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Design and Implementation of Energy Saving Controller for Air-Conditioner in Building

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Abstract

This paper has completed the hardware design of STM32F103 system circuit, infrared code learning module, human body infrared sensor module, indoor temperature and humidity sensor module, completes the software design of learning air conditioning remote control code, indoor temperature and humidity sensor module, also completes the energy-saving controller hardware and software debugging. Finally, this paper takes split type air conditioning units in a conference room as the control object (including indoor lighting system) to complete the energy-saving controller in air conditioner electrical system design, installation and debugging, completes the air conditioning start-stop and infrared temperature control code learning test. The test results show that energy-saving controller has realized infrared automatic perception of human activity, machine start-stop code self-learning and temperature settings and other functions.

Keywords: *Split air conditioner, STM32, Controller, Temperature and Humidity Sensor, Test*

1. Introduction

In the last decades, power consumption in building has experienced a significant increase [1-3], with the continuous improvement of people's living standard and the continuous improvement of the construction of the indoor environment. The situation is obvious for China, which has doubled its energy consumption at an average rate of 3.7% [4]. Buildings contribute to 42% of energy consumption in Western countries [5,6] and to1/3in China [7]. What is serious is that, the increasing trend is bound to continue in the future, so it is necessary to carry out actions that promote energy savings and efficiency to reach a more sustainable development [8].

In 2011, the electricity consumption of the society is 4.69 trillion KWH in China according to the statistical data, the per capita consumption is 3 483 KWH, which is more than the world average. Nowadays in China, most commercial buildings, schools, government offices, and residential houses have installed window or split air conditioners (ACs) that have infrared (IR) remote controls. Hence, the energy consumption of air conditioning (AC) is soaring along with the rapid popularization of AC in buildings, and the electricity load of AC has accounted for about 15% of the country's electricity consumption, the value reaches up to 40% when summer peak season in cities and towns. Therefore, how to decrease the energy consumption when the building is in use process has become a national policy.

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It is found that the phenomenon of "forgetting to turn off AC", "the temperature of AC set is too low in summer" *etc*. is very common in office buildings through actual audit, which not only causes the AC energy consumption too high, and affect the indoor thermal comfort. The emission of carbon dioxide could be reduced 21kg if we set the temperature 1 ℃ higher. How to design a remote control and electrical system to realize this purpose automatic without destroying the premise of exiting ACs, has important practical significance and practical value. Thanks to the rapid progress in the embedded system and data acquisition technologies, several micro-controller-based modules are developed and presented in this paper for the purpose to monitor and control the electricity demand of ACs.

The rest of this paper is organized as follows: Section 2 introduces the function and scheme design of the system. Section 3 presents the detail design for the AC controller, which includes IrDA module, body sensor module, temperature and humidity sensor module, electrical meter and flowchart of system. The implementation and simulation result are given in Section 4. Finally, Section 7 contains the conclusions.

2. Function and Scheme Design

2.1. Function of AC Controller

The AC controller should be integrated with following functions, in order to realize the automatic shutdown when there is nobody in a room, and switch on the machine automatically when someone enters.

(1) Intelligent learning functions: it could learn control code from the air conditioning directly, so as to control the machine turn on or shut down mode, which is without any changes modified of the air-conditioning.

(2) Detection function: it could check if there is anyone indoor through infrared body sensor, and turn on the lighting if someone in, or turn off the lighting if all the people leave the room.

(3) Monitoring temperature: read the indoor temperature through the temperature and humidity sensor, which is hung on the wall.

(4) Set different control modes: summer, winter mode, which can set the lower temperature in summer or winter mode.

Summer mode: when the environment temperature is lower than the minimum temperature, infrared remote control module starts to control, and turn off the air conditioning. On the other hand, turn on the machine if the indoor temperature higher than the setting maximum temperature. Both of the two processes are executed automatically.

Winter mode: when the environment temperature is higher than the upper limit, infrared remote control module starts to control, and the air conditioning will be automatically closed. Until the temperature drops below the lower limit temperature, infrared remote control module will turn on the air conditioning again automatically.

2.2. Scheme Design of AC Controller

The controller is modularized design, which makes it more convenient to add some function in the future. Figure1 shows the design architecture of AC controller. The controller is mainly divided into two parts, one is the human body infrared detection module, and the other is indoor temperature and humidity detection module. The detailed functions of each module are given in Table 1. The microcontroller used in this research is STM32F103VET6 from ST Company, which is a 32-bit microprocessor based on ARM Cortex-M3 core. The STM32 contains 512 kB Flash, 64 kB SRAM, 8 timers, and multi-interfaces [9]. Its developing environment, Real View Microcontroller Development Kit (MDK), uses IDE

environment Vision, which has the ability to generate reentrant code. It fully meets the requirements of this controller. The other modules will be introduced below in detail.

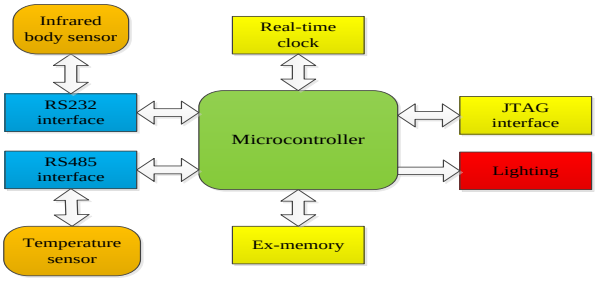


Figure 1. The Design Architecture Of Energy Saving Controller

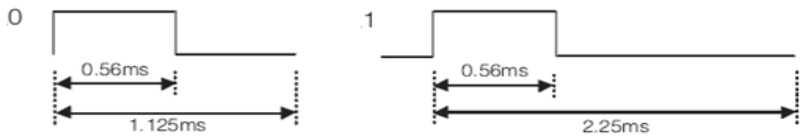
Table 1. The Function Of Each Part Of Energy Saving Controller

Module	Function
Microcontroller	Coordinate with other modules
RS232 communication interface	Communicate to the IrDA module
IrDA module	Control the air conditioning
Body sensor module	Check if there is someone
RS485 communication interface	Communicate to the temperature
Temperature sensor	Collect the temperature indoor

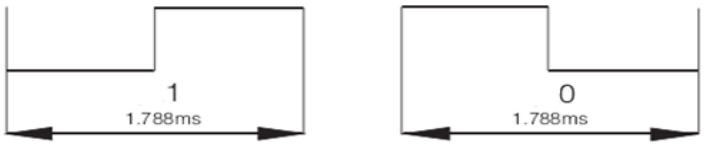
3. Design AC Controller

3.1. IrDA Module

The first step to control air-conditioning is obtaining the control command codes, which not only contain on and off, but include temperature, wind speed, working mode, timing, humidification and heating, *etc*. At present, there are mainly two coding standards used in air conditioning remote control, namely NEC protocol (Pulse Width Modulation, PWM type) and Philips RC-5 Protocol (Pulse Position Modulation, PPM type). The waveforms are shown as in Figure2, respectively. The carrier frequency of both is 38 kHz.



(a) NEC PWM



(b) Philips PPM

Figure 2. The NEC and Philips Standard Expression of 0 and 1

The common method for infrared learning is a complete copy from the infrared signal waveform directly, which is simple and easy for operation. Furthermore, the

copy methods contain fixed code learning (FCL) and copy waveform learning (CWL). The advantage of FCL is low requirements on the hardware, it just need huge storage space, which is used to save the mass control code of different types controlling code. However, it does not allow the flexibility when adding a new type of control code. On the other hand, if we select CWL method, it could make this process easier.

3.2. Body Infrared Body Detection Sensor

Anything could generate thermal radiation if the temperature of which is above absolute 0℃, the wavelength is between 0.75 ~1000 microns. Furthermore, the radiated energy is greater along with the higher of temperature. The human body infrared radiation is mainly between 3~50 microns, 46% of which focus on 8~14 microns. The system could detect whether there is a human activity by using body infrared body detection sensor.

Figure 2. The Infrared Body Detection Sensor

Figure 2 shows the real product photo of infrared body detection sensor, which is consists of pyro-electric infrared sensor (PIR), Fresnel optical filter and the signal processing circuit, *etc*. PIR could translate the infrared signal into electrical form, namely, have inhibitory effect to the nature of the white light signal. The maximum induction distance of body infrared sensor module is 12m, horizontal direction angle is 180 degrees, vertical direction is 60 degrees and the best fixed height is 2.5m.

3.3. Temperature Module

Figure 3 shows the physical and internal pictures of the integrated temperature-humidity sensor, by which we could collect the indoor temperature and humidity real-time through RS485 communication interface. The humidity measurement range is 0~99.9%RH, and the resolution is 0.1%RH, on the other hand, the temperature measurement range is -40~80℃, and the resolution is 0.1℃. The integrated temperature-humidity sensor supports standard Modbus Protocol.

Figure 3. The Detector of Temperature and Humidity

3.4. Electrical Meter

In order to record the electrical energy consumption and evaluate the performance of designed AC control system, we add an electrical meter in system. Figure 4 shows the photo of meter, which has advantages of high precision, high reliability, low power consumption and also supports RS485 communication interface.

Figure 4. The Crystal Watt-Hour Meter of Three Phases

4. Implementation and Simulation Analysis

Figure5 presents the system diagram, when infrared sensor detects human body enter the room, it will trigger internal relay and open the indoor lighting facilities. Besides that, the infrared sensor will provide a signal to the controller, which could control indoor temperature and humidity condition according to the ambient temperature and setting temperature.

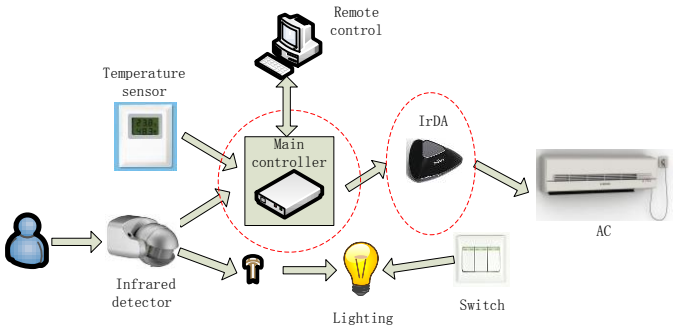


Figure 5. Topology Figure of System

In order to ensure that the human body infrared sensor detection range covers the whole room effectively, we install two human body infrared sensors on the north wall, with the height is 2.5m, which could guarantee the validity of the detection system.

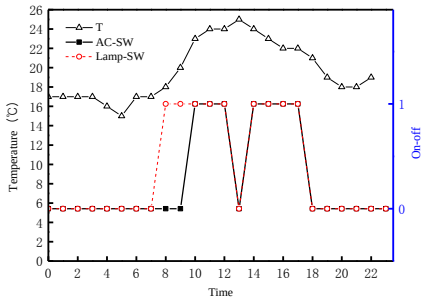


Figure 6. Data Graph For Energy Saving Controller Running A Day

Figure 6 shows the energy saving result of this system for air conditioning in one day. The left side shows temperature changing curve, here, we select 20℃ as the setting point as the highest temperature during the experimental period did not reach 26℃. The right side shows On-Off states of air conditioning and lighting. It can be seen that, if the staff opens air conditioning and sets 18℃ as the working point of air conditioning, the controller will force to shut down air conditioning. Only when the indoor temperature is higher than 20℃, air conditioning will open automatically. Besides that, when there is nobody at lunch break, air conditioning will be automatically closed along with lighting.

We assume that, the power of a cabinet air conditioning is 1.65kW, the energy saving during the working period (8 hours) is 1.65kWh *3 = 4.95 kWh. The amount is about 1331kWh for a year. It is just a rough calculation; the specific consumption is on the basis of actual working status of air conditioning. However, it can be seen that, the energy saving effect of the proposed controller.

5. Conclusion

With the continuous improvement of people's living standard and the improvement of building indoor environment, the related energy consumption in building is increasing too. This paper proposes an air conditioner self-learning wireless energy-saving controller to decrease the lighting and air conditioning power energy consumption.

(1) As for the phenomenon of forgetting to turn off the lights when there is nobody in room, we design human body infrared detection sensor module. When people enter the sensing range, it will automatically open the lamps, when people leave, the lamps will automatically shut down after 5 minutes.

(2) By using the same human body infrared sensor module, we could control the air conditioning open and close, which could save lots of energy due to air conditioner is the most power-hungry appliances in daily life.

(3) According to the indoor temperature, this controller could automatic control air conditioning, setting the temperature is 26℃in summer and 18℃ in winter, and build a comfortable and energy saving living environment.

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