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Design of Smart Home Monitoring System Based on ARM and Power Line Carrier Communication

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Abstract

For the shortcoming of smart home monitoring system(SHMS), such as high spend of wiring, difficulty of maintenance, poor penetration using traditional communication etc.., designed a SHMS based on embedded system. By using LPC2000 series processor as a core, selecting power line carrier communication (PLCC) module for interior communication mode, GSM for remote communication mode, and then transplanting RTOS μC/OS-II, the system can monitor environment, security of home. The results indicate that SHMS has the advantages of convenient installation, low cost, easy to upgrade, can realize the local and remote control.

Keywords: *Embedded; Power line carrier communication; Smart home; Distributed control mode*

1. Introduction

Smart home synthesizes building decoration, internetwork communication, information home appliance, equipment automation technology *etc.* based on house. It is a high effective, safe, convenient residential environment. The information society changed people's life style and work habits, simultaneously challenged traditional residence, the concept of public changed remarkably with the improve of society, technology, economy. The demand of people's home is not only physical space, but also a safe, convenient, comfort Figure home environment.

Now inner-net of smart home monitoring system (SHMS) are based on bus [2-3] and Zigbee [4-10] mostly. Using bus for inner-net, the connection has defects of complex wiring and influence of indoor appearance. Yet the mode has the disadvantages of poor penetration, radiation *etc.* when using traditional wireless communication, such as Zigbee. In addition, the design of Smart Home is based on 51 series as control core. For the hardware and software resources of single-chip microcomputer are limited, it brought great difficulties to upgrades, maintenance and debugging of system [2,11-12].

For overcoming the above disadvantages, the system selected a core chip LPC2103 for a high performance control and lower power consumption. The measurement module and control module which were connected by power line carrier communication (PLCC), realized the monitor of interior environment and

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safety, the GSM module sent the information of interior environment and safety to user, and then controlled smart home remotely.

2. Monolithic Construction of Smart Home

Smart home monitoring system (SHMS) adopts distributed control mode, the structure of SHMS is illustrated on Figure 1. The scene nodes which are composed of measurement module and control module scatter every room, and then control every room separately. The scene nodes are connected to MCU by PLCC module. The interior real-time information can be gathered, shown, controlled in time, and then the information of environment, security and household electrical appliances' safety are sent to users' mobile through GSM module. The system can realize embedded SHMS.

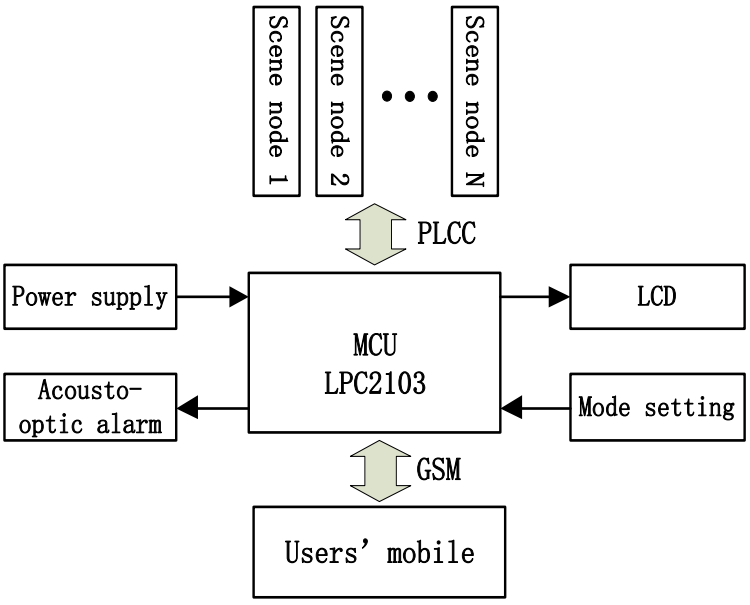

Figure 1. Distributed Control Diagram of SHMS

3. Hardware Design

All of microcontrollers of SHMS selected LPC2103, which is produced by PHILPS Corporation, base on ARM7TDMI-S, has a package of LQFP48. LPC2103 has advantages of small package, low power, can also optimize power by enabling/prohibiting several peripheral unit. LPC2103 has the characteristics of the 10-bit A/D converter provides eight analog inputs, with conversion times as low as 2.44 ms per channel and dedicated result registers to minimize interrupt overhead, low power Real-Time Clock (RTC) with independent power and dedicated 32 kHz clock input, up to 32 5V-tolerant fast general purpose I/O pins which is sui Figure for using most of sensor module.

3.1 Scene Node Control Module

The modularization scene nodes scattered every room, as shown in Figure 2. Every scene node, which were composed of power supply, LCD, mode setting, environmental monitoring, security detection, home appliance control, curtain control and power line carrier communicating module, can realize and display of Humidity & Temperature and light intensity, detect the invasion of robbers, control of household electrical appliances and curtain *etc.*

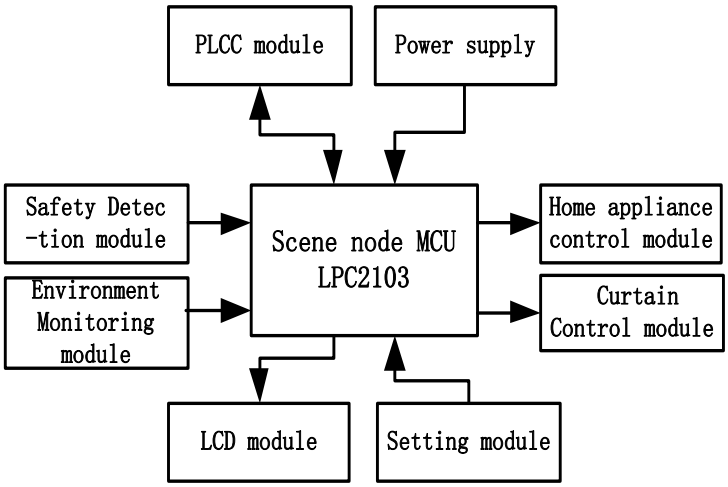

Figure 2. Diagram of Scene Node

Environmental monitoring module can measure Humidity & Temperature and light intensity. The system used BH1750FVI to measure light intensity. It is digital light intensity sensor, which adopt parallel line serial bus interface. It communicated with MCU with I2C bus specification. BH1750FVI has 6 pins, consisted of I2C address port, power supply, reference voltage of SDA and SCL, two interface of I2C. In the system, the ADDR pin of BH1750FVI was suspended (as connected low level). Its slave device address was 0100011. P0.3 (SDA0) connected to the SCL, P0.2 (SCL0) connected to SDA of light intensity module. The system measure light intensity through the two pins.

The system used digital Humidity & Temperature sensor DHT11 to measure of Humidity & Temperature. DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness. Single-bus data format is used for communication and synchronization between MCU and DHT11 sensor. The system transmitted data to P0.10 of LPC2103 with GPIO.

Security detection module selected HC-SR501 Infrared human body induction module. HC-SR501 is a automatic control module based on infrared technology. It adopted LHI778 probe, which is imported with original packaging from Germany. HC-SR501 has characteristics of high sensitivity, high reliability, extra low voltage pattern. If someone goes into the sensing range, it will output high level. On the contrary, if someone goes out of the sensing range, it would close high level with delay automatically, and then output low level.

The human-computer interface chose SO12864 LCD, which is a 128×64 dot matrix LCD without character library. The communication mode of SO12864 LCD module is serial. The LCD module, which was connected to LPC2103's SPI bus, can display the humidity, temperature and light intensity of the present room.

The control of domestic appliance, lighting and curtain adopted the infrared remote control module. The infrared remote control module and LPC2103 were connected through UART0 interface. It adopted normal UART mode, baud rate 9600 bps, 8 data bit, no parity check bit, 1 stop bit.

Scene nodes communicated with MCU module through power line carrier communication (PLCC) module. The core chip, HLPLC520F, is a FSK modulation and demodulation chip with high integration degree, designed for the power line

carrier communication specially. PLCC module adopted FSK communication mode, super fuzzy algorithm. Even if transmission signal is interfered, we can resume the original carrier signal also. The method has characteristics of Figure communication, strong anti-interference ability. The module has a 110 KHz carrier center frequency, can switch between zero transmission mode and normal transmission mode freely. In alternating current 220V, the PLCC module of each scene nodes connected to LPC2103 through UART0, *i.e.* P0.0 and P0.1. Each nodes was connected through AC 220V, the carrier module connection diagram as shown in Figure.3.

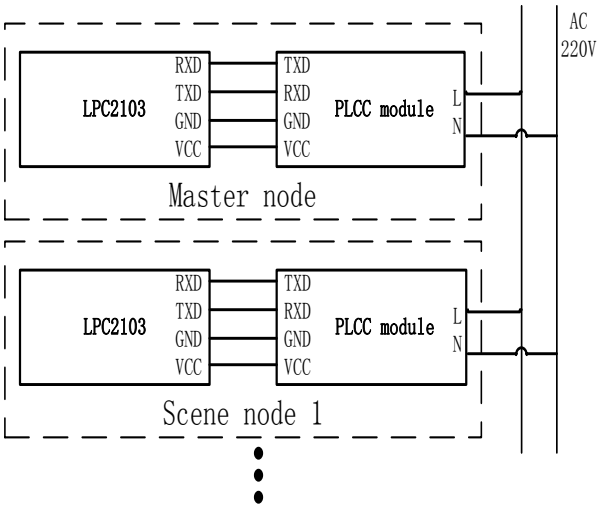

Figure 3. The Carrier Module Connection Diagram

3.2 Main Controller Module

As a core of LPC2103, SHMS's main controller module accomplished primarily mode setting, receive, display, control of all scene nodes' information and alarm, communication with users' mobile *etc.* Main controller module was composed of power supply, mode setting module, LCD module, acousto-optic alarm module and communication module.

The communication module consisted of two parts, one was GSM module for communication with users' mobiles. The other was PLCC module, which communicated with scene nodes. The communication of main controller module and scene nodes selected HL-PLC-V2.0 PLCC master mode connected to UART0 of LPC2103. After the system initialized, the setting of present mode would send to every scene nodes. The system adopted GTM900-C, which is connected to UART1 of LPC2103. The UART interface of GTM900-C receives and send short message by operating this module though AT command. The SIM card interface can connect SIM card with 1.8V or 3.0V. The RTC Backup module provides internal real time clock input of back-up power.

4. Software Design

4.1 Operating System Transplantation

In this design, μ COS-II operating system was transplanted for managing and scheduling hardware and software, so that it make the system work in low power consumption, as embedded system can cut out hardware and software according to applying requirement.

Transplant μ COS-II to LPC2103, we need to alter OS_CPU_C.c、OS_CPU_C.h and OS_CPU_A.s. We need to modify data type define, macro definition related to ARM processor, stack's growth direction in OS_CPU_C.h. It needs to initialize stack of tasks in OS_CPU_C.c. In OS_CPU_A.s, we need to transplant some function, such as interrupt service function, functions for entering, and leaving a critical section, context switching function of task level *etc.*

4.2 Program of Main Controller Module

Main controller module was fixed on the entrance, accomplished mode setting, receive and send information of scene nodes, send SMS to users' mobiles, display, acousto-optic alarm *etc.* Task partitioning and task priority was shown in Figure 1.

Table 1. Main Controller Module Task Partitioning

Task partitioning	Task name	Task priority
Mode setting task	Task_mode()	3
Mutex	Mutex_PLCC	5
Users' short message task	Task_GSM()	6
Acousto-optic alarm task	Task_Alarm()	7
PLCC receive task	Task_PLCC_Receive()	8
PLCC send task	Task_PLCC_Send()	9
Display task	Task_LCD()	10

When it was executing, the other task could not work because of the highest priority of mode setting task. The flow sheet of mode setting is shown in Figure 4.

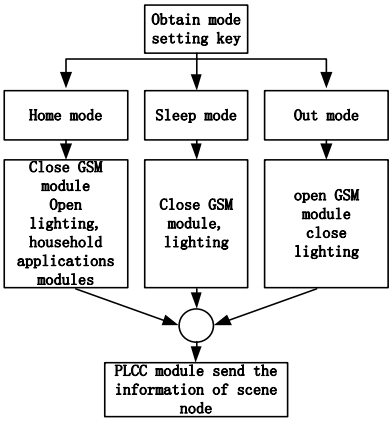

Figure 4. Flow Sheet of Mode Setting

After mode setting, the parameters of current mode would be sent to every scene nodes through PLCC send task, and then non-essential peripheral unit would be closed for energy conservation. PLCC receive task would receive the scene nodes' parameters at regular time, that would identification system's safety. AS PLCC master module would be monopolized when the system received data from scene nodes, mutex Mutex_PLCC was created for ensuring the integrality and reliability of data. Synchronous mode of tasks is shown in Figure 5.

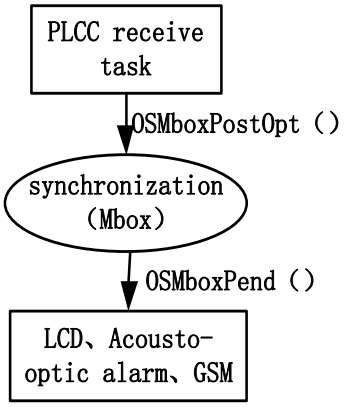

Figure 5. Synchronization of Tasks

4.3 Program of Scene Node Module

The scene node modules were installed in different room. After system's initialization, the scene node modules would set current node's parameters through keyboard. If the parameters were not set, the system would wait for the information from main controller module. Subsequently, the scene node would detect scene node's environment and safety, and then execute corresponding control task. Therefore, task partitioning and task partitioning of scene node is shown in Figure 2.

Table 2. Scene Node Module Task Partitioning

Task partitioning	Task name	Task priority
Parameter setting task	Task_Set()	2
PLCC receive task	Task_PLCC_Receive()	3
PLCC send task	Task_PLCC_Send()	5
Humidity & temperature acquisition task	Task_Collect_T_H()	7
Light intensity acquisition task	Task_Collect_Light()	8
Humidity & temperature control task	Task_Control_T_H()	10
Light intensity control task	Task_Control_Light()	11
Display task	Task_LCD()	14

5. Conclusion

A multi-node embedded smart home monitoring system (SHMS) was designed based on ARM in this paper. Scene nodes can detect environment, safety parameters, control in real time, display, send information of environment, safety parameters to main controller module. Main controller module can send all information of SHMS to users' mobiles, at the same time, users can control each scene node of SHMS remotely. The system has the characteristics of power, low power consumption, low cost, can monitor and control household appliances, human settlement intelligently and remotely. It shows broad application prospect.

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