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Non-intrusive Household Appliances Management

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Abstract. The single-phase electric appliance analysis and detection device are divided into signal sampling, signal amplification and AD conversion. The system takes analog circuit as the main body, and takes digital circuit as the auxiliary, realizing precise control through STM32F4.And transforms the low voltage signal into the input through the voltage transformer and the current transformer through the front stage. The input signal is low-pass filtered and two-stage amplified by using the OPA2277A chip. We use the ADC channel ADR421AR 8-channel ADC, synchronized to capture the amplified voltage signal. We calculate the apparent power, active power and reactive power to find the power factor. We construct a binary tree based on the power factor and various powers. At the same time, we classify appliances by reading and matching feature arrays. Then, we compare the previous steady-state and the steady-state feature arrays and subtract them to get the feature array of the increased and decreased electrical devices. Finally, we determine the type of electrical devices by performing the feature matching.

Research Background

With the development of smart grids, the demand for power grid management is becoming more and more intense, and the management of intelligent power generation equipment has made a great breakthrough. Intelligent management for the user's power side is still not enough .

At the same time, the reasonable distribution of medium and low voltage power grids is also a key part to reduce the energy consumption of power grids. For the management of electricity users, the current market generally adopts the method of adding sensors in the position of electrical appliances.

Through wireless communication, the consumption of electricity will be sent to users in real time, the main products can be divided into two categories: total power consumption identification: most of these devices are used to set the sensor on the switchboard, collecting the user's total power consumption. Their structure is simple and the cost is low. However, they can not accurately identify the status of each electrical appliance, and can not provide reference information for the user to adjust electricity.

The other is invasive electrical testing. They are located in each of the electrical appliances installed sensors, collecting electricity information, so that real-time reflect the specific use of electricity for each appliance, but the system structure is complex, higher costs; Although there are non-intrusive products in the market, most of them use machine learning algorithm, which can not effectively guarantee to learn time and accuracy. Therefore, we propose a new non-intrusive identification method.

Overall Design Plan

Our power supply adopts dual power supply mode, the module provides positive and negative 10V power supply, uses voltage transformer and current transformer to convert the input signal into small voltage signal,. Then we use the OPA2277A chip to perform low-pass filtering and two-stage amplification of the input signal. We use the 8-channel ADR421AR ADC chip to collect the amplified voltage signal synchronously and calculate the power factor by calculating the apparent power, active power, and reactive power. In addition, we construct a discriminant binary tree based on the power factor and power. We classify the appliances by reading and matching the array of features. Then, by comparing the upper steady-state and the steady state characteristic array, we

subtract them, and get the characteristic array of the increasing and decreasing electrical appliances, and judge the type of the electric appliance by matching the features.

The Main Components of the System Hardware

Acquisition Module: Acquisition Module Contains Data Acquisition and Amplification Part
The data and signal module acquisition part collects the information of voltage and current, and transforms the two signals into small voltage signals through voltage and current transformer. In addition, the current measurement interface reserved for the input of the power supply is inserted into the interface.

AD Module: AD adopts the ADC ADR421AR which is carried by the electric plate, in this task, in order to facilitate the FFT sampling, it can control the sampling rate of 12.4K.

System Control Part: this part uses STM32F407IGT6 as the core, the board has 25M crystal oscillator, at the same time, the board contains ADR421AR, and each channel has voltage follower for isolation.

LCD Part: We use JLX12864 yellow-green liquid crystal display to display parameters at intervals to refresh the data;

Regulated Power Supply Section: This section uses the 7812 and 7912 three-terminal voltage regulator regulator, and through a series of capacitor filter combination, in order to stabilize the output voltage of positive and negative 12V.

The Theoretical Analysis of Each Module Unit and the Actual Circuit Design

Signal Acquisition Part of the Circuit Design

The signal acquisition chip is ADR421AR, ADR41 is ultra precision, the second generation of external ion implantation field effect transistor (XFET) reference voltage source, with low noise, high precision and excellent long-term stability characteristics. The nonlinearity of voltage varies with temperature. The XFET architecture can provide excellent accuracy and thermal hysteresis performance for bandgap voltage reference. The ADR421 has excellent noise performance, stability and accuracy. The output voltage is adjusted in the range of + 0.5%, and the other performances are not affected.

Signal amplification part of the circuit design. As shown in Figure 1:

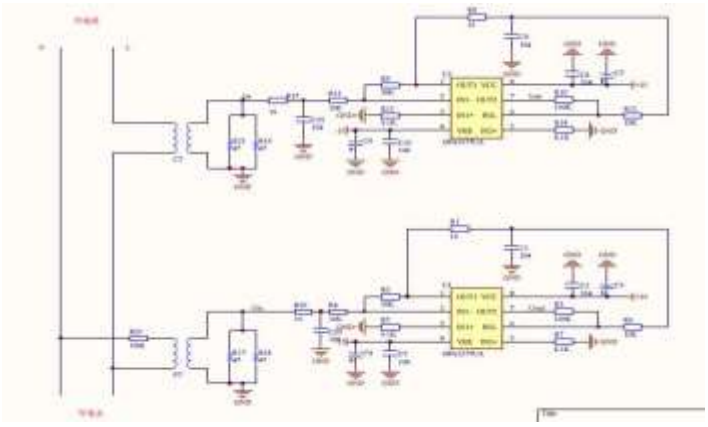

Figure 1. Signal amplifying circuit diagram

Voltage Regulator Power Part of the Circuit Design

SCM power supply required positive and negative 15V, LCD power supply is +5V, so we design a 15V double power supply module and 5V single power supply mode.

Display Part of the Circuit Design

We use 12864 to complete the task of display, using serial data transmission to connect the GPIO port of the microcontroller. In order to control power consumption, we did not supply the backlight to the screen. In addition, we use the 12864 font library.

The Theoretical Analysis of Each Module Unit and the Actual Circuit Design

The System Control Circuit Design

STM32F407IGT6 is a 32 bit microcontroller with low power consumption and high performance. It has 196k programmable Flash memory. The speed of CPU can reach 168MHZ, and the program memory can reach 1MB. It has the characteristics of large memory and fast running speed, so it can be competent for the control work.

Debugging Platform Construction: We build debugging platform. At the same time, we choose the voltage transformer and current transformer, and connect them in the circuit of parallel connection and series connection;

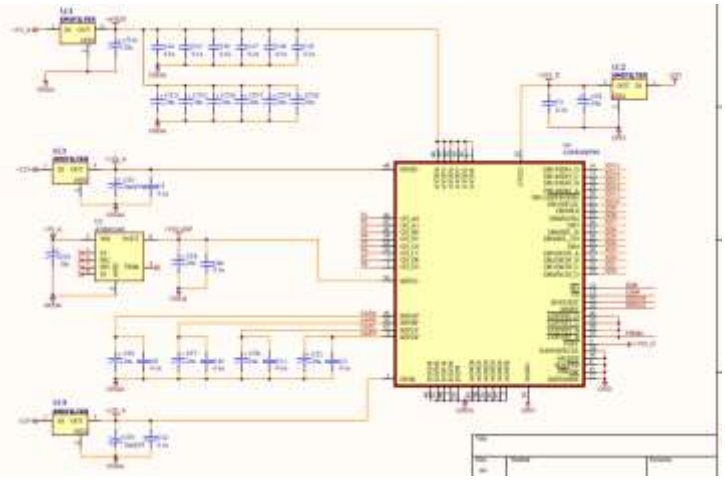

Figure 2 STM32F4 core board and peripheral circuits

Circuit Parameter Measurement Observation: We choose the appropriate electrical appliances: small fan, energy-saving lamps, the smallest resistors, incandescent lamps, notebook coolers, electric kettles, switches. We measure the parameters separately, use oscilloscope and printer to grab the instantaneous voltage and the waveform of the voltage and current, and record the voltage peak, peak current and phase difference of the corresponding electric apparatus,

Amplifier Circuit Design and Printing: We choose OPPA2277UA to design and manufacture two stage amplifier circuit. Among them, the former amplification is 3 times, and the second stage magnification is 10 times. In the end we conducted a DXP drawing of the circuit and eroded the printing

Calculation and Selection of Characteristic Parameters of Circuit Parameters: The overall variable ratio coefficient calculation formula: current ratio QC, voltage ratio QT

QP = CT * 10 / (32768 * Amp * R)

QC = PT * 10 / (32768 * Amp * R)

Judging method: distinguishing the construction of two forks tree,

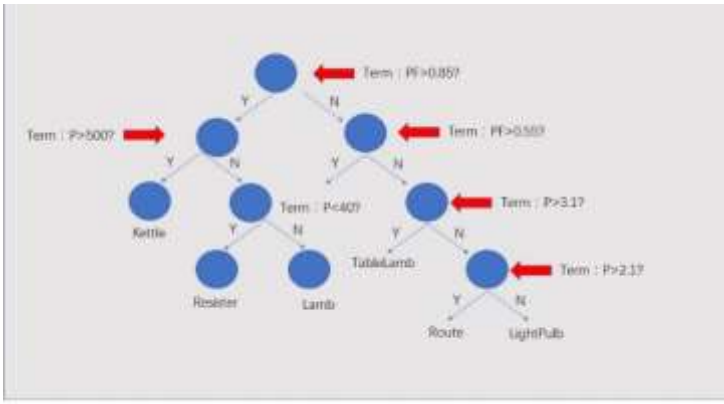

Figure 3 Binary tree structure diagram

Circuit Optimization: The waveform of the initial circuit parameters have a lot of more uniform glitches, affecting the performance of the high frequency noise of the current signal itself. In order to overcome this interference, we have specially replaced the high-precision low-noise resistor, which has achieved immediate results.

In the design of the amplifier circuit, according to the experience of the previous design circuit, we connect analog and digital through the resistor, which plays a role of isolation.

After the signal acquisition, we add the resistance capacitance filter circuit. This allows the appropriate low frequency signal to pass, and these indispensable steps make our front input circuit more normal.

In the power supply circuit, we have adopted the linear voltage stabilizing circuit to filter the power supply ripple.

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