REMOTE POWER ON/OFF CONTROL AND CURRENT MEASUREMENT FOR HOME ELECTRIC OUTLETS BASED ON A LOW-POWER EMBEDDED BOARD AND ZIGBEE COMMUNICATION

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ABSTRACT

In this paper we have designed a remote power On/Off control and a current measurement for electric outlets, based on both an embedded board and on ZigBee communication. This design consists of two parts: the ZigBee control module and the server module. The ZigBee control module contains several controllable outlets, a current measurement circuit, the ZigBee receiving and transmission circuit and a micro control unit. The measurement circuit senses the current and sends back a signal to the server module through the ZigBee. The measurement data of the current and voltage detection can be stored in the embedded board, and they can be designed to become aware of any overload and to send out a message to the circuit breaker for safety. We use Visual Basic as the interface software for the design of the graphic user interface to provide a user-friendly operation of a typical home's electric outlets.

Index Terms—Home Electric Outlet, Current Measurement, Embedded Board, ZigBee

1. INTRODUCTION

Many countries which have proposed energy conservation projects use both existing information and communication technology to control or manage electric appliances to save power. The transmission media are generally classified into two classes: wireless control and wired control. The most frequently used are Irda, RF wireless module, Bluetooth and ZigBee. Table I shows a comparison among those media. Furthermore, both the safety of electric appliances and the current and voltage measurement for electrical components such as rooftop solar cells can be very important issues. There are also several wireless technologies in use such as infrared rays, wireless LAN, Bluetooth and ZigBee [2]. ZigBee, based on IEEE 802.15.4, is a type of low-power communication technology for distances within 200 m, with a transmission rate ranging from 20 Kbps to 250 Kbps [3]. ZigBee focuses on simpler applications, and it is suitable for use in home networks, especially for the remote control of electric home appliances [4-7].

TABLE I
Comparison of different transmission media

Characteristics	Infrared	RF Module	Blue Tooth	ZigBee
Power Consumption	Low	Medium	Medium	Low
Controlled units	1	1	7	254
Distance	15m	50m	100m	100m
Transfer Rate	38Kbps	4800bps	1Mbps	250Kbps
Expansion	Low	Low	Medium	High

As ZigBee communication technology has high expansion, low power consumption and a medium transfer rate. This technology can be used with various applications. However, the related products need a special-purpose circuit to meet the needs of a specific application. For example, we utilize the coil to measure the amount of electric current and digitize the measurement for the management and control [8].

This paper proposes a remote power On/Off control and current measurement for electric outlets based on an embedded board and ZigBee communication because of our design's simplicity and low cost. The user need not change the traditional electric outlet; instead he just adds the simple interface circuit to integrate the electric outlet into the network. We have designed the interface modules between the embedded board and the ZigBee module, which connect either dynamic host configuration protocol (DHCP) or HUB to the Internet. The user can check the record of the power consumption of electric appliances through the Internet and reset the threshold of the power consumption of electric appliances to avoid an overload.

This paper is organized as follows. In Section 2 the software and hardware architecture are introduced. In Section 3 the function of the embedded home server is presented. In Section 4 the implementation results are summarized. In Section 5 our conclusions are presented.

2. SOFTWARE AND HARDWARE ARCHITECTURE

The whole power management system for the electric outlet consists of three parts as shown in Figure 1: the ZERCM, the home server and the remote control module. The ZERCM consists of MCU, a ZigBee module, a relay and a current transducer. The home server module consists of a ZigBee module and an embedded board. The remote control module can be a PDA or a PC.
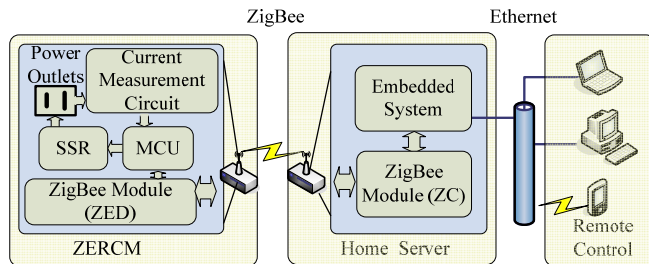

Figure 1 The block diagrams of the power management system

The sensor of the ZERCM detects the electric current being used. The MCU handles the ID, turns the electric outlets On/Off and then sends a control message to the other end of the ZigBee module through the ZigBee interface. The MCU provides a bi-directional control mechanism: one direction for current measurement and the other for On/Off control. We can then detect the status of many electric home appliances.

Figure 2 shows that we use a CT coil plus a simple bridge rectification circuit as a sensor detecting module, and we put an amplifier in the end part to transfer the electric current signal into a voltage signal of between 0-3V which is sent to the MCU. To reduce power consumption, we have used SSR to replace the traditional relay for controlling power outlets on/off.
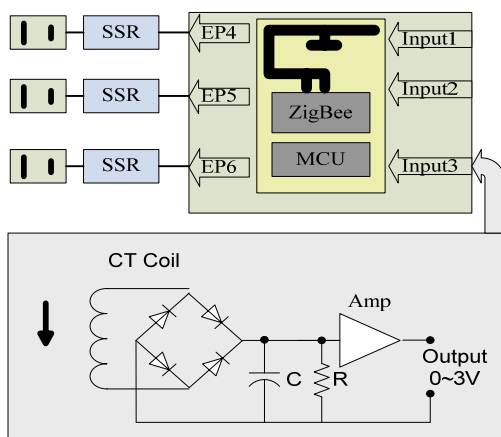

Figure 2 The circuit diagram of the ZERCM

The user can access the system status, the response time and the power consumption through the GUI software as shown in Figure 3. If necessary, the user can turn off the power by means of manual button as seen in the lower corner of Figure 3. The user can use the graph bar at the left of the control form to show the real-time power consumption and

he can control the switches for the electric outlets by way of feedback. To turn a control on or off takes less than one second.

To reduce the cost, size and power consumption of the home server, we have used the low-power embedded board to replace the traditional PC. This board equips the network, I/O and OS and becomes a "full function". The user can adjust the function according to need. This design measures the current use and detects the status of every node. If checking shows that a node is in "overload state", the embedded server cuts off the power supply for that home electric outlet. The system calculates and stores the power consumption of this home appliance. Because these functions have not used the whole function of the embedded board, our design uses a slightly smaller kernel with enough procedures, as shown in Figure 4.
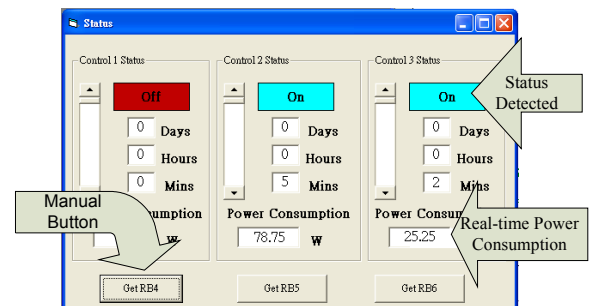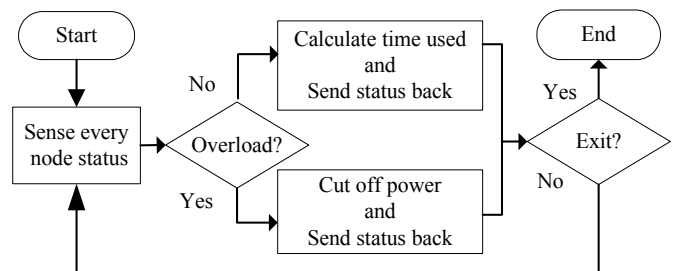

Figure 3 The control form

Figure 4 The flowchart of the current measurement

It is easy to develop a kernel in an embedded system environment [9]. Figure 5 shows the flow chart which develops the kernel procedures embedded in the system. The first procedure is to store the loader the data into the NandFlash, so it functions like the BIOS in a general personal computer. The second procedure is to store the kernel procedure name NK.bin in the main memory. The next step, depending on the user's software and hardware requirements is to add a reserved hardware driver into the kernel procedure through the Platform Builder. Finally, the whole application program is compiled by means of Visual Studio 2005. The user can connect to the development board to make DEBUG or write a DEBUG directly by means of simulator. Both ways can make use of writing,

Finally the application program and the key procedure (NK.bin) are bound together and downloaded to the development board or the application program that is stored in the memory card, which is like an SD card in the outside storage device. The developing procedure is as convenient as the application program used in a Pocket PC or a Smart phone.
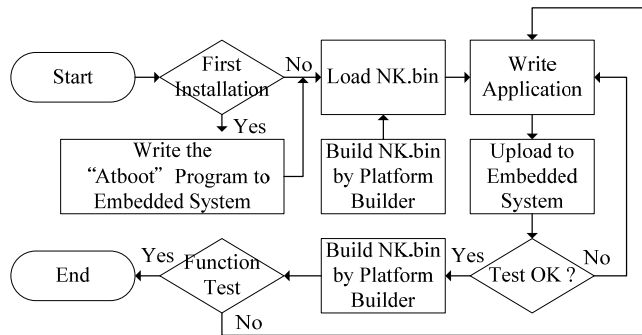

Figure 5 The flowchart of the developing kernel in an embedded system

3. THE FUNCTION OF THE EMBEDDED HOME SERVER

In comparison with other designs, our design, by using ZigBee, provides the functions of measurement data storage and overload protection. In addition, our design provides a user-friendly interface which can control home electric outlets [10]. Figure 6 shows the flowchart of the data processing of the embedded home server which directly receives and stores the measurements of electric current from the ZigBee. If the measurement data shows` that there are more electric current signal changes in the electric equipment, the home electric outlets will be turned off. At the beginning the detection mechanism is based on values D (0) and D (1). The measurement data decide the display for the system state, Device off, Overload, and Manual cut off, as shown in Figure 6. So, according to the flow chart in Figure 6, the system will judge whether this electric appliance operation is normal or abnormal, based on the amount of electric current it consumes. After the system stores a large amount of measurement data of current and voltage, the store device for monitoring the operation of the electric appliances will be fully loaded. So, the system has set up a certain limitation; in this design we use "n" =100 to save memory space. However, the valise of "n" can be adjusted by the user.

The embedded home server module contains a ZigBee module and an embedded board. The ZigBee module receives and transmits the control signal and the current measurement signal. There are several functions of the home server module. Firstly it determines the present state of the home electric outlets. Secondly it calculates the total time that the electric home appliances are used. Thirdly it controls the On/Off function of the electric outlets. The

measurement data for the use of current and voltage are stored in the embedded board. The checking software module not only examines the operation conditions with respect to the presetting values but also determines when to send the message to the circuit breaker to avoid any overload. Fourthly, by using Visual Basic, the software is matched with the home server, which provides a user-friendly and machine-compatible interface. To connect with more groups of electric outlets we can easily extend the design by adding a field for establishing IP addresses and sending control messages to the Internet ports. Our design also provides settings for an IP address, On/Off, scan rate and service time. The control form has an option to establish the ZigBee module as the receiver and dispatcher. When the firmware changes the setting, the system also has to set up an MAC address. The setting mode also examines the processes of all equipment in the ZigBee network.
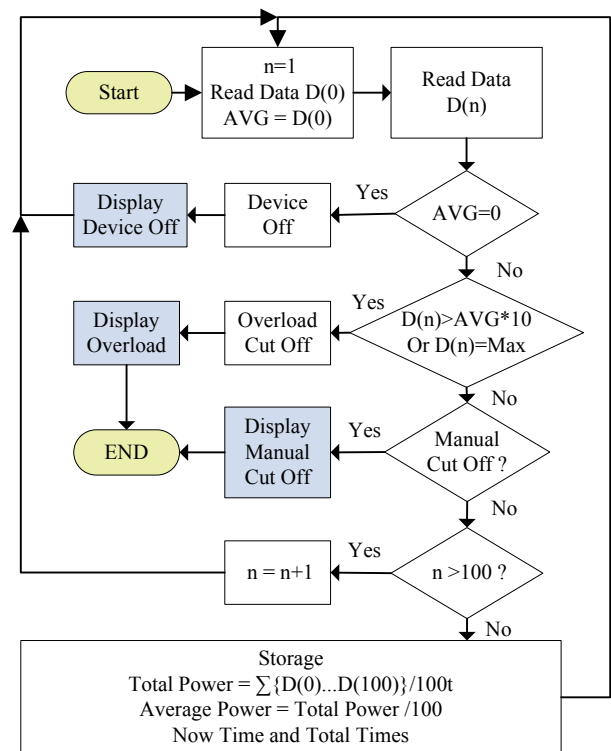

Figure 6 The flowchart of the data processing of the embedded home server

4. IMPLEMENTATION RESULTS

The ZigBee network is used to connect with the electric outlets through the interface circuit which is mainly coordinated by the home server. The interface circuit includes the outlet circuit and cooperates with the current measurement circuit and the relay to form the ZigBee power control module. To the single node of the ZERCM we add an MCU to set up the interface circuit and to provide a potential to increase the number of nodes. This part of the design, which can connect two nodes, is called "Binding"; it

can also increase the number of system nodes. The design integrates some ZERCM as a group and allows the user to connect to the Internet with the on-line service to learn the power consumption and the operation states of the home electric appliances.

Table II shows the ZERCM power consumption of three controlled units, which is low during the sleep state. At the beginning, ZERCM uses the maximum when searching its sub to set up the connection within the network. The system will enter the sleeping mode at once after setting up the network connection. When ZERCM enters the sleeping mode, the power consumption of the whole system is based on the power consumption of CT coil with the number of SSRs turned on.

Table III shows the system's total power consumption including ZERCM and embedded board. In comparison with the PC based home server, our design consumes less than 100 times as much, since our design uses a low-power embedded system. In addition, with our design, a user can operate a general handheld device like a PDA or a smart phone to control the ZERCM. The communication method of the family power monitoring system of the ZigBee is peer-to-peer topology.

TABLE II
ZERCM POWER CONSUMPTION

	Search Network			Sleep Mode		
Power Consumption (mW)	66-75			0.18		
CT Circuit (mW)	54			54		
Power Consumption of Relays (mW)	1	2	3	1	2	3
	126.6	162.6	198.6	69.2	84.2	141.2
Total (mW)	246.6	282.6	318.6	123.4	138.4	195.4

MAXIMUM POWER CONSUMPTION 318.6 mW

TABLE III
System power consumption

	Design 1: PC-based Home Server	Our Design: Embedded and ZigBee System
Maximum power consumption (W)	300	2.568
Minimum power consumption (W)	100	1.415

5. CONCLUSION

In this design the embedded board and the ZigBee provide low power consumption, low cost and simple wireless communication to allow remote control and current measurement of home outlets in order to save power. Although the transmission rate of the ZigBee is low, it is enough both for current measurement and state control. We combine the Zigbee and the Internet protocols to carry out both remote power On/Off control and current measurement for home electric outlets.

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