Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 92 (2016) 305 – 310

Procedia Computer Science

2nd International Conference on Intelligent Computing, Communication & Convergence

(ICCC-2016)

Srikanta Patnaik, Editor in Chief

Conference Organized by Interscience Institute of Management and Technology

Bhubaneswar, Odisha, India

Design and Implementation of Standby Power Saving Smart Socket with Wireless Sensor Network

Singaravelan.A*, Kowsalya.M

VIT University, Vellore

Abstract

Most Electrical Appliance in home still use electricity while turned-off. Turned-off electric appliance generally still require standby power when they are plugged in. In this paper we proposed a way to reduce standby power of electric home appliance and ZigBee based smart meter for smart grid application. The proposed socket supplies the appliances with power when the user turns them on. Our socket shuts the electric power off and reduces the standby power to zero when the user turns them off. The proposed design uses a microcontroller unit (MCU) receives signals from a Core Balanced Current Transformer (CBCT) and from a Pyroelectric Infrared (PIR) sensor which detects the user approaching the socket and provides MCU to control the relay On/Off when used as an appliance switch for shutting off the standby power. The components used in the proposed design are low cost and consume only 0.5 W. The MCU monitoring program provides both automatic detection of the user by the PIR sensor and detection of power consumption. The MCU measure the instantaneous current values and send it to data center computer through ZigBee module which acts as a smart meter for smart grid application.

Peer-review under responsibility of the Organizing Committee of ICCC 2016

*Keywords:*Smart Meter, Smart Grid, Power Consumption, Standby power, Electric Home Appliances, PIR Sensor, Relay, ZigBee, Current Sensor.

* Corresponding author. Tel.: +918870411118.
*E-mail address:*a.singaravelan2013@gmail.com

1877-0509
Peer-review under responsibility of the Organizing Committee of ICCC 2016
doi:10.1016/j.procs.2016.07.360

1. Introduction

Plugged-in Electric Home Appliance consume electric power even it is turned off, because it require standby power. More number of home devices increase power consumption in two aspects, normal operation power and standby power. This two kind of power consumption are proportional to the number of home appliances. Most modern home appliances contain digital electronics components like clocks, memories, remote controls, microcontrollers and instant-on features that consume electricity whenever they are plugged in. Most of the home appliances are plugged in 24 hours a day and 7 days a week. This build-in digital electronics in home appliances are for the convenience of the user. The microcontroller inside the appliance is in standby state awaiting user commands while the appliances are either plugged in or turned off. An adapter supply standby state power to microcontroller which has no power off switch. The adapter, which is very inefficient at low power, consumes between 4 to 8 Watts or about 100 to 200 Watt-hours daily, which is not only many time the power actually used by the microcontroller but also enough to run a compact fluorescent light for about 10 hours. The reduction of standby power is greatly necessary to reduce the electricity cost in home.A simple solution to eliminate the standby power consumption of an appliance would be unplugging switch from the power outlet or turning OFF the switch. To do this user need to interact directly with the appliance for manual control, this will cause inconvenient for user. Some commercial products [1] and [2] recognize the device's operation of standby mode automatically and enable power cutoff in a standby mode. But that products only cut off the power and user must manually activate the power supply, as the power supply cannot be controlled automatically or remotely. Many researches were performed to reduce standby power of home electric appliances [3]-[7]. Those technical research deals only either standby power reduction alone or electrical energy monitoring alone.

In this paper we present a design to reduce the standby power of a socket with smart meter. The circuit in the proposed design consist of a few common components with low cost and low power consumption. This low standby power socket consume low standby power and it can be used by existing appliances. Installing this socket is easy, it saves power more efficiently and it is cheap. Therefore, it is suitable for use in most home appliances.

The organization of this paper is as follows. In Section II we propose circuit design and a programming logic of the low standby power socket. In Section III we describe the measurement of the power consumption of our design to verify the total power saved and we show the wireless communication of smart meter. In Section IV we draw the conclusions.

2. Circuit Designs Of The Low Standby Power Socket

Standby power, often called vampire power, is electricity consumed by an electrical appliance when it is plugged. Most electric home appliances such as microwave ovens, induction stove are operated manually. Most control panels on electric home appliances are easy to operate, but when using a remote control, the user must still be near the appliance in question to turn it off again. Electric home appliance could still be running whenever the user has left. If the user is not around the appliances, then the electrical home appliance are not being used and should always be in the turned-off state. To reduce the total amount of standby power used we propose a design that detects the user approach to electrical appliance. PIR sensor is used to detect the user approach to the appliance. When user approach is detected by the PIR sensor, the power for the electric home appliances is enabled. In contrariwise, if user approach is not sensed by PIR sensor, the power is disabled as if the appliances were unplugged. If user approach is not sensed by PIR but the appliance is working, then the power continues to come from the socket until the work is finished. To achieve the above requirement we have use Current Transformer (CT) and signal conditioning circuit to detect the working status of appliance and also to measure the current for smart metering application. The block diagram of the proposed low standby power socket is shown in Fig. 1.

Fig. 1. Shows how a MCU controls the relay to supply the power for electric home appliances. The PIR sensor detects whether the user is approaching or not [8]. If user approach the appliance the PIR sensor send a signal to microcontroller. When user approach is sensed by PIR, the relay supply power to the appliances, and if no one nearby, the power source to appliance disconnected by relay. In order for the appliance to stay on after the user

leaves, the relay supplies power until the work is finished. The microcontroller programming logic is shown in the Fig. 2.

The working condition of the appliance is detected by CT signal conditional circuit and the user approach is detected by the PIR sensor. The signals from CT signal conditioner and the PIR sensor are send to MCU. The relay is controlled by MCU with respect to the sensor signals. From the Fig. 2. If appliance is working with user approach then the relay allow power to appliance, like normal condition. If appliance not working with user approach then the relay allow power to appliance.

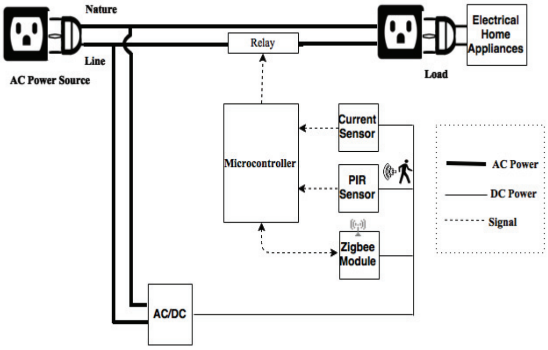

Fig. 1.Block diagram of low standby power socket

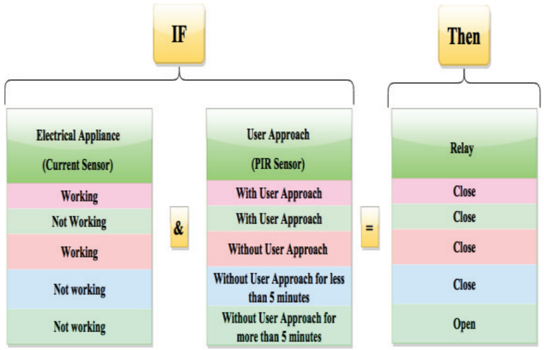

Fig. 2.Microcontroller Programming logic

If appliance working without user approach relay allow power to appliance, because power should supply to appliance until appliance work is complete. If appliance is not in work and no user approach then the relay will wait for 5 minutes before going to disconnect power supply to the appliance. If appliance is not working and the user interface is not present for more than 5 minutes then the relay immediately disconnect power supply to the appliance.

2.1. PIR Sensor

PIR sensor is an electronic device to sense nearby human bodies. The PIR sensor generate a voltage signal when motion is detects and this signal is amplified, digitalized and send to microcontroller unit to judge whether a user is approaching the appliance or not. The signal from PIR sensor is shown in the Fig. 8. (a).

2.2. CT Signal conditioning circuit

For the electric home appliance stay on until appliance is working but no user interface, we use a Core Balanced Current Transformer with 1000/5A ratings and a signal conditioning circuit to measure the appliance load current and also the working status of the appliance. Fig. 3. Shows this signal conditioning circuit.

The step-downed current is passed through a burden resistor of 100k, a small sinusoidal voltage is induced at the burden resister. The amplitude of the induced voltage is proportional to the amplitude of the used current. This small voltage is amplified by operational amplifier, and converted into DC signal by diode and capacitors, this amplified signal rectification and filter acts as signal conditioning circuit. And the DC signal is given as current sensor input to microcontroller unit. Sinusoidal voltage of CBCT and Signal Conditioning (SC) circuit output of a home appliance (induction stove) are shown in Fig. 4.

The current sensor analog signal is converted into digital with sampling time of 0.04 second. The output of Analog to Digital Converter (ADC) is multiplied with a constant 2.3(Scaling Factor) to get actual load current value of the appliances connected with low standby power socket. To Calculate the ADC Scaling Factor, an experiment conducted with five 100W incandescent lamp connected series with single source. Each lamp is switched on one by one from 100W to 500W and the readings from SC Circuit output and the actual load current value from Clamp meter is noted and compared. Fig. 5. Shows the comparison between SC Circuit Output and Clamp meter Output. From the comparison the scaling factor 2.3 is calculated.

To validate the ADC Output, Microcontroller PIC18F4520 [9] is programmed to send the ADC output data to RS232 serial port. Then the microcontroller is connected with computer through RS232 serial port. An open Source software CoolTerm [10] is used to monitor serial communication data received from microcontroller. The readings from clamp meter and the serial communication data with different lamp load is shown in Fig. 6. From Fig. 6. We conclude that the ADC output and Actual load Current value of the appliance connected with the socket is same with negligible error.

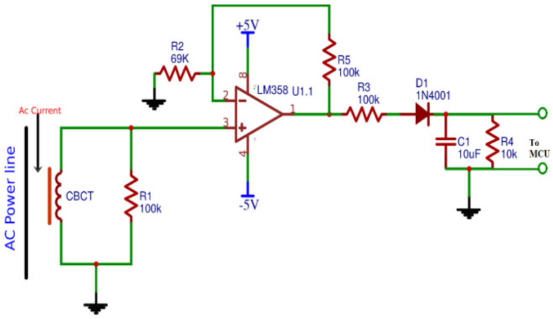

Fig. 3.CBCT signal conditioning circuit

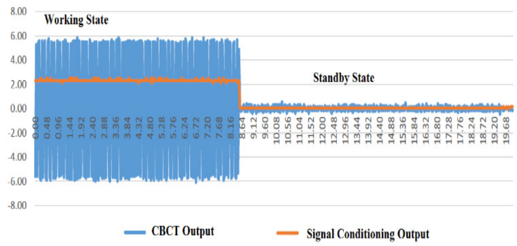

Fig. 4.Current sensor output of induction stove

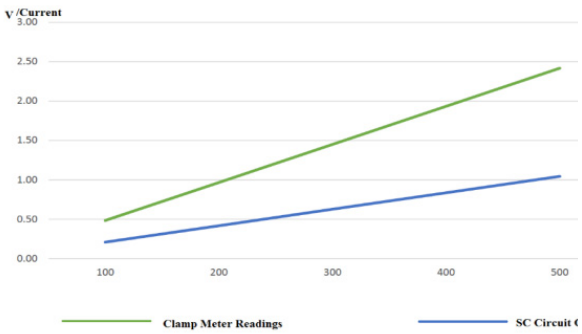

Fig. 5.Comparaison between SC circuit output and Clamp meter output

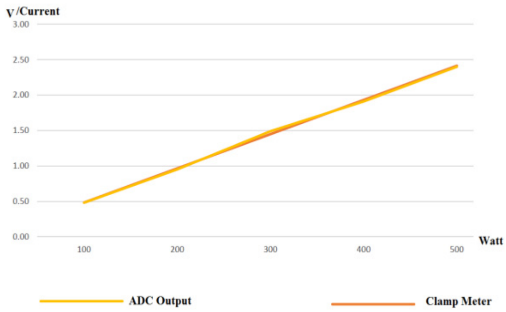

Fig. 6.Comparision between ADC output and clamp meter output

2.3. ZigBee Data Communication

With the low standby power socket we added communication system for smart metering application in smart grid. The ADC output from MCU is feed to ZigBee module [11] through RS232 port. ZigBee from socket side and ZigBee from Data Center side are configured as Router and Coordinator respectively. Socket side ZigBee sent Load Current data to data center ZigBee with time interval of one second delay.

2.4. Implementation

We connect both current sensor circuit and PIR Sensor to microcontroller as input, Relay signal and RS232 serial Communication as output. Relay is connected with Socket as shown in the Fig. 1. And the relay is controlled by microcontroller. For testing the proposed method we connect an induction stove to the socket as the appliance. A demo is conducted with different stages of induction stove, working State, standby state with user approach, standby state without user approach for less than 5 minutes, without user approach for more than 5 minutes. For all stage, the load current data is received from microcontroller to a computer wirelessly through ZigBee module. The hardware is shown in Fig. 7. From Fig. 7. The Numbered components from 1 to 7 are ZigBee, MCU, Signal Conditioning Circuit, Relay, PIR Sensor, Socket, and CBCT respectively.

3. Measuring Power Consumption

The proposed design of low standby power socket still need power to work with average power consumption of 0.5 W when no user approach and appliance is not in work. This consumed power is lower than normal standby power of electric appliance. The load current value and calculated power consumption is shown in Fig. 8. (a) and Fig. 8. (d) Respectively. From the Fig. 8. (c) and (d) shows that the standby power without user approach is reduces to 0.5W and with user approach standby power consume 20W in induction stove. Fig. 8. (b) shows the relay signal change 0 V from 5 V when no user approach for more than 5 minutes and relay signal changes immediately to 5 V from 0 V when user approaching the appliance. The load current value shown in Fig. 8. (c) is the data received through ZigBee module from MCU when conducting the experiment. The power is calculated by multiplying 230V with received load current data shown in Fig. 8. (d). the calculated power is instantaneous power so we not considered the Power Factor [11].

Fig. 7.Hardware setup of low standby power socket with smart meter

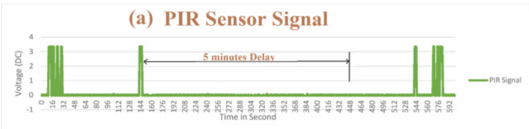

Fig. 8. (a) PIR Sensor Signal,

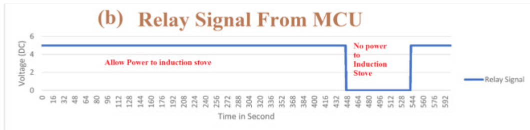

Fig. 8. (b) Relay Signal from MCU,

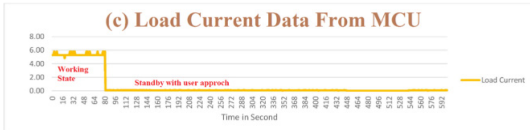

Fig. 8. (c) Load Current Data,

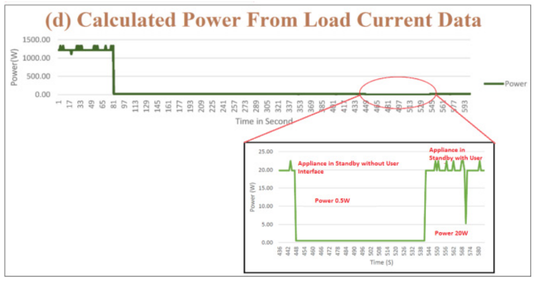

Fig. 8. (d) Power Consumption.

4. Conclusion

Even though standby power of electric home appliances is not more, it influence the electricity bill in the long run. In this paper we propose a design which reduces the standby power considerably. The MCU in the proposed Socket control the power supply by considering user approach and working status of appliance, which is new and more benefit than the products available in market. The proposed low standby power socket consumes only 0.5 W. Additionally, our design, which is equipped with ZigBee module for smart metering application. The proposed system is easy to set up. The demo experiment and the load current data received form MCU shows that the proposed system working correctly based on the logic used in this design.

References

1. "Power Manager, (2012). [Online]. Available:" [online] Available: http://www.powermanager.co.kr/
2. "Kill a Watt Edge, (2013). [Online]. Available:", [online] Available:http://www.p3international.com/brochures/p4490.pdf
3. HamedMorsali and Seyed Mohammad Shekarabi, "Smart Plug for Building Energy Management System,"SmartGrid(ICSG) 2ndiranianConference.Tehran, 2012, pp. 1-5.
4. Shajahan and Anand"Data acquisition and control using Arduino-Android platform: Smart plug," ICEETS international conference. Nagercoil, 2013, pp. 241-244.
5. Brenkus and juraj, "Power-efficient smart metering plug for intelligent households," RADIOELEKTRONIKA international conference. Pardubice, 2015, pp. 110-113.
6. Ju-Yong Kim, june-Whan Choi, and Kyoung Choi, "Design of Automatic Energy Saving-Monitor for reducing the waste of PC electricity," INC 7th international conference. Gyeongsanbuk-do, 2011, pp. 28-31.
7. Jinsoo Han, "More Efficient Home Energy Management System Based on ZigBee Communication and Infrared Remote Controls," ICCE international conference. Pardubice, 2011, pp. 631-632.
8. "HC-SR501 PIR MOTION DETECTOR, (2015).[Online]. Available:" [online] Availabble: http://www.mpja.com/download/31227sc.pdf
9. "Microchip PIC18F4520, (2015). [Online]. Available:", [online] Available: http://ww1.microchip.com/downloads/en/devicedoc/39631a.pdf
10. "Roger Meier's Freeware, (2015). [Online]. Available:", [online] Available: http://freeware.the-meiers.org/
11. " Xbee ZB RF Modules, , (2015). [Online]. Available:", [online] Available: http://www.adafruit.com/datasheets/XBee%20ZB%20User%20Manual.pdf
12. Gill, S.P.S, "Smart Power Monitoring System Using Wireless Sensor Networks," ICST 6th international conference. Kolkata, 2012, pp. 444-449.