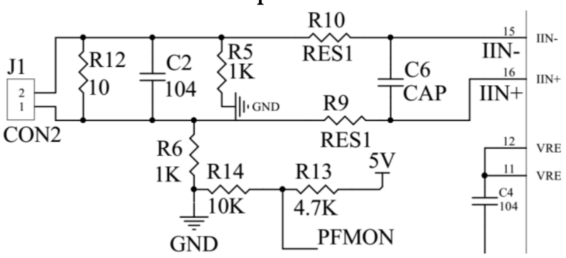

Figure 4 Current measurement circuit

The power module circuit is shown in Figure 5, in which the 1 and 2 ports of the P1 terminal are respectively connected to the external 5V voltage and ground wire, and U2 is the voltage conversion chip ASM117, which converts the 5V voltage to 3.3V voltage.

ISSN: 2664-9640

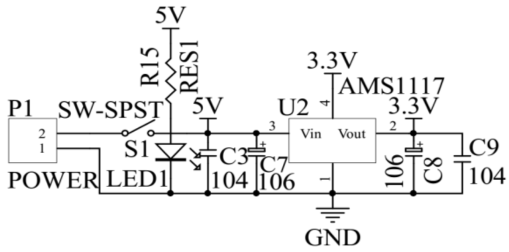

Figure 5 Schematic diagram of the power module of the acquisition circuit

3.2. Hardware Design of Wireless Module

The sending and receiving circuit of LoRa is shown in Figure 6. The LoRa transceiver module adopts the SX1278 chip, the 16-19 pins are the SPI communication interface, the 1 pin RFI_LF is the input pin, which is used to receive data, and the capacitor C106 and the inductor L103 are LC Filter circuit, 27 pins are high-power output pins, used to output the transmitted data, the external crystal oscillator is 32Mhz. The communication distance can be as high as 10KM without relay station.

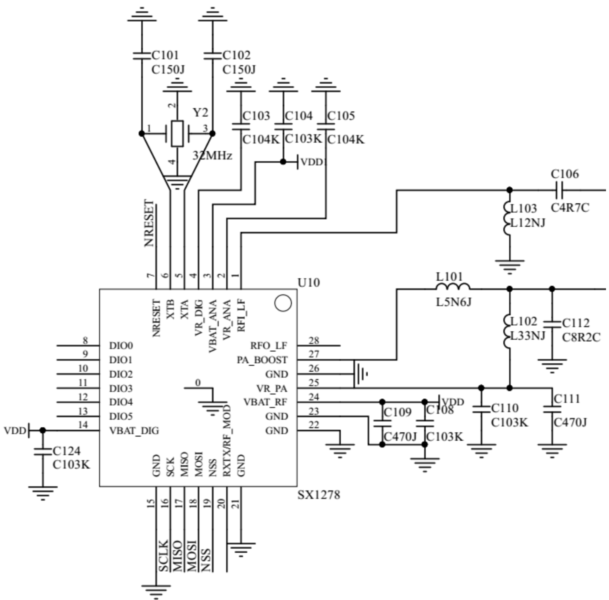

Figure 6 LoRa transceiver circuit schematic

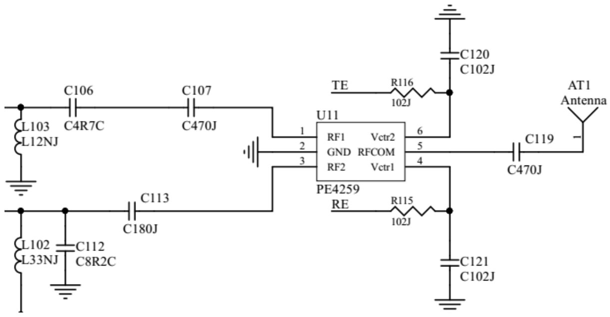

Figure 7 Antenna circuit design

Figure 7 shows the antenna circuit design in the LoRa module. The 1-pin RFI_LF of the chip SX1278 is connected to the 1-pin RF1 of the PE4259, the 27-pin PA_BOOST of the chip SX1278 is connected to the 3-pin RF2 of the PE4259, and the 5-pin RFCOM of the PE4259 is connected through a capacitor Antenna AT1. By controlling the voltage of the Vctr2 and Vctr1 pins of the chip PE4259, it is possible to control whether the pin RECOM is connected with RF1 or with

RF2. So by controlling the pins 4 and 6 of the chip PE4259, you can choose whether to send or receive data.

4. System Software Design

4.1. Wireless Communication Software Design

LoRa can establish an ad hoc network and a star network. The network nodes are composed of terminal nodes and master nodes. The acquisition end sends data to the relay end, and the relay end forwards the data to the receiving end, which can improve the wireless communication distance. The communication process of this system can be seen in Figure 1. The sender can be used as the master node, which receives the data of the acquisition module and sends the data to the receiver. The receiver receives the data from the master node and transmits it to the PC through the serial port. At the same time, the sender will analyze information such as power factor and current to determine whether the current device is normal, and if an abnormality is found, the receiver can be reminded remotely, which plays a certain protective role. The communication flow chart of the sender is shown in Figure 8. When the current is detected, the collected data is sent to the receiver. When there is no current, the data is not sent, and the sender is in a dormant state. Figure 9 is a flow chart of the receiving end. According to the preamble, it is judged which data is sent from the sending end. The main function is to transmit the data to the upper computer and store it on the device, which can facilitate future reference.

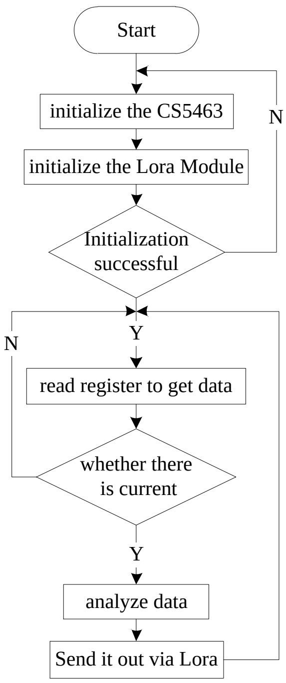

Figure 8 Communication flow chart of the sender

4.2. Design of Electrical Appliance Identification Algorithm

The collection end of this design uses the K-nearest neighbor algorithm to identify the electrical appliance number and its power on and off, and at the same time, it identifies whether the pure resistive load is powered on or not according to the power change. The K-nearest neighbor algorithm is simple and easy to implement, without parameter estimation or training and the sample also belongs to this category[7-8].

The K-nearest neighbor algorithm identifies the electrical appliance numbering method as shown in Figure 10.

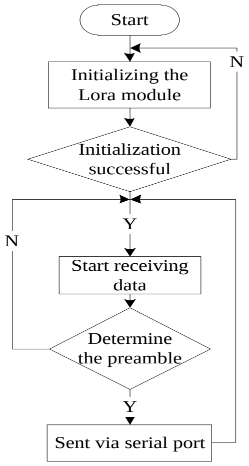

Figure 9 Receiver flow chart

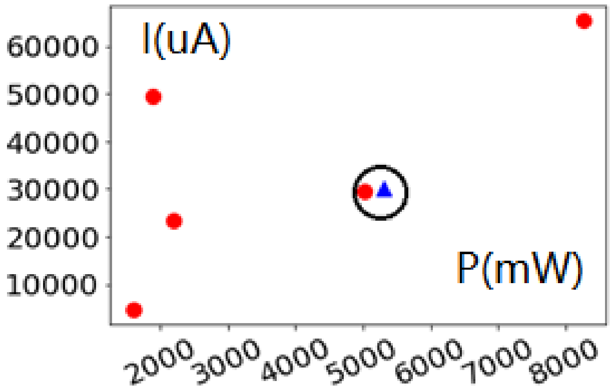

Figure 10 Diagram of K-nearest neighbor algorithm

The x-axis is the power, the y-axis is the current, the dot is the database, and the triangle is the currently collected data. Select the data closest to the five-pointed star in the dot, and the electrical appliance number corresponding to this data is the current electrical appliance number. By analyzing the currently collected data, it can be determined which number of electrical appliances have started to work. When the difference between the database data and the collected data is found to be large, it is determined as a new electrical appliance, and the collected data is stored in the internal flash for numbering.

Among them, the data in the database is to collect 5 data such as voltage and current of electrical appliances and save them. If X electrical appliances are collected, record MAX=X, number the electrical appliances [0, MAX-1], and define DATA[MAX] as follows:

```
struct property
{
char *eigenvalue ;
U32 current ;
U32 voltage ;
U32 powerfactor ;
U32 power ;
U32 currentchange[20] ;
};
struct property DATA[MAX];
```

The characteristic code of the electrical appliance is stored in the eigenvalue. Combined with currentchange, the waveform of the electrical appliance being powered on or off can be restored.

The code of the discrimination algorithm for the electrical appliance number is:

sig1=ABS(sample.current - DATA[i].current)

sig2=ABS(sample. power - DATA[i]. power)

tempf1=MAX(sample.current, DATA[i].current)

tempf2=MAX(sample. power, DATA[i]. power)

Sigma = sig1/tempf1 + sig2/tempf2

Among them, i represents the number of the data in the database, that is, the attribute information of the i-th data. sig1 and sig2 are the difference between the current collected current and voltage and the database. The larger current value and the larger voltage value are stored in tempf1 and tempf2, and the summed value after normalizing the two differences is stored in Sigma. Choose the smallest Sigma to lock in the most likely consumer number. Finally, according to whether the total power rises or falls, the power-on and power-off of the i-th electrical appliance is distinguished.

At the same time, check the tempf1 and tempf2 corresponding to the minimum Sigma. If there is a value greater than 0.6, it is judged as a new electrical appliance, and it is automatically entered into the flash to expand the existing database.

Figure 11 is the data analysis flow chart of the sender. According to the increase of current, it can be judged that a new electrical appliance is connected. According to the change of power factor, pure resistive load can be intelligently identified, which can effectively eliminate the hidden danger of electricity consumption.

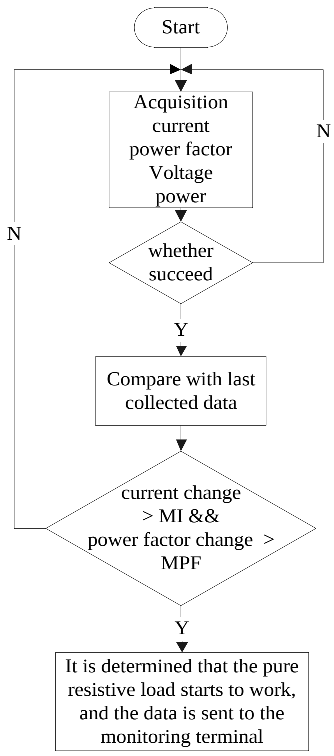

Figure 11 Data analysis flow chart

4.3. Host Computer Development

The MCU software is developed by Keil5[9-10], and the human-machine interface of the host computer is developed by QT, which can display data in real time on the PC, as shown in Figure 12. Users can intuitively see data changes on the dial, and can also understand historical information by viewing the database.

ISSN: 2664-9640

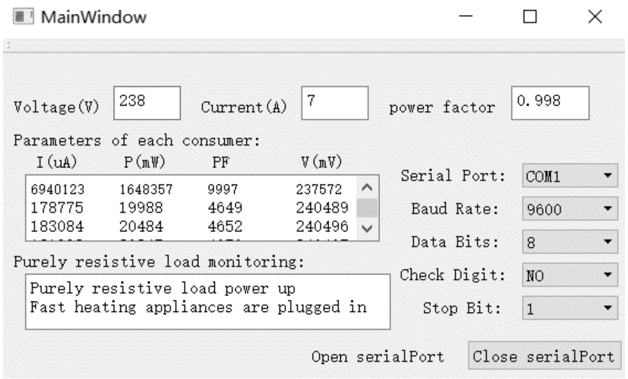

Figure 12 PC software diagram

5. Experimental Results

The test of this system is to collect the data of voltage, current, power factor and power supplied by the grid to the desktop host and household appliances as a reference. Figure 13 and Figure 14 are the physical map of the collecting end and the physical map of the receiving end, respectively. The collected data is shown in Table 1, in which the collected data interval is 1 second, the power factor shows the fractional part, and the integer part is 0.

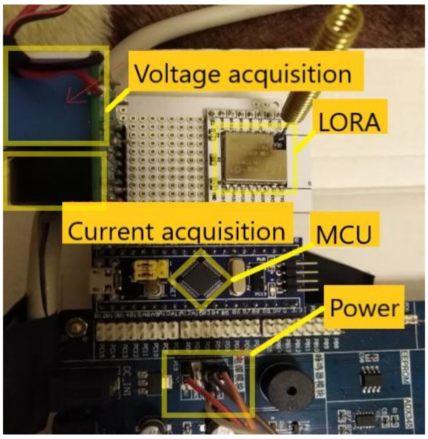

Figure 13 Collection terminal physical map

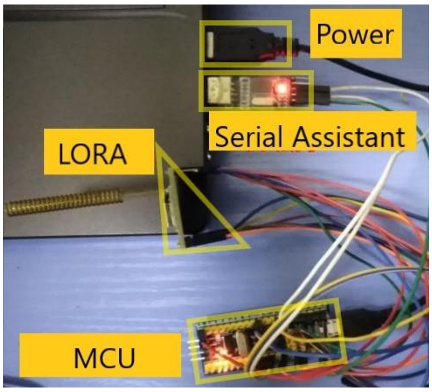

Figure 14 receiver module

Nos. 1-5 in Table 1 indicate the charging state of the notebook computer, the power factor is less than 0.5, and serial numbers 6-10 are the state of turning on the kettle. At this time, the power factor is close to 1, and it can be judged that a pure load circuit is connected. No. 11 is the state after the kettle is turned off, and No. 12-17 is the state when the refrigerator is turned on. At this time, the power factor is below 0.6. The identification of high-power purely resistive loads can be completed by analyzing the above data.

Table 1 Data collected by the collecting terminal

serial number	current/(uA)	power/(mW)	Power Factor	Voltage/(mV)
1	176268	19681	4641	240570
2	184282	20757	4684	240488
3	178775	19988	4649	240489
4	183084	20484	4652	240496
5	181993	20347	4650	240405
6	6940123	1648357	9997	237572
7	6931346	1645819	9997	237505
8	6923571	1643444	9997	237431
9	6912273	1639504	9997	237252
10	6907549	1638766	9997	237313
11	177472	19365	4537	240477
12	527790	68158	5502	234696
13	526973	68131	5508	234700
14	526916	67743	5478	234667
15	526386	67799	5488	234678
16	526323	67594	5474	234600
17	526314	67785	5488	234646

6. Conclusion

This design monitors the voltage, current, power and other power consumption of electrical appliances through LoRa wireless communication, and the following conclusions are obtained:

(1) According to the K-nearest neighbor algorithm and the changes of power and power factor, high-power purely resistive loads can be effectively identified, so that power-off measures can be taken to avoid accidents.

(2) This design uses LoRa wireless communication distance up to 10KM, which realizes low power consumption and low cost.

(3) This design can provide a reference for the design of the voltage and current monitoring system, and can be improved to send information to the server and interact with the user through the mobile phone application.

References:

[1] Zhou Weilong，Xiao Shenping，Chen Gang， etc. Design of High-Power Electrical Monitoring System Based on the Internet of Things [J]. Journal of Hunan University of Technology, 2012, 26(5): 95-99.

[2] Dong Zhangkai, Ye Yanpei. A Lora Communication Data Terminal and Its Data Processing Method Based on Circular Queue Buffer [J]. Industrial control computer, 2018, 31(5): 18-19.

[3] Yang Yang. Design of Intelligent Farm Monitoring System Based on LORA Technology [J]. Computer Measurement & Control, 2018, 26(6): 49-52.

[4] Dong Hui, Huang Shizhen. Design and implementation of intelligent agriculture system based on LoRa technology [J]. MICROCOMPUTER & ITS APPLICATIONS, 2017, 36(22): 106-108 .

[5] Chen Yian. Research on the application of meter reading based on LORA full wireless smart water meter [D]. Changsha: Hunan University, 2018.

[6] Luo Guiying. LoRa-BASED water meter reading system design and implementation [D]. Hangzhou: Zhejiang University of technology, 2016.

[7] Dou Xiaofan. Overview of KNN Algorithm [J]. Telecom World, 2018(10): 273- 274.

[8] Dai Puwei, Pan Bun, Wang Yuming, etc. An improved KNN Algorithm Based on Analytic Hierarchy Porcess [J]. JOURNAL OF LIAONING PETROCHEMICAL UNIVERSITY, 2018, 38(4): 87-92..

[9] Tan Haoqiang. C Programming [M]. Version 4. Beijing: Tsinghua University Press，2011

[10] Zhang Yanni. The principle and practice of STM32F0 series Cortex-M0 [M]. Beijing: PUBLISHING HOUSE OF ELECTRONICS INDUSTRY, 2016.