**Design and Implementation of an Intelligent Hotel Room Controller**

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**Abstract**

With the rapid development of computer technology, control technology and communication technology, intelligent control and management of hotel rooms have become a hot field. A hotel room control system includes the management system (upper computer) and the intelligent hotel room controller (lower computer). In this paper, hardware and software design of an intelligent hotel room controller based on LPC11C14 are introduced. The experiment and application in hotel room show that this system can provide a high stability and high reliability controller for the hotel managers. Furthermore, it can improve the automation and intelligence of hotel management.

**Keywords**: Intelligent Controller, LPC11C14, Hotel Room

**1. Introduction**

Recently, with the rapid development of national economy and the improvement of standard living, holiday economy and tourism economy have become the hot spot, this promotes forward of the hotel industry rapid development and intense competition [1]. There's a growing need for the usage of computer technology, control technology and communication technology in the hotel rooms to make the control and management more safe, comfortable, convenient, efficient and energy-saving. Many experts and scholars both at home and abroad have studied on this subject [2-7]. In the past, due to the domestic hotel managers are not too concerned about the concept of intelligent hotel rooms, requirements are relatively low. Designers consider the cost, they often use the 8-bit micro-controller and simple logic chips to build a circuit [8-11], and this makes the system function rather meager. Now, computer network and embedded systems technology have been used in hotel management system, which conveys the electrical information of a hotel room to the managers through the computer network, realize room status monitoring and respond promptly to customer service requests. There are many products of foreign hotel room control systems in the current market. Although their functions are relatively complete and have high security and stability, the price is high and many buyers shrink back at the sight of its price. Therefore, the application is also limited.

Hotel rooms intelligent control system consists of two parts: the control system and management system. The control system is taken as the entire system of lower computer part which is installed in the hotel room.

In this paper, we focus on the designing and implementing lower computer of the hotel room control system which is named as the intelligent hotel room controller, which is the core of the entire control system. Even if the room does not have the admission card to take power, the room controller also has been in a running state, controlled electrical appliances except the door switch is not subject to its control. After the admission card is inserted, room controller will bring them within range of the control system. Most of the appliances in the room need the lower computer to complete its function. At the same time, lower computer needs to send room status data to the upper computer, its function should be relatively complete, stability, and reliability requirements are also high.

The paper is organized as follows: Section 2 presents an overall architecture; Section 3 introduces hardware design, it includes the main controller LPC11C14 and its peripheral circuit, the power modules, input and output module, communication module, watchdog circuit and so on. Section 4 presents software design, the software system can realize the communication between the upper
computer and the hotel room controller; inquire the state of the air controller through the RS485 bus. It also can upload the state of the room and the request of customer information to the upper computer.

system debug is introduced in Section 5. Conclusions and future work are presented in Section 6.

2. System overview

A hotel guest room control system includes the management system (upper computer) and intelligent hotel room controller (lower computer). Lower computer is responsible for real-time acquisition of all relevant information on the hotel rooms as well as the corresponding control of all function equipment. Upper computer realizes data communication with lower computer based on CAN Bus.

Room controller is mainly composed by the master controller, power circuit, input module, output module, the communication interface circuit and watchdog circuit, etc. The overall architecture of the system is illustrated in Figure 1.

![Figure 1. Architecture of the system](image)

Main controller communicates with temperature-controlling instrument via RS-485 bus. Temperature-controlling instrument is used to set the room temperature, display set temperature value and actual value, set and control high, medium and low-speed running state of the air-conditioning fan, display clock and calendar.

3. Hardware implementation

As it is mentioned above that controller consists of the master controller, power circuits, input modules, output modules, the communication interface circuit, watchdog circuit, etc., so the implementation is also made by these parts.

3.1. Master controller

The main controller in this design uses LPC11C14 made by NXP Semiconductors Company, it is an ARM (Advanced RISC Machines) Cortex-M0 based, low-cost 32-bit MCU family, designed for 8/16-bit micro-controller applications, offering excellent performance, low power, simple instruction set and memory addressing together with reduced code size compared to existing 8/16-bit architectures[12].

The LPC11C14 operates at CPU frequencies of up to 50 MHz. The peripheral complement of the LPC11C14 includes 16/32 kB of flash memory, 8 kB of data memory, one C_CAN controller, one Fast-mode Plus I2C-bus interface, one RS-485/EIA-485 UART, two SPI interfaces with SSP features, four general purpose counter/timers, a 10-bit ADC, and up to 40 general purpose I/O pins. On-chip C_CAN drivers and flash In-System Programming tools via C_CAN are included.

LPC11C14 has the following characteristics:
1. Operates at CPU frequencies of up to 50 MHz.
2. Crystal oscillator with an operating range of 1 MHz to 25 MHz.
3. PLL allows CPU operation up to the maximum CPU rate without the need for a high-frequency crystal. CLOCK may be run from the system oscillator or the internal RC oscillator or watchdog oscillator.

4. 12 MHz internal RC oscillator trimmed to 1% accuracy that can optionally be used as a system clock.

5. Single 3.3 V power supply (1.8 V to 3.6 V). Clock output functions with divider that can reflect the system oscillator, IRC, CPU clock, or the watchdog clock.

6. 32 kB of flash memory.

7. 8 kB SRAM data memory.

8. General Purpose I/O (GPIO) pins with configurable pull-up/pull-down resistors.

9. Four general purpose counter/timers with a total of four capture inputs and 13 match outputs.

10. On-chip C_CAN and CAN open drivers included.

The functionality and scalability of LPC11C14 are very powerful compared with SCM (Single Chip Microcomputer) control system as well as its competitive prices, so it is chosen as the main controller.

### 3.2. Power supply circuit

The power supply circuit, which is shown in Figure 2, is built to supply the power or voltage to the circuit [13]. It can be divided into three parts: the first part provides 3.3V DC (Direct-Current) power supply to GPIO ports of the main controller and the chip of peripheral circuit parts, the second part provides 5V DC power supply to input and output module and part of the peripheral circuit, the third part is to provide a 12V DC power supply to the control coil of relays.

![Figure 2. Power Supply circuit](image)

12V power supply for the system is provided by 220V switching power supply which can be converted to 12V, and then step-down regulator can transform 12V DC into 5V and 3.3V. Thus, it provides a stable voltage to the whole system. LM2596 is selected as a buck chip, which is manufactured by National Semiconductor Corporation of USA. The LM2596 regulator is a monolithic integrated circuit ideally suited for easy and convenient design of a step-down switching regulator. It is capable of driving a 3.0 A load with excellent line and load regulation. This device is available in an adjustable output version and it is internally compensated to minimize the number of external components to simplify the power supply design. Since LM2596 converter is a switch-mode power supply, its efficiency is significantly higher in comparison with popular three-terminal linear regulators, especially with higher input voltages. The LM2596 operates at a switching frequency of 150 kHz thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators. The other features include a guaranteed 4% tolerance on output voltage within specified input voltages and output load conditions, and 15% on the oscillator frequency. External shutdown is included, featuring 80A (typical) standby current. Self protection features include switch cycle-by-cycle current limit for the output switch, as well as thermal shutdown for complete protection under fault conditions. The chip has under voltage protection, over voltage protection, over temperature protection and cycle-by-cycle current limit.
3.3. Input Module

The switch in each room, such as a light switch, admission card switch (take power switch), the door magnetometer sensor, the clean-up, do-not-disturb and service request switch, etc., enters the main controller via the input module. Due to many instruments inside the modern hotel rooms and abundant input information, it is necessary to extend the input module of the controller.

![Figure 3. Input extended circuit diagram](image)

74HC373 is used to extend the room controller input as shown in Figure 3. It is a tri-state octal D-type latch; these high speed octal D-type latches utilize advanced silicon-gate CMOS technology. They possess the high noise immunity and low power consumption of standard CMOS integrated circuits, as well as the ability to drive 15 LS-TTL loads. Due to the large output drive capability and the tri-state feature, these devices are ideally suited for interfacing with bus lines in a bus organized system. When the latch enable input is high, the Q outputs will follow the data (D) input. When the latch enable goes low, data at the D inputs will be retained at the outputs until the latch enable returns high again. When a high logic level is applied to the output control input, all outputs will go to a high impedance state, regardless of what signals are present at the other inputs and the state of the storage elements. All inputs are protected from damage due to static discharge by internal diode clamps to VCC and ground. 74HC373 truth table is shown as Table1.

<table>
<thead>
<tr>
<th>Output Control</th>
<th>Latch Enable</th>
<th>Data</th>
<th>373 Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
<td>H</td>
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<td>X</td>
<td>Q0</td>
</tr>
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<td>H</td>
<td>X</td>
<td>X</td>
<td>Z</td>
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</table>

3.4. Output Module

Output module controls the operating status of the room lamps, curtain motor, sockets and other controlled electrical equipment by controlling relay. This design does not use the transistor drive style, instead of using the integrated chip-ULN2004 driver. The output of the main controller enters optical coupler UNL2803 via the expansion port, UNL2803 is high-voltage, high-current Darlington arrays comprised of eight NPN Darlington pairs. All units feature integral clamp diodes for switching inductive loads. The output of Darlington driver tube is used to drive relay’s control coil, sucking-making of control coil indicated that it works, so does the external devices.

To ensure all the control coils are in a disconnected state when the system power-on, 74HC273 is selected as output expansion. The 74HC273 is high-speed Si-gate CMOS devices and is pin compatible with low power Schottky TTL (LSTTL). The HCT273 has eight edge-triggered, D-type flip-flops with individual D inputs and Q outputs. The common clock (CP) and master reset (MR) inputs load and reset (clear) all flip-flops simultaneously. The state of each D input, one set-up time before the
low-to-high clock transition, is transferred to the corresponding output (Qn) of the flip-flop. All outputs will be forced LOW independently of clock or data inputs at a low voltage level on the MR input. The device is useful for applications where the true output only is required and the clock and master reset are common to all storage elements. The output expansion circuit is shown as Figure 4.

![Figure 4. Output expansion circuit](image)

All devices have open collector output and clamping diodes to inhibit transition or jump. Its function is equivalent to an 8 digital inputs and 8 digital outputs inverter. When the input is high, the output is low; when the input is low, the output is high. Each input and output are independent and will not affect other roads’ work. Simple circuit diagram of ULN2803 connection to relay is shown in Figure 5.

![Figure 5. Circuit diagram of 2803 drive relay](image)

When the system power-on or reset, 74HC273 clears all the flip-flops, their outputs are forced to set at a low level. Under this condition, ULN2803 input becomes low level, output high level. At this time, the relay control coil is not energized and the relay does not work, so as to ensure that the entire system and all electrical appliances in the room will not work in a short period of time when re-power-up or reset.

### 3.5. Communication interface

Communication subsystem is responsible for real-time communication between the upper and lower computer. On the one hand, the guest room information acquired by lower computer is transmitted to the upper computer through the communication subsystem; on the other hand, the upper computer also conveys control strategy to the corresponding equipment of guest room through the communication subsystem.

The key to the system is to choose a suitable communication bus mode. The choice of the communication bus mode must meet the requirements of the system response time, reliability, data-carrying capacity, stability and should consider the factors of the product cost, the users’ cost. The following analyzes two kinds of commonly used bus: RS485 bus and CAN bus.
3.5.1. RS485 bus

RS485 bus is a serial communication bus with a differential signal traveling along the bus and sends the information from one point to another point. The maximum length of the bus is around 1000 m. The bus is allowing multi-master or single master, as long as only one point is sending data at a time on half duplex network. Since RS485 is a multi-drop point bus, a communication protocol is needed between the units. The bus protocol normally starts with the address byte of the receiver, then follow by the data bytes. The address byte will trigger the receiver with the right address to receive the data bytes.

3.5.2. CAN bus

CAN (Controller Area Network) bus is a type of serial communication protocol, which was developed for the vehicle by the Robert Bosch Company of German in 1980s. CAN bus is a serial communication protocol used in a relatively small amount of information transmission, unlike Ethernet or USB which is used for transfer of large blocks of data. Reliability of the entire CAN bus nodes is guaranteed to be consistent [14]. It has predominant performance of bus sharing and arbitration, can exchange information quickly and forcefully. Compared with the general communication bus, CAN bus data communication has outstanding reliability, real-time and flexibility.

3.5.3. Communication mode choice and interface design

Hotel room control system requires the relatively far transmission distance. The system requires stability and real-time. When some of the equipments are for maintenance, all other equipments can keep in the normal operation state. So CAN bus communication mode is used for the communication between the upper and lower computer, the communication mode is shown in Figure 6.

![Figure 6. The RS485 bus interface](image)

LPC11C14 is with on-chip CAN 2.0B controller, so the system design does not require a separate CAN interface peripheral circuit [15]. While RS485 communication mode is used between air conditioning thermostat and room controller. Therefore, RS485 interface circuit needs to be designed, as shown in Figure 6.

RS485 interface chip is SP3485, it is a family of +3.3V low power half-duplex transceivers that meet the specifications of the RS-485 and RS-422 serial protocols up to 10Mbps under load. In Figure 6, PIO1_5 is the main controller pin, SP3485’s RXD and TXD pin are connected directly to the main controller’s RXD and TXD.

3.6. Analysis on the Anti-Interference Measures ---watchdog circuit

Since the operation of the system is often subject to interference from external electromagnetic fields, which can cause program fleet and run into an infinite loop. The normal operation of the
program is interrupted, the system cannot continue to work and come to a standstill. Thus, it will lead to an unpredictable consequences. In order to monitor the operational status of the system in real time, external watchdog circuit is added in the design. Circuit diagram is shown in Figure 7.

![Figure 7. External watchdog circuit](image)

MAX706S is +3V Voltage Monitoring, Low-Cost μP Supervisory circuit, reduces the complexity and number of components required to monitor +3V power-supply levels in +3V to+5V μP systems. These devices significantly improve the system reliability and accuracy compared to separate ICs or discrete components.

4. Software Implementation

The main function of the software includes:

1. Monitors room digital input points, implement the corresponding output action according to the default logical relationship.
2. Supports CAN bus communication, uploads room status in real-time via the CAN bus.

4.1. Software Development environment

The Keil uVision4 supports 51 single-chips and ARM chips, has obvious advantages with function, structure, readability, maintainability compared with the compilation [16]. Meanwhile, it also has a very powerful feature in the debugger and software simulation.

4.2. System Flowchart

Figure 8 shows the flow chart to implement the system.
After powering up, the system finishes initialization and is put in working order. The system has three processes operating at the same time: Scanning input, performing output, sending and receiving instruction. Scanning input information includes the scanning of the light switch, take power switch, door sensor, clean-up, do-not-disturb, service request. When the system scans the input data, the system will perform an output operation according to the custom internal logic. Scanning output will work by cyclically scan the output list of internal storage. Sending and receiving instruction is completed by CAN and RS485 interface.

5. System debug

Debugging of the system is divided into the hardware debugging and software debugging. In order to prevent the main chip from being burned because of the errors during the design debugging, each sub-module is debugged separately. Hardware debugging includes: power module, input module, output module, CAN interface, etc. Software debugging should be combined with hardware debugging, which is mainly about communication function debugging between room controller and air conditioner controller. After debugging, each module of the system can work well. All the communication modules can complete the corresponding function.

6. Conclusions

This paper presents the design and implementation of a hotel room control system. It focuses on the hardware and software design of lower computer. Its core chip is LPC11C14. This system can improve the automation and intelligence of hotel management and make it easy simple and efficient. The control system has been applied in some hotels, from the current experiment stage point of view, this system has been implemented and has reached the expected goals. Therefore, it can be popularized and applied in more hotels in the future.

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References


