Remote Controllable and Power Saving of House Hold Appliances Based on Zigbee Communication

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***Abstract* - This project proposes remote-controllable and energy-saving room architecture to reduce standby power consumption and to make the room easily controllable with an IR remote control of home appliances. To realize the proposed room architecture, I proposed and designed the automatic standby power cut-off outlet and a ZigBee controller with IR code learning functionality. The proposed outlet monitors the power consumption for the predetermined time and completely cuts off the power supply when the monitored power is below the threshold power. This power outlet has a function of changing the threshold power, which enables any kinds of home appliances to be applied to the power outlet. To efficiently manage the power outlets and the lights, we proposed the ZigBee controller with IR code learning functionality .The ZigBee controller has several on-board buttons to wake up the power outlets and control the dimming light. By using IR code learning functionality, the ZigBee controller can assign a certain IR code of a remote control of a home appliance to the power outlet or the dimming light. A user can control the power outlet of any home appliance. The proposed room architecture provides the remote –controllable and energy-saving room.**

***Keywords* - Zigbee, IR Remote Control, Home Appliances, Threshold Power, Dimming Light**

I. INTRODUCTION

As more and more consumer electronics and home appliances are deployed and the size of them is becoming large, power consumption in home area tends to grow. Moreover, useless power consumption occurs when they do not perform the primary function or even when they are turned off. This is called standby power. It is known that average 10% of a total household power is consumed during standby power state.

To reduce the standby power of electrical apparatus less than 1w, International Energy Agency (IEA) proposed '1-watt plan'. Several researches were conducted to reduce the standby power in the region of chip, hardware and system. Although much effort is made to reduce the standby power of consumer devices themselves, efficient power management schemes over a room or home region are greatly required to reduce the total power consumption in home. The controlling and power monitoring capability is indispensible to home power management. The network capability is also required to communicate one another. Several controlling and power monitoring systems have been proposed and implemented. In these systems, power line communication (PLC), Ethernet, Bluetooth and Zigbee as wired or wireless networks are used to transfer the control information and the measured power. The signal transformation circuit is designed to measure the working power of the electric outlet. The measured power is recorded and transferred periodically to the remote control unit such as a cell phone, a personal computer (PC) and a personal digital assistance (PDA). When the measured power is above the maximum load, the power outlet is electrically turned off through the solid state or mechanical relay for safety. The user can also check the power consumption of the home appliance through the remote control unit. However, these previous systems only monitor the consuming power and protect the overload of the power outlet.

Efficient power-saving methods are not provided to cut off useless standby power consumption. A central unit such as a PC or a PDA is required not only to monitor and control the power outlet but also to manage the home automation.

In this project, I propose a remote-controllable and energy –saving room architecture. To realize our proposed room architecture, the automatic standby power cut-off outlet and the zigbee controller with IR code learning functionality are described and their operation mechanism is explained. The proposed automatic standby power cut-off outlet and the zigbee controller are described in detail. The proposed room architecture is illustrated and the operation mechanism is explained. The implementation results of the power outlet and the zigbee controller is given. Finally the conclusion is summarized.

II. POWER CONSUMPTION ANALYSIS

Estimated **electricity consumption in a month : 491.25kwh**

SI.NO	Appliances used in the house	Power consumed
1.	Rice cooker – 600w (2 to 4 persons)	600w (2 to 4 persons)
2.	Fluorescent – 40w	
3.	Incandescent – 100w	
4.	Colour tv – 21 inches	

Table 1

III. PROPOSED POWER OUTLET AND ZIGBEE CONTROLLER

AUTOMATIC STANDBY POWER CUT-OFF OUTLET

The proposed power outlet is designed to have the capability of automatic power cut-off in standby power state.Fig.3 shows the architecture of the power outlet, which is composed of an AC/DC conversion, one two port relay, a power monitoring circuit and a microcontroller. The AC input is connected to the two port relay. One output port is connected to it via the power monitoring circuit.

Architecture of the Power Outlet

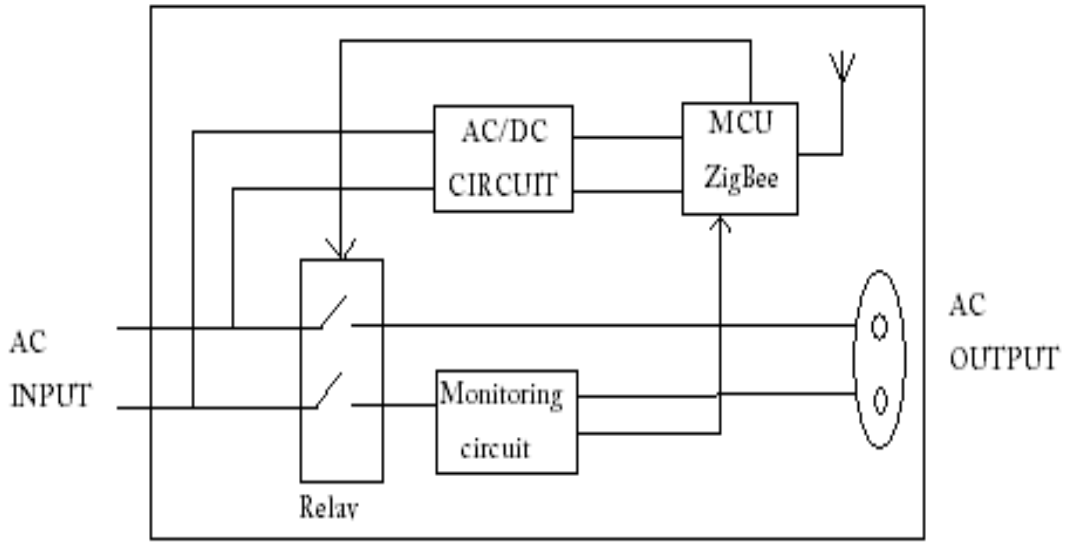

Figure 1: Architecture of the power outlet

The power monitoring circuit consists of a transformer, rectifying diodes and additional components. It converts the measured power consumption into a voltage. The microcontroller digitizes the voltage and calculates the consumed power. Based on the calculated power, it controls the relay to cut off the power supply. The AC/DC conversion circuit supplies the necessary DC power to the microcontroller in which a ZigBee Radio Frequency (RF) module is integrated to communicate with the remote control unit. ZigBee is a wireless network standard which is aimed at remote control and sensor applications requiring for low power consumption and low data rate. Several studies were performed based on ZigBee in home area.

A usual home appliance has two power state, normal and standby. In the normal state, a home appliance consumes a large amount of power. In the standby state, it consumes a small amount of power, which is not negligible. As mentioned above, the standby power consumption amounts to 10% of a total household power. To more efficiently reduce total power consumption, it is required to completely cut off the power supply at the power outlet in standby power state .

This proposed power outlet periodically monitors the power consumption via the power monitoring circuit. Initially, it has its own threshold power in the memory of the micro controller. When the connected home appliance is changed, the threshold power can be reconfigured by measuring the normal power consumption and the standby power consumption.

The power outlet has four kinds of state: boot, on, normal and off state.Fig.4 shows the state transition diagram. When the AC power is initially supplied to the power outlet, the microcontroller boots and executes the firmware. After booting, the microcontroller goes to the on state. In this state , the microcontroller does not monitor the consumed power but turns on the relay and waits for the guard time, for example, **t**wo minutes. After the guard time elapses, the normal state starts. In the normal state, the microcontroller monitors the consumed power. As the monitored power can have ripples, hundreds of monitored powers are averaged. When the monitored power is below the threshold power for the pre determined time, for example, two minutes, the microcontroller turns off the relay to completely cut off the AC power. Then it goes to the off state. Now the microcontroller does not monitor the consumed power but waits for a turn-on command through ZigBee communication .When it receives the turn-on command, it turns on the relay to supply the AC power to the output port. It is the on state. This state transition repeats continuously. This method can reduce even the standby power of the home appliance because the power outlet completely cuts off the power supply. Although some power is consumed in the microcontroller and the AC/DC circuit, it is very small compared to the standby power of the home appliance. This proposed automatic standby power cut-off outlet can cut off standby power without the central units.

State transition diagram of four states in the proposed power outlet.

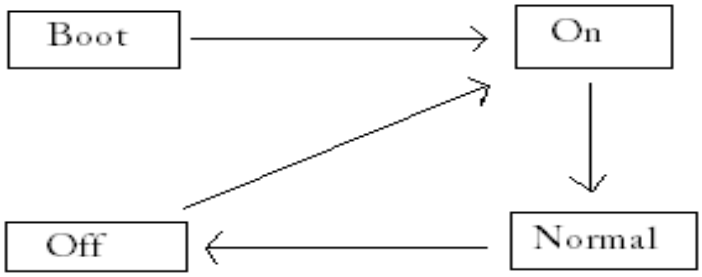

Figure 2

ZigBee Controller with IR Code Learning Functionality

In the normal room, there are several power outlets, several lights and one dimming light. To control these power outlets and lights, it is necessary to equip the ZigBee controller in the room. The ZigBee controller plays a role of a coordinator and the power outlets and the lights become end devices. The ZigBee controller can control and communicate with the power outlets and the dimming light. Fig.5 shows the architecture of the ZigBee controller and the system configuration through ZigBee communication.

Zigbee controller with IR code learning functionality

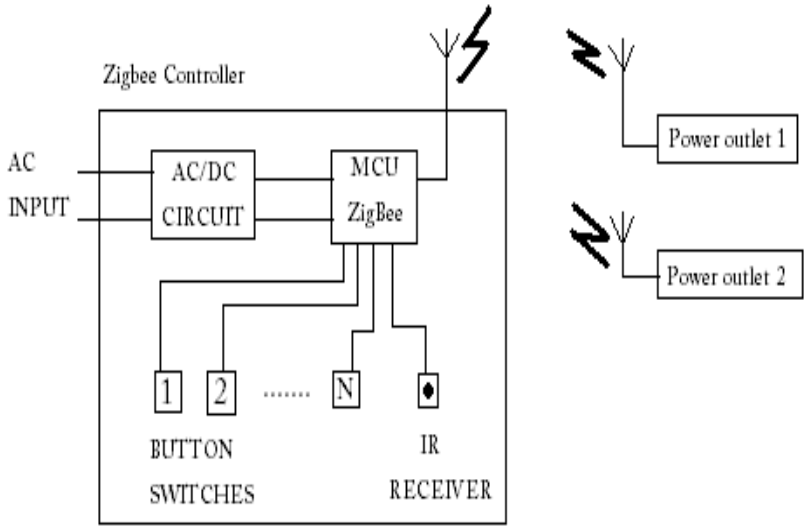

Figure 3

The ZigBee controller consists of an AC/DC conversion circuit, a microcontroller with ZigBee RF module, several button switches and an IR receiver. The AC/DC conversion circuit supplies the stable DC power to the microcontroller. Each button switch can be assigned to the power outlets or the dimming light. If the first button is assigned to the first power outlet, to press the first button wakes up the first power outlet and makes it transit to the on state. Other two buttons can be assigned to the dimming light, one for 'light' function and the other for 'dark' function. If a user comes close to the ZigBee controller and pushes a specific button, he can control the power outlets and the dimming light. With the help of this ZigBee controller, a user can wake up the power outlets and make the dimming light lighter or darker.

If the home appliance connected to the power outlet is changed, standby power can be different compared to the previous home appliance. In this case, the threshold power should be reconfigured for proper operation. It can be done as follows. First, a user wakes up the target power outlet and then plugs a new home appliance into it. He turns on the new home appliance. Then he presses the button switch corresponding to the target power outlet and holds it. If he does not release that button for a little bit longer time, the microcontroller goes to the learning mode and measures the normal power consumption. When he releases the button, the microcontroller finishes measurement and memorizes the normal power. Second, he turns off the new home appliance. If he presses the button switch and holds it for a little bit longer time, the microcontroller goes to the learning mode and measures the standby power consumption. When he releases the button, the microcontroller finishes measurement and memorizes the standby power. Then, the microcontroller calculates the threshold power by using these two measured powers. Various calculation methods can be utilized. For example, the average of the normal and the standby power can be the threshold power.

When a user wants to turn on the home appliance connected to the power outlet, he needs to wake up the power outlet by pressing the corresponding button and then turn on the home appliance with an IR remote control. The power outlet turns off automatically, but it should be waked up by the user manually. And the user should always come close to the ZigBee controller and press the corresponding button to turn on a home appliance. To make the control more convenient, IR code learning functionality is added to the ZigBee controller. In general, an IR code stream is composed of a carrier and a baseband signal. A carrier frequency normally ranges from 19 kHz to 50 kHz with some duty ratio. It can be considered as a pulse stream having some high time and low time as shown in Fig.6

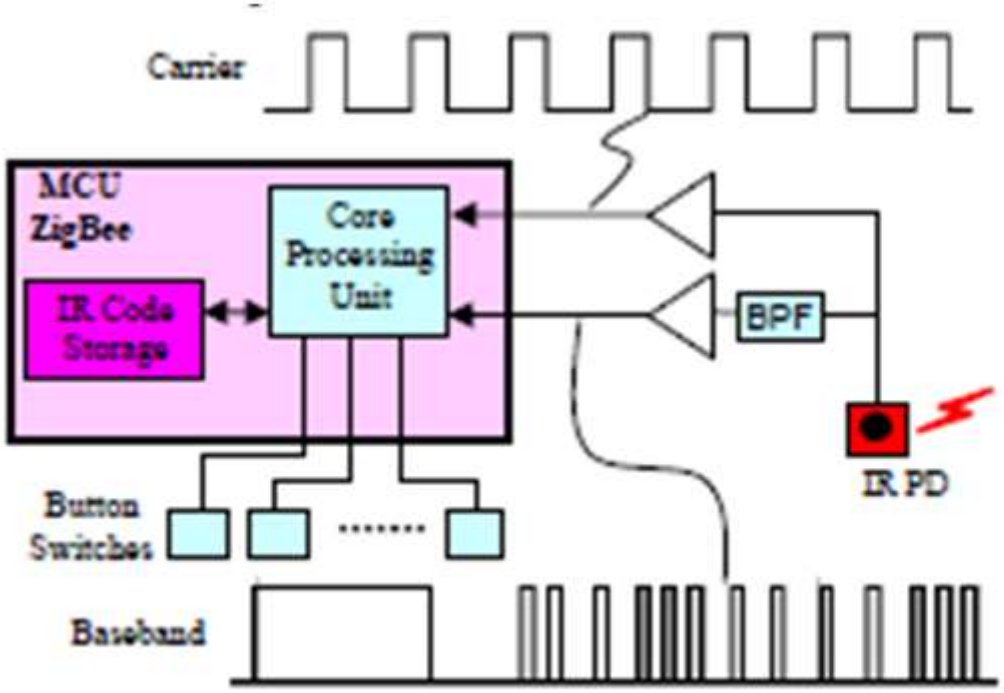

Fig. 6 IR code learning function block for the ZigBee controller. PD: Photo Diode, BPF: Band Pass Filter.

The carrier signal can be sampled and recorded by measuring the high time and low time of the output signal of the IR PD. The high time is calculated by measuring the time between the rising edge and the falling edge. The low time is calculated by measuring the time between the falling edge and the rising edge. As the carrier signal is a pulse stream having a constant pulse width, the measured and calculated high and low time can express the carrier signal completely.

A baseband signal has time duration from sub millisecond to a few milliseconds. But it is not a constant pulse stream. It can be considered as repeated pulse streams having different pulse durations. It can also be sampled and recorded by measuring the high and low time of the repeated pulses after rejecting the carrier frequency component via the band pass filter. The consecutive inverting pulse times can describe the baseband signal. Therefore, the core processing unit can identify the IR code by analyzing these time information..The ZigBee controller has two kinds of mode. One is a learning mode and the other is an operating mode. In the learning mode, a user can assign a specific button to some IR code. The IR code learning process is done as follows. A user presses a button twice consecutively, which switches the ZigBee controller to the learning mode. Then he transmits the IR code of the remote control toward the IR receiving block .The core processing unit records the carrier and the baseband signal, and stores them at the IR code storage corresponding to that button. The operating process is done as follows. If a user transmits the IR code of the remote control toward the IR receiving block, the core processing unit records the carrier and the baseband signal, and then compares the recorded IR code with the stored ones. If the matching code is found during search, the core processing unit executes the command corresponding to that button. If there is enough memory to store the codes, it is possible to assign many IR codes to one button. So a variety of IR remote control can be recorded for convenience.

IV. PROPOSED ROOM ARCHITECTURE

Fig.5 illustrates our proposed room architecture. There are two automatic standby power cut-off outlets and one dimming light. They are controlled by a ZigBee controller which has four button switches. The first button is assigned to the power outlet 1 and the second one to the power outlet 2. The third and fourth buttons are assigned to the dimming light. As the ZigBee controller has a function to learn IR codes, the power button of an IR remote control can be assigned to the first button of the ZigBee controller. So it corresponds to the power outlet 1. When a user wants to watch television connected to the power outlet 1, he does not have to press the first button of the ZigBee controller to wake up the first power outlet. He only has to press the power button of the IR remote control of the television toward the ZigBee controller on the wall. This wakes up the power outlet 1. Then, if he presses the power button of the same IR remote control toward the television, it turns on the television connected to the power outlet 1. Now he can enjoy watching television. Likewise, another button of the IR remote control of the TV can be assigned to the second power outlet A user can also assign the volume up/down buttons of the IR remote control to the third and fourth button of the ZigBee controller. So the volume up/down buttons correspond to the dimming light. He can control the dimming light with the IR remote control of the TV. By using a ZigBee controller with IR code learning functionality, a user can control the dimming light and the power outlets with one IR remote control of a home appliance like a TV. As the illustrated room has energy saving outlets and can be controlled by an IR remote control, it deserves a remote-controllable and energy-saving room.

HARDWARE UNITS USED:

- Zigbee module with 2.4 GHZ ISM.
- Microcontroller PIC18F4520.

- For lower power consumption nanowatt technology.
- IR coding functionality.

SOFTWARE TOOLS:

- MPLAB IDE 8.40V
- C18 Compilers. ('C' language)
- MPLAB ICD2 Debugger

ZIGBEE PROTOCOL NODE HARDWARE(CONTROL SIGNALS ADDED)

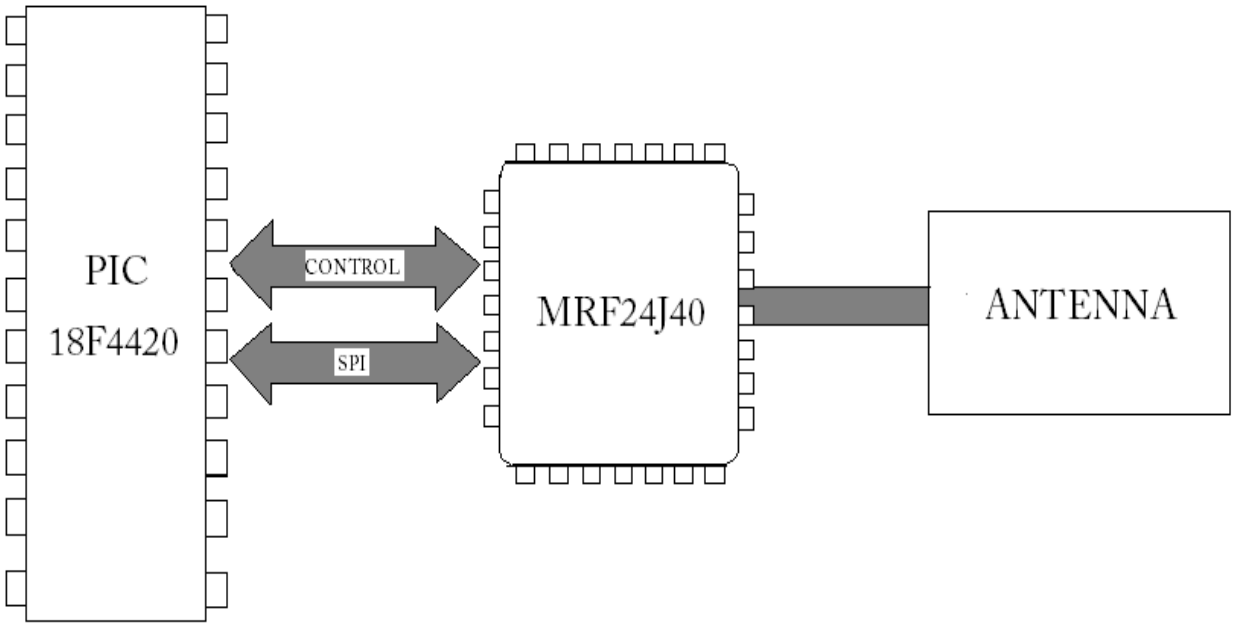

Figure 5

Photo graph of project prototype developed

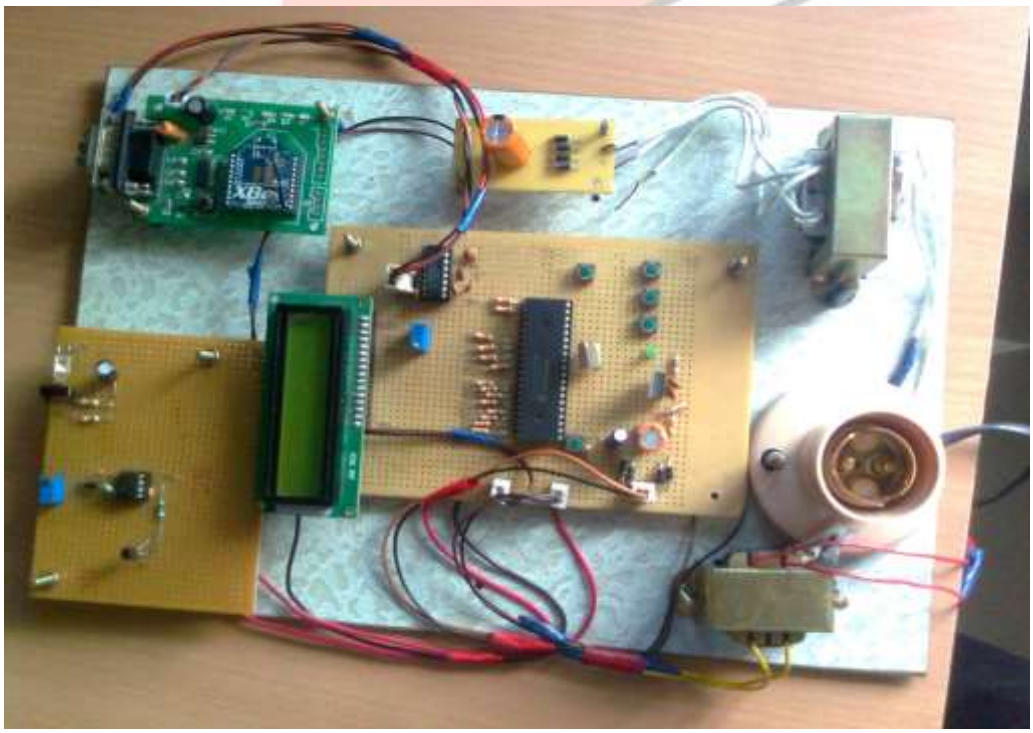

Figure 6

V. IMPLEMENTATION RESULTS

To confirm the feasibility of our proposed room architecture, we implemented the Zigbee controller with IR code learning functionality and the automatic standby power cut-off outlet. The implemented automatic standby power cutoff outlet is shown in Fig.8. It is composed of a power board and a control board. The AC/DC conversion circuit and the power monitoring circuit are located at the rear side of the power board. The relay is under the control board. The control board consists of a microcontroller, a variable resistor, a 2.4GHz antenna, a 32 MHz crystal, and a 10 pin connector. The power board and the control board are connected through the10 pin connector. The DC power, the power monitoring voltage and the relay control signal are linked through the connector. The variable resistor is used to calibrate the measured power. The power monitoring signal is input to the ADC (Analog to Digital Conversion) port of the microcontroller and is digitized. As the power monitoring voltage fluctuates a little bit, it is sampled at every one hundred millisecond and averaged over ten samplings. When the monitored power is below the threshold for two minutes, the microcontroller turns off the relay. To test its operation, I connected 21 inch flat panel TV to the power outlet. The standby power of this TV is about 550 MW. So I set the threshold power at 800 m W. In two minutes after I turned off the TV with a remote control, the power outlet automatically cut off the power supply. The implemented power board can be easily deployed by adding this board to the general outlet. The power outlet consumes about 140 mW in the standby state. This amount of power consumption is very small compared to the normal standby power target 1W and the standby power of the tested 21 inch flat panel TV.

Table of standby mode power consumption

Table 2

State	Time	Power Usage (KWH)	KWH/hr	KWH/Day
Off but Plugged In	8hrs	0.08	0.01	0.24
Standby mode	14hrs 23 min	0.16	0.011	0.27
Regular Usage	6hrs 40min	1.15	0.173	4.15

VI. CONCLUSION

With the design a user can control the power outlets and the light with an IR remote control of any home appliance and save the total power consumption of a room. IR sensor is connected in the front of the home for sensing the human who entering in the home. It makes activation of the network automatically.

By using zigbee network with server all the rooms in a home can be connected together for total home automation. Black body radiation sensor can be connected in the front of the home for sensing the human who entering in the home. It makes activation of the network automatically.

VII. REFERENCES

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