Design of Smart Power Socket based on FreeRTOS and STM32F103

Pei Shi[1, a], Chunlai Zhou[1, b], Yongqing Gao[1, c] and HengNing Deng[1, d]

[1] Information School, Communication University of China, Beijing, China

[a]emmasp@foxmail.com, [b] clzhou@cuc.edu.cn,

[c]gaoyq2008@163.com, [d] hengningdeng@cuc.edu.cn

Keyword: smart power socket; Zigbee; Cortex-m3; FreeRTOS

Abstract. The paper presented the design and implementation of the multifunctional smart power socket based on Cortex-M3 kernel STM32F103 MCU, using Zigbee technology for network communication and FreeRTOS as task scheduling management. The hardware design and software framework of smart power socket are described. Features of the smart power socket are high reliability and practicality, and meet the needs of the smart home power management.

Introduction

With the development of telecommunications and Internet, the concept of the Internet of Things has emerged, and is deemed to an important part of the next generation of information technology. Smart home system is one of the main applications of the Internet of Things by using a variety of information and communication technologies to integrate household appliances to realize family management of daily affairs [1]. The framework of the smart home network includes the family Zigbee network system, smart home gateway, smart user terminal and smart sockets, and data communication between home network and external network system. Gateway is the control unit of the smart home system, and it packs the data from smart sockets into the network data packages, and then delivers through the 3G network or wi-fi to monitor computer in real time. Computer or handheld device allows the user to log on remotely smart home management system to search information and control the household appliances.
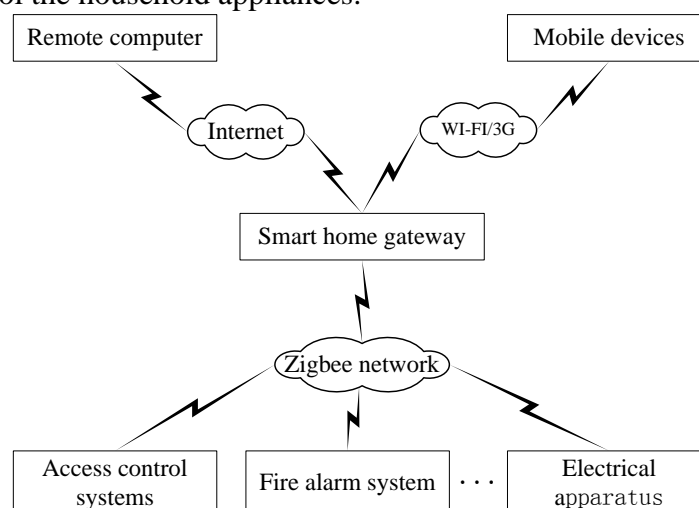

Fig. 1 Structure of smart home system

Function Design of smart power socket

Smart power socket is a node of smart power of family, and used to implement electricity metering, status monitoring, protecting of over voltage and current, and opening and closing control of household appliances. The nodes communicate with the home gateway by Zigbee protocol to realize smart household power management. The system structure is shown in Fig.2.
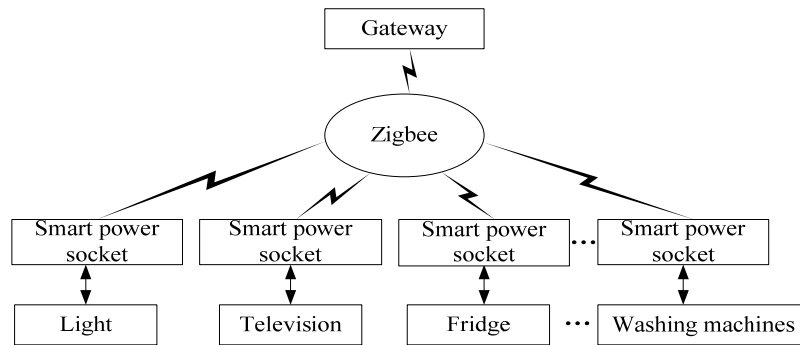
Fig. 2 Smart power of family system

While designing smart power socket, the relevant national standards should be considered, for example, communication standards, socket standards, cable standards and so on. Besides that, the reliability and functionality, security and cost are also important factors. The designed functions are:

(1)*Socket type*. Smart power socket should be a standard electric jack, using a common socket type.

(2)*Smart control*. Users can set multiple time control modes by pressing the keys.

(3)*Measurement energy*. The socket has the functions of energy metering, accumulation and reset. Users can view the current cumulative energy at any time and also can clear the cumulative energy to restart.

(4)*Display function*. The LCD in the smart power socket displays voltage, current, active power, total consumed power, time, control state and so on.

(5)*Protection function*. When current or voltage is too high or too low, the smart power socket can be automatically cut off power to protect the security of household appliances.

(6)*Communication function*. Using Zigbee protocol for network communication, among each node with the home gateway.

(7)*Remote control*. Users can control the appliances through the home gateway.

(8)*The clock function*. Node has its own clock, when blackout for more than half a year, it can keep the data.

Design and Realization of smart power socket

Hardware Design of smart power socket

Zigbee is a low power personal area network protocol based on IEEE802.15.4, and is a two-way wireless communication technology with close range, low complexity, low power consumption, low rate and low cost and it has the features of short delay, high network capacity, reliability and security[2]. In this article, Zigbee wireless transceiver chip CC1101 is used for hardware communication, and STM32F103 with the kernel of ARM7 Cortex-m3 is used as MCU. Structure of smart power socket system is shown in Fig.3.

STM32F103 MCU in the figure 3 is the core in the system to coordinate actions of all modules, and CC1101 is responsible for the wireless network communication. Current and voltage sampling circuit collects alternating current and voltage and transforms analog data to digital data. Power supply circuit supplies DC power to all modules. Relay circuit controls the power supply on and off as soon as current or voltage is out of normal value, LCD displays the current status as a human-computer interaction interface. Keyboard input circuit allows user to control the socket. MCU pin assignments are shown in Fig. 4 according to above function designing.
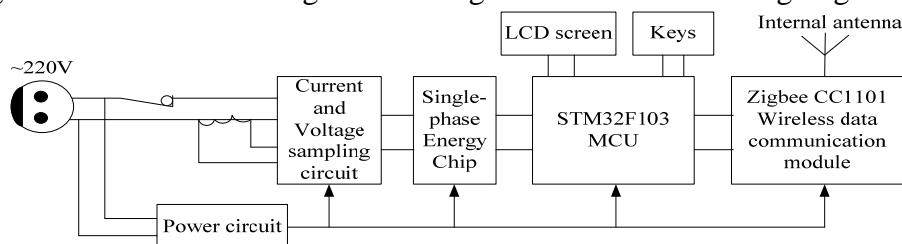

Fig. 3 Structure of smart power socket system

STM32F103C chip is a 48-pin chip. PB0~PB7 are used as data port of LCD; PB12~PB15 as four keys; PA13~PA15 as JTAG; PA2~PA4 as Zigbee wireless transceiver circuit; PB8 and SCLK as read and write clock; PB9 and SDO as measure the output data; PA13 and SDI as measure data; and PB11 and INT as interruption of CS5460A.
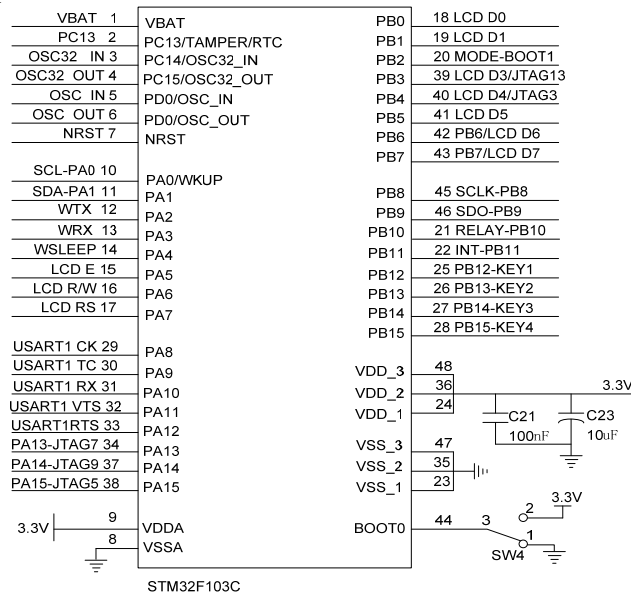

Fig. 4 Pin assignments of STM32F103

Software Design of smart power socket

Application software is developed based on FreeRTOS embedded real-time operating system, which is a lightweight free, open source one. The tree structure is shown in Fig.5.
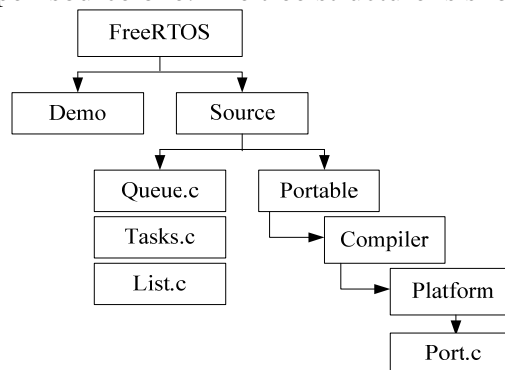

Fig. 5 Tree structure of FreeRTOS

FreeRTOS consists of Tasks.c, Queue.c, List.c and Port.c. FreeRTOS provides task management, time management, semaphores, message queues and memory management functions, and it can meet the needs of embedded systems. In FreeRTOS each thread of execution is called "task" and there is no limit on the number of tasks. Task can run on the advantage or coordinated fashion, when it runs under the advantage, the high priority task in a ready state can first use the CPU in order to ensure real-time system requirements. When it runs under the coordinated fashion, the tasks take turns to use CPU time that ensures tasks with the same priority to use the CPU fairly [3]. There are five task statuses of FreeRTOS: ready, block, run, pause and delete as shown in Fig.6.

First FreeRTOS allocates memory for the task just created, if allocation is successful, it initializes the task name, stack depth and task priority, then depending on the direction of stack growth, initializes the stack of the task control block. Then FreeRTOS joins the current task created to the ready task list. Scheduling algorithm begins running, which selects the current highest-priority task ready task chain, to carry out [4]. If there is only one ready task, the task is in the running state at once and if there are many ready tasks, rotation scheduling algorithm is used to realize multi-task carrying out.
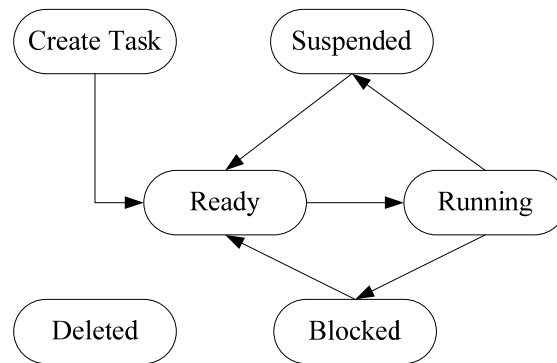
Fig. 6 Task state of FreeRTOS

Software hierarchy of FreeRTOS is shown in Fig.7. Hardware layer declares the chosen chip architecture of the application. Hardware-independent layer implements basic function of FreeRTOS, and the user task and ISR processing code implement various functions of the definition [5].

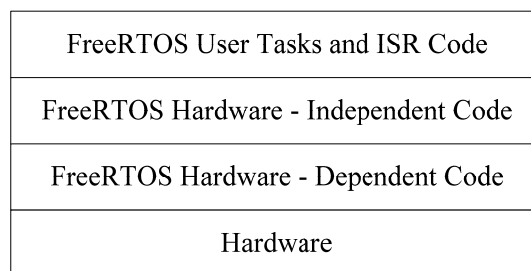| FreeRTOS User Tasks and ISR Code |
| :---: |
| FreeRTOS Hardware - Independent Code |
| FreeRTOS Hardware - Dependent Code |
| Hardware |

Fig. 7 Software layer of FreeRTOS

The main function of the program flowchart is shown in Fig. 8.

After the power on the system, hardware and clock will be initialized, and operating system will take over the control to run the tasks. According to the need of smart power socket, this paper defines 4 tasks: power data acquisition and process; UART communication; LCD display and key's process.
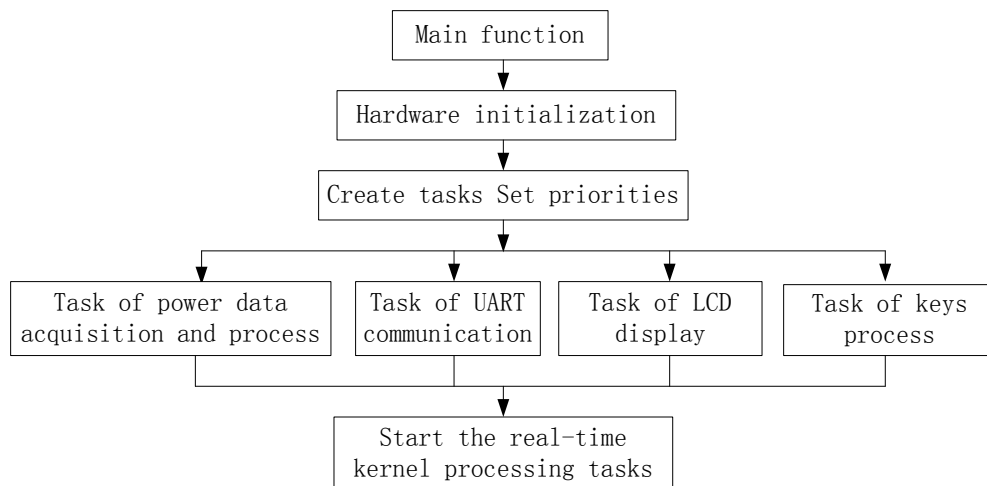

Fig. 8 Flow chart of the program's main function

1) Wireless data from the gateway is received by the transceiver of the socket that triggers interrupt. The interrupt program analyzes the data package, for valid package, sets task flag. Scheduling system distinguishes flag and calls UART communication tasks, sends the data to Zigbee wireless network, and implements command from the gateway.

2) LCD task displays the values of voltage, current, active power and energy accumulation in turn.

3) Household appliances can be controlled by keys, which task will trigger interrupt service routine (ISR). 4 keys are named power on/off, time setting, ID setting and confirm button. The user must press the confirm button when setting any function to applications, in case wrong operating. At present, the relay will closed, as soon as the control circuit put into operation, the power can be

cut off by key. The setting time key is used to change the operating time by plus or minus keys so the household appliances can work in different timing modes. ID key is used to label household appliances.

Conclusions

The smart power socket designed in this article has the functions of control, timing, data collection and transmission, and LCD displays, which meets the needs of smart home system and the Internet of Things. The experiment has showed that it is of high reliability and works well.

References

[1] Wenjun Yu, Zhihao Ling: Research on the Smart Home System Based on Internet of Things[J]. Process automation instrumentation. Forum Vol. 32(2011), p.56

[2] Jie Zhang:Application of Zigbee technology in the Internet of Things[J].Wireless Internet technology.Forum Vol. 3(2012), p.33

[3] Rich Goyette:An Analysis and Description of the Inner Workings of the FreeRTOS Kernel, Carleton University Department of Systems and Computer Engineering, SYSC5701: Operating System Methods for Real-Time Applications, 1st (2007)

[4] Bin Liu,Qi Wang and Lili Liu:Principle and realization of embedded operating FreeRTOS [J].Application of MCU and embedded systems.Forum Vol.7(2005), p.8

[5] FreetRTOS Datasheet. http://www.freertos.org.