

# Energy-Saving System Designed with Combining Ultrasonic Position and ZigBee Wireless Net Work

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**Abstract-** In this paper, the first time energy-saving system implemented with the design of combining ultrasonic position system with Zigbee wireless net work. There were some studies about Zigbee wireless networking and ultrasonic positioning respectively instead of combining the two systems in unique system to accomplish a task together. The study adapted ultrasonic positioning function to correctly detect both people's position and the number of them in a living space, and then send the information to servo computer through Zigbee wireless sensor net work as a data by which the control microprocessor would dynamically computer controlling signals to control related circuits on power-consumption facilities in living space so as to save energy consumed by facilities. After real experiment in a certain designed living space, the system was proved successfully control lights and air-conditioning facilities in order to get to the goal of energy-saving.

**Keywords:** Energy-saving, Wireless Sensor Network, Power Consumption, Power Factor Correctuon

## 1. Introduction

From industrial revolution to information revolution, the fast progress of man civilization in the past two centuries was closely due to sufficient supplying of energy including oil, coal, and petroleum gas. But into 21<sup>st</sup> century the supply of oil can merely be provided about 41 years while coal can provide more than 333 years. Considering from the progressing demand on energy in developing countries, the energy resource mentioned above would be exhaust out entirely before 21<sup>st</sup> century.

Energy is the fundamental necessity to get the economic activities of a country moving as well as positively important for people life and national safety. Since short of natural resource in Taiwan, all the energy for life and industry requirement in Taiwan depended on import and the situation was easily affected by shifting of international circumstance. Hence, how to respond the outer change of environment as to steadily provide Taiwan with adequate energy needs a proper long-term energy policy. Moreover, because of arising of conscious of

environmental protection resulting in the Agreement of Kyoto, in which all countries in the world compromise to decrease the green-house effect, Taiwan has faced strictly challenge of high-price trend and shortage of traditional energy owing to cut down green-house effect causing from atomic and firepower electrical generator. How to find replaceable energy to simultaneously meet with the resolution of energy demand, environmental protection, and requirements of industries depends on effective and proper policy constructed by the government.

Owing to the rising of living level and increasing of economical activities, the electricity energy consumption became more and more. The related government department responsible for the energy policy suggested saving energy, and the concrete measures are as follow: (1) Suggesting advancing progressive fare of electricity consumption in all buildings. (2) Constructing long-term standards of energy efficiency in non-tub air-conditioning, refrigerator, lights and related manage-rules for merchandises testing and certification. (3) Revising Energy Management Rules to intake energy efficiency of energy consumption facilities into management system so as to positively advance green building into city planning mechanism and direct people to participating energy-saving movement.

It was pity that the energy-saving movement of people were always under passive recognition against the government policy direction in long time, so the effect was limited, especially after intensive investigation, some computers opening all day long in campuses or private offices, lighting facilities in large office during the night, and huge cooling facilities and air-conditioning which consisted of the main part of electricity energy-consumption. Hence, how to construct an active and intelligent system of energy-saving in those spaces of huge electricity energy-consumption becomes a critical and worth exploring issue. This research tried to use new generation sensors WSN (Wireless Sensor Network) combining with ultrasonic position device to detect the position and the number of the people in the energy-consumption space [1], and then with designed algorithm to create the controlling mechanism to get to control

energy-saving system, and that means we adapt an active mechanism in energy-saving instead of passive conception in the past.

## 2. Study Purposes

In order to explore all possibilities of energy-saving for all kinds facilities or home-appliance, the first factor we consider was what the design mechanism of energy-saving on all electrical facilities and appliances was and the second was the using time the user spend on the facilities and the manner when using those appliances. Those issues have much to do with space condition and operational condition of facilities, so in this study we tried to implement WSN combining with ultrasonic positioning devices to detect the position of users in the living space [7], and then with this detected data to judge the relation between users and living space and constructed an algorithm to control the circuits which could do benefits to the energy consumption of all facilities or home-appliances.

In this study, we now take lights and air-conditioning facilities as example to experiment the energy-saving mechanism embedded into all kinds of living space in homes, offices or schools. To detect the distance and number of the people in the living space, and then decide how many lights [5], where the lights should be turned on instead all the lights in the space. As to the air-conditioning [8], the output power of the facility depend the position and number of the people in the space and the control method was used SPWM to save large amount of energy in-necessary for wasting in the space [8].

## 3. Energy-saving System Design

- A. In order to accomplish the goal of detecting the precise position of people in a certain space, a positioning system was necessary in the system, in this study we adapted ultrasonic positioning system with Tri-angle method and combined with Zigbee WSN [3,4] module to deliver the information of position to the servo PC through wireless communication system.
- B. To design a control system board in which an electricity-energy control system controlled by microprocessor and user position and number detecting system are combined together to get to energy-saving function.
- C. To design a PWM (Pulse Width Modulation)[8] generator on the control-board to control the power inverter circuit for huge energy-consumption facilities such as air-conditioning or refrigerators, and some home-appliance such as TV or audio sets we could design the auto-controlled volume system so as to control the volume of those facilities according to the user's distance to those facilities.

- D. As to the facilities of the largest consumption of electricity would be the lights; especially those were all turned on during the night in an office without full staffs in the office. So we could design the automatically turn on or off mechanism for the lights with the circuits controlled by the users' distance between the lights as well as the computers judged by the user's presence or absence in the office detected by RFID system[13].

### 3.1 Main Part of The Control System in Energy-Saving System

The control-system in the energy-saving could be divided into three parts as shown in Fig. 1. A users' position and number detecting system which was consisted of PC servo computer, Zigbee wireless communication device [3], ultrasonic positioning sub-system module[5]. 2. Users' position reflecting system which combined the ultrasonic positioning signals reflecting to the three Zigbee position detecting system through Triangle Positioning Method as well as users' number information collected by RFID system[13]. 3. Controlling Board attached on home-appliances or large-power consumption facilities consisted of Zigbee communication device to receive the controlled code from servo PC and microprocessor through Input/Output interface to control the circuits which would generate the proper control signals for the power consumption to get to the energy-saving purposes. As shown in the Fig 1[2,10], when user approaches into certain area in the space and the position and number of the users are detected by the positioning system on the servo PC, and then the Zigbee wireless communication system would send the control code to the control board attached on the facilities and the microprocessor would respond the right action to the power control circuits[12].

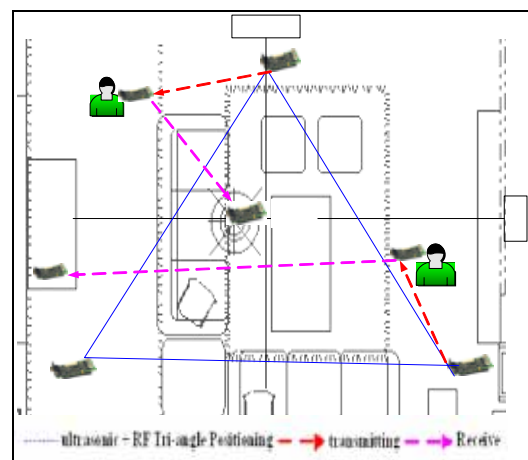


Fig. 1 Energy-saving system and its detecting system conception

As the Fig 2, there were three ultrasonic positioning modules MCS410 being triangle

position and placing on the ceiling[3]. Every home-appliance in the space would be embedded into a MCS410 combined with Zigbee Modules to reflect the precise position information to the positioning system on the servo PC. Then the control-board attached on servo PC would send control codes to the control-board attached on the home-appliances to generate PFC+PWM[8,9] digital control signals to control the power circuits on the home-appliances to get to control the brightness of the lights or the power of air-conditioning.

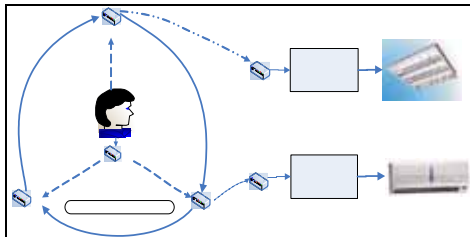


Fig. 2 The practical operation mechanism of energy-saving system

### 3.2 Design with ultrasonic system

In this research, the ultrasonic positioning module was designed and implemented in this energy-saving system. Sound-wave comes from anything vibrating and it seems to appear in different form, in short, sound-wave is a kind of mechanical vibration in a plastic media substance. Generally, the audible frequency of sound-wave is 20Hz ~ 18,000Hz per second, which was called sub-sound-wave, and if the frequency is higher than 20,000Hz, then it was called "ultrasonic"[7].

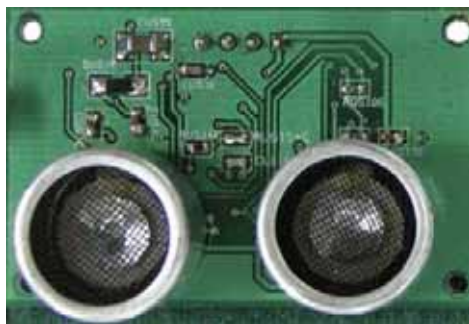


Fig. 3 Ultrasonic positioning device practical products

There were some applications of ultrasonic in medical field long ago such as implementing the mechanic vibration generated by ultrasonic reflecting from physical objects in many treatments and diagnosis and the frequency range of the sound-wave was about 1~30MHz. In the science field there was a most well-known application was that the USA NASA took advantage of time-interval between two sets of ultrasonic modules mounting on automobiles (as Fig. 3) to figure out the distance and shape

surface of some obstacles during landing Mars in 1997.

The transmitting and receiving structure of ultrasonic could be divided into reflection and face-to-face modes shown as Fig. 4. When compared with the precision of distance measure, the accuracy of face-to-face structure would be more than that of reflection[1]. The reason is that there is distortion of the reflective signal after the sound-wave touching on the different surface of the substance or materials, and so this condition would generate errors of distance measure.

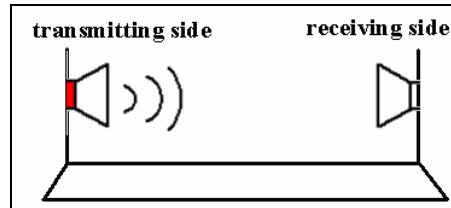


Fig. 4 Face-to-face ultrasonic structure

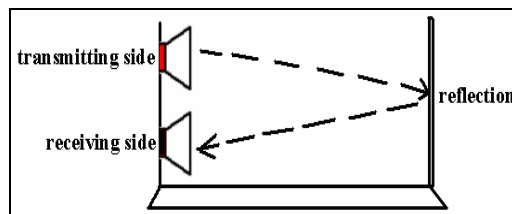


Fig. 5 Reflection ultrasonic structure

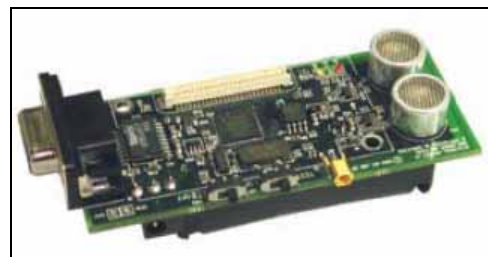


Fig. 6 Ultrasonic positioning module MCS410

In this study, we selected MCS410 as our ultrasonic-positioning modules as in Fig. 6. The MCS410 included one transmitting and receiving set simultaneously[3]. MCS410 was a positioning module based on low-power consumption microprocessor MICA2 and Cricket Mote included a standard MICA2 with all hardware and ultrasonic receiver. Because the ultrasonic was quite different from RF, Cricket Mote used the time-interval of their arriving to figure out the distance, and Cricket Mote module could be built as Listener or Beacon.

Beacon was scattered over the buildings or facilities and transmitted RF and ultrasonic signals simultaneously[13], and Listeners was set up the servo PC or portable facilities to receive the reflected signals of RF. After receiving the RF signals reflected from Beacon, Listener waited the reflected signals of ultrasonic afterwards. When received the two reflected signals, Listener would estimate the distance

between Listener and Beacon according to the arriving time-intervals[3]. Listener executed the certain algorithm to select the best couple signals of RF and ultrasonic. Cricket Mote could fast response and get to its accuracy and precision even if there appear several Beacon signals simultaneously. MCS410CA Mote module was called Cricket V2, which was developed under the cooperation of Crossbow Technology and MIT. I was adapted the same microprocessor and RF modules as standard 433 MHz MICA2 (MPR410) that directly coupled with RS-232 port[3].

MCS410 Cricket Wireless Positioning System owns features as follow:

- high performance MICA2 wireless positioning system
- ultrasonic receiver and transmitter and measure distance with time-intervals
- distance precision could get to mili-meter/resolution
- embedded or antenna mode

Applications of MCS410 Cricket Wireless Positioning System are as follow:

- inner-space wireless positioning system
- business logistics and man-power resource management
- research of ultrasonic positioning

#### 4. Software develop environment of Tiny-OS

The software developing environment of MCS410 Cricket Wireless Positioning System was based on cluster-software of Crossbow. The interface of software programming was Tiny-OS and the software finally was programmed by MIB510 as shown in Fig. 7[2].



Fig. 7 Software programmer of MIB510

Tiny-OS adapted embedded operational system with Open Source[4], which was mainly used in wireless sensor network and it was a structure of Component – Based to meet up with all kinds of implementations. The procedures of Tiny-OS was adapted module-designed, so the core of its procedure was usually tiny, generally speaking, the codes of core and data were about totally 400 Bytes and this feature could break out the constrain of limited resource of sensors. In addition, Tiny-OS could perform effectively in

wireless sensor network to execute all management work. Tiny-OS provided a serial of components which could easily organize procedures to get or deal with the data and to transmit them by wireless communication mechanism. Therefore, Tiny-OS could be regarded as connector between sensor network and API and execute all kinks of communication.

Tiny-OS needed a control basement when constructing wireless sensor network, in which the main function of the basement was to control the sub-notes of the sensor networks and to deal with the information they gathered. Tiny-OS only need to declare the management information, and all of the sub-notes would communicate one another according to the agreements declared by the Tiny-OS.

#### 5. The energy-saving system design of home-appliances

The digital light-brightness controller used electronic ballast to combine with Power Factor Correction (PFC) as shown in Fig. 8 and Pulse Width Modulation (PWM)[5,11]. PFC indicated the relationship between effective power and total consumption power that meant using effective power divided by the total consumption power. Basically, the PFC could indicate whether the electrical power was efficiently used or not, the higher the PFC is, the more efficiently the power was used. The principle of the energy-saving system for lights was that the system was to control and adjust the input AC current wave form so as to let the current wave form to be the same as the DC voltage wave form as possible as could, that meant the power factor was almost close to 1[11]. This condition was very important for an electronic facility when the power consumption was huge to high degree. Otherwise, the power consumption of the system would surpass highly and could do damage to the other facilities in the same system.

Under general condition, electronic facilities have got PF only 0.5 without Power Factor Correction[5]. The benefit of PFC are saving electricity fare, increasing the capacity of the power system, stabilizing the low PF of current. Because lower power factor meant the higher energy wasted in the electricity distribution system, and supposed that without PFC to up-rise the lower PF, the power plant must need to provide the virtual power that was nothing to do with the necessary power in the work in addition to the effective power. So, this condition could result in necessity of larger power generator, transformer, distribution facilities, cables, and extra distribution system[9]. But if there were PFC in electronic facilities then not only to improve the energy-consumption efficiency for facilities themselves but also to save the



electricity fare. PFC is also one kind of environmental protection technology that could effectively decrease the harmonic wave causing electrical-power pollution, and so it would do benefit to the whole society.

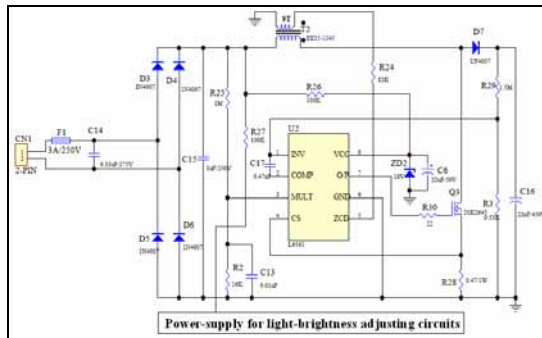


Fig.8 Circuit of active adjustment for power factor

As to the air-conditioning, the control-system of strength of the cool air was controlled with PWM (Pulse Width Modulation) as shown in Fig. 9. PWM was a very effective way to control traditional analog circuits with the digital output of the microprocessor[6], and it was widely used in some fields such as measurement system, communication, power control and transformation. One of the superiority of PWM was that all the control signals from microprocessor to the controlled system were digital form no need for A/D convention, and this feature could make the longer distance of communication system possible[6]. At the side of receiver, the system could filter and modulate the square wave of high frequency through proper design of RC or LC circuits and then return the original form of analog signals back.

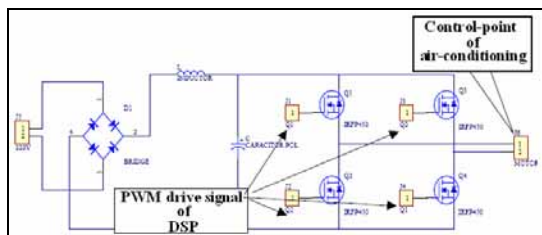


Fig. 9 PWM generated by DSP for controlling power circuits of energy-consumption facilities

## 6. Conclusion

Because the National Science Council has cooperation works with Energy Bureau of Economic Ministry of Taiwan to together promote the researches of renewable energy and energy saving system, this research tried to use one brand-new way combining ZigBee wireless sensor networks and ultrasonic positioning method to design one energy-saving system. In this latest technology adapted in the system, the users' position in a certain space to create the information for the energy-saving system to

figure out the related parameters to control those power consumption system or facilities so as to achieve the purpose to save the energy. In the final experiment stage, a single space was arranged for system experiment, in which, lights and air-conditioning facilities were used the methods and algorithm mentioned above to control those energy-consumption facilities. The outcomes of the experiment indicated that the energy-saving system could really improve the energy-consumption. In the near future, we would implement large amount related wireless sensor network to design the intelligent living space with other energy control systems.

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