Design and Implementation of a Socket with Zero Standby Power using a Photovoltaic Array

Cheng-Hung Tsai, Ying-Wen Bai, Chun-An Chu, Chih-Yu Chung and Ming-Bo Lin, Senior Member, IEEE

Abstract — This paper further enhances our previous research into reducing the standby power of electric home appliances. Turned-off electric home appliances generally still require standby power when they are plugged in. We present a way to reduce the standby power of a socket. Our socket supplies the appliances with power when the user turns them on. When the user turns them off, our socket shuts the electric power off and thus reduces the standby power. Our design, which uses an MCU, receives signals from a PIR sensor which detects the user approaching the socket. The MCU controls the SSR On/Off when used as an appliance switch for shutting off the standby power. A load current sensor circuit provides a signal to the MCU to keep the SSR on until the appliance has finished its work. The MCU monitoring program provides both automatic detection of the user by the PIR sensor and detection of the load current. The MCU with low-power technology has internal modules to simplify the hardware circuit design. The PV array is added in our design to reduce the consumption from the local electric power company. The standby power consumption of an appliance with our new design is 7 mW in a darkroom and less than 7 mW in a non-darkroom. When the illumination intensity suffices, the consumption is 0 W from the local electric power company.

Index Terms — Electric Home Appliances, Standby Power, PIR, SSR.

I. INTRODUCTION

A surprisingly large number of electric home appliances—from TVs to microwave ovens to air conditioners, cannot be switched off completely without being unplugged. These products draw power 24 hours a day. We call this power consumption “standby power” which appliances use in standby mode either while they are switched off or while they are not performing their primary function. The wasted standby power consumption of individual electric home appliances is typically small, but the standby power consumption sum of all such appliances within the household becomes significant [1]-[4]. Although the appliance in standby mode is not performing its main function, it is performing some secondary function, such as remote control, continuous display and internal timer that cannot be switched off unless the unit is unplugged. The secondary function not only needs low DC voltage to operate but also will draw power continuously. The power is supplied by an AC/DC converter which has no power-off switch. The AC/DC converter as a power supply in appliances converts AC 120 V into low voltage DC for the secondary function operation [5]. The AC/DC converter, which is very inefficient at low power, consumes between 1 and 4 W [6], which is many times more than the power actually used. In the long run electronic devices in standby state, therefore, consume much power, usually ten percent of the electricity used in a home [7] [8].

In 2000 the International Energy Agency (IEA) adopted a proposal to reduce the standby power of each electrical apparatus to less than 1 Watt within ten years [9]-[11]. A recently published survey shows that various attempts have been made to reduce such power leakage to make their adapters more efficient [12]-[15]. Another way to improve efficiency is accurate control of the apparatus by both software and microcontroller [16]-[18].

In this paper we present a new design to enhance our previous research by reducing the standby power consumption of electric home appliances. The standby power consumption of an appliance with our previous design is reduced to 0.2 W [19]-[20]. In this new design, the standby power is 7 mW and when the illumination intensity suffices, the standby power required from the local electric power company is 0 W. We call our design the “zero standby power socket”. The socket with its zero standby power can be used by existing appliances. In addition, this socket is easy to set up, inexpensive, and saves power more efficiently. Consequently it is suitable for use in most home appliances.

The organization of this paper is as follows. In Section II we present the circuit designs and a flowchart of the zero standby power socket. In Section III we present the measurement of the power consumption of our design to verify the total power saved. In Section IV we show the mathematical equation for interpreting the zero standby power socket. In Section V we draw the conclusions.

II. CIRCUIT DESIGNS OF THE ZERO STANDBY POWER SOCKET

The main consumption of appliance standby power is the power consumption of the AC/DC converter that supplies electricity to the secondary function of an appliance in
standby mode. The AC/DC converter power consumption is many times more in comparison with the power actually used by the secondary function. For the reduction of standby power, the AC/DC converter is cut off which is the main idea of our circuit design. Most electric home appliances such as television sets, washing machines and microwave ovens are operated manually. Most control panels on electric home appliances are easy to operate. But even when using a remote control, the user must still be near the appliance in question to turn it off again. If the user is not in the vicinity of the appliances, they are not being used and should always be in the turned-off state, so they won't use any unnecessary standby power. Therefore all power could be cut off completely by means of a solid state relay (SSR). To reduce the total amount of standby power used we present a simple design that detects any approaching user. The block diagram of the zero standby power socket is shown in Fig. 1. When the user is detected by the PIR module used in our design, the main power SSR for the electric home appliances stays turned on. Conversely, if the PIR module doesn’t detect the user, the main power SSR is turned off as if the appliances were unplugged. If the appliances are working but the user leaves, the main power SSR is turned on from the socket until the work is finished. Because of this requirement we have designed the load current sensor circuit to detect whether an appliance is working. If the work current is passing through the load current sensor, our sensor circuit converts the current into a proportional voltage signal. The MCU judges from the voltage signal whether the appliance is working or not. The Photovoltaic (PV) array converts solar energy into direct current electricity to increase the ultracapacitor energy. The operation voltage detector, the ultracapacitor, and the ultracapacitor charge SSR are designed to reduce the AC/DC converter’s power consumption.

The ultracapacitor charge SSR and the main power SSR which are normally open, are turned off initially. Thus at first, the zero standby power socket is plugged into AC power source. As there is no power in the ultracapacitor, the MCU can’t work, both SSRs are turned off and no electricity flows into the socket. As the socket can’t work, the appliance can’t work. To prevent such a situation, we place a start button in the circuit that parallels the ultracapacitor charge SSR load terminal. First, the user presses the start button in the circuit that parallels the ultracapacitor charge SSR load terminal. After the MCU begins its work, the ultracapacitor charge SSR is turned on to charge the ultracapacitor for 10 secs to provide the MCU start work power. The ultracapacitor charge SSR supplies power to the appliance. When the work current is passing through the load current sensor, our sensor circuit converts the current into a proportional voltage signal. The MCU judges from the voltage signal whether the appliance is working or not. If the MCU judges the voltage signal is lower than the predefined value, the ultracapacitor charge SSR is turned off and the ultracapacitor charge SSR load terminal is turned off. For the first time, after the user presses the start button for 10 secs, the socket is plugged into AC power source. After the user presses the start button, the socket will automatically work well.

The ultracapacitor thus functioning as a battery supports the whole circuit operation. If there is no appliance working and no user approaching, the MCU goes into the sleep state and the peripheral circuit is cut off to save power. When the user approaches or if the operation voltage is lower than the predefined value, the MCU will wake up from its sleep state and turn the SSR on. When the voltage is lower than the predefined value, the ultracapacitor charge SSR is turned on to charge the ultracapacitor until the operation voltage is raised to a normal level. If the user is approaching, the main power SSR supplies power to the appliance. When the appliance is working, the MCU controlling the main power SSR first judges a signal from the load current sensor circuit and then turns on. The SSR supplies the main power to the appliance until the work is finished.

Our design is made up of an MCU, a PIR circuit, a load current sensor circuit, operation voltage detector, a PV array, two SSRs and an AC/DC converter. The flowchart for our design is shown in Fig. 2.

### A. Operation voltage detector circuit

The power consumption from the AC/DC converter, which is more than the circuit actually needs, is largely wasted. To overcome this problem we have designed the operation voltage detector circuit shown in Fig. 3.
The ultracapacitor as a battery supports the zero standby power socket. The ultracapacitor voltage is the socket operation voltage (VCC). The AC/DC converter DC output is the power source that provides the ultracapacitor with a current of a sufficient charge when its voltage is lower than a predefined value. The ultracapacitor charger SSR is set on the primary side of the AC/DC converter as a switch controlled by the MCU. Both V+ and V- voltage are connected to the MCU comparator module. The MCU judges when to charge the ultracapacitor by means of the comparator module output. To save power, the MCU controls NMOS Q1 as a gate; when the voltage signals are needed by the comparator module, the Q1 is turned on; otherwise it is turned off. The MCU turns on the Q1, and the comparator module detects the operation voltage every 2.3 secs, which is enough time to get an accurate judgment while at the same time consuming less power. The resistor RC limits the charge current from the AC/DC converter to protect the circuit. The highest VCC for the whole circuit is 4.2 V and the lowest is 3.1 V. Between these voltages the circuit operates normally. We decrease the VCC from 4.2 V to 3.1 V and measure V+ and V-. The voltage relationship of the operation voltage detector circuit is shown in Fig. 4.

The voltage relationship in Fig. 4 can be written as:

\[
\begin{align*}
V+ < V- & \Rightarrow \text{Comparator output} = 0 \Rightarrow \text{Discharge} \\
V+ > V- & \Rightarrow \text{Comparator output} = 1 \Rightarrow \text{Charge} \\
\end{align*}
\]

At the start, the user presses the start button on the socket for 10 secs to charge the ultracapacitor and provide the necessary MCU start work power. After the MCU starts, the ultracapacitor charge SSR is turned on to charge the ultracapacitor to achieve a sufficient normal operation voltage value. The timing diagram of the socket’s first charge is shown in Fig. 5.

In our measurement the charge time for the ultracapacitor from 3.1 V to 4.2 V is 74 secs. After that the MCU uses the timer to count the charge time and turns off the SSR. Then the zero standby power socket consumes power from the ultracapacitor and the VCC voltage decreases. When the VCC has decreased to 3.1 V, the MCU not only detects this by means of the comparator module but also causes the SSR to turn on so that the AC/DC converter charges the ultracapacitors. And, therefore, as a result, the VCC rises. After the AC/DC converter has charged the ultracapacitors for 74 secs and the VCC has reached 4.2 V, the MCU causes the SSR to turn off, thus stopping the charge. Since the design keeps the MCU detecting the VCC’s rise to 4.2 V, we save both power consumption and cost. Fig. 6 shows both the VCC and the power consumption with respect to the charge and discharge times.
more power during the first charge. In our design, the operation voltage detector circuit is designed to reduce the power consumption of the AC/DC converter. The power consumption of the discharge time is 0 W. The charge and discharge of the ultracapacitor are a cycle whose time is

\[ T_{\text{cycle}} = T_{\text{charge}} + T_{\text{discharge}}. \]

We denote the average power consumption in \( T_{\text{cycle}} \) as

\[ P_{\text{ave}} = \frac{\sum P_{\text{charge}} + \sum P_{\text{discharge}}}{T_{\text{charge}} + T_{\text{discharge}}}. \]  

where \( \sum P_{\text{discharge}} = 0 \) W

thus \[ P_{\text{ave}} = \frac{\sum P_{\text{charge}}}{T_{\text{cycle}}} = 7 \text{ mW}. \]  

The AC/DC converter power consumption without any load is 0.521 W. The average power consumption of our socket has, therefore, been reduced to 7 mW, an improvement of 98.6%.

B. PIR module circuit

The PIR sensor is used as an electronic device to measure the infrared light radiating from human bodies nearby to detect whether the user is approaching or not, in order to decide whether the main power SSR should supply power to the appliance. The PIR sensor detects motion and generates a small voltage signal which is amplified by the PIR motion detector IC. The output signal is active high and is sent to the MCU external interrupt input pin (INT) to judge whether a user is approaching. The external interrupt on the INT pin wakes up the MCU from the sleep state. The PIR module output signal triggers the MCU external interrupt and the MCU turns on the main power SSR for 30 secs, which is convenient for the user.

C. Load current sensor circuit

For the electric home appliances to stay on after the user leaves, the function must continue with power coming from the socket until the work is finished. We have designed a load current sensor circuit for this requirement [9] [10]. Fig. 7 shows this circuit in which we use a toroidal coil inductor as a load current sensor that detects whether the appliance is working. When an AC current passes through an inductor, a small sinusoidal voltage \( v \) is induced.

\[ v = \frac{\partial}{\partial t}(\cos \theta) \]

where \( L \) is the inductance of the toroidal coil inductor.

The amplitude of the induced voltage is proportional to the amplitude of the used current. This small induced voltage is amplified and is then input to the MCU analog-to-digital converter (ADC) module input channel (AIN) to determine whether the appliance is in the work state or not. We have measured the load current by a current probe and the load current sensor circuit output voltage to the MCU with a DVD player and a microwave oven as AC load. The measurement result is shown in Fig. 8. The load current sensor circuit works well not only with both high and low-power home appliances but also with other appliances.

To save power, the NMOS Q2 drain is connected to the power pin of the amplifier and the gate is connected to the MCU I/O pin. The MCU, when it needs the load current detector output signal, sets the I/O pin high to enable the amplifier. The MCU, after it has obtained the load current output signal, then sets the I/O pin low to disable the NMOS device. Both the AC power frequency and the output voltage are 60 Hz, and the resulting amplitude depends on the AC current quantity. There are two classifications in the output signal of the load current detector circuit in both high and low operation voltage with different home appliances. If the appliance is working, a signal is generated; if it is not working, there is no signal. The MCU judges whether the appliance is working or not by means of these two classifications.

The load current detector circuit output signal is an analog and is converted to a digital signal by means of the MCU ADC module. The load current detector circuit output signal period is 16.67 msec. To obtain an accurate judgment the signal length should be longer than one period. Consequently, the signal is sampled at 8 sample points during one period. To curtail the operation, the ADC samples 21 sample points in the load current detector output signal. This load current signal digital number is stored in the general purpose registers (GPRs). The MCU processes the digital number to judge whether the appliance is working.
or not. The pseudo code of the procedure of the MCU used to judge whether the appliance is working is as follows.

Step 1: Start.
Step 2: Store the input signal digital number in GPRs as $x(n)$. $x(n) = \{ \text{The load current digital number}\},$ 0 $\leq n \leq N$. $N$ is the sum of the GPRs that store the load current digital number.
Step 3: Bitwise OR of $x(n)$ and $x(n+1)$.
\[
x(n+1) = x(n) \text{ OR } x(n+1)
\]
Step 4: Read $x(k)$, $k=N-1$.
if ($x(k)$=threshold value), appliance is working, else ($x(k)$=threshold value), appliance is not working.
Step 6: End.

The MCU detects the high level signal to judge whether an appliance is working or not. At step 3, the bitwise OR function maintains a high level signal in the GPRs during the signal sample interval. After step 3, if the value of $x(k)$ is large, we can confirm that the appliance is working. If the value of $x(k)$ is small, we know that the appliance is not working.

The DVD player is a low-power home appliance; the load current detector circuit output signal is small when the zero standby power socket operation voltage is 3.1 V. We represent the load current digital number procedure of the DVD player in Fig. 9 with a work voltage of 3.1 V. We show the $x(k)$ value after we have completed the necessary procedure to judge that the different appliances are working.

The current produced by the PV array circuit depends on the operation voltage and the illumination. Fig. 10 shows the current produced by the PV array circuit in respect to the VCC and the illumination at 25-30 °C. The area of the PV array is $15 \times 15$ cm$^2$, and the illumination comes from an artificial light source.

![Fig. 10. PV array circuit current with respect to the socket operation voltage and the illumination.](image)

The PV array circuit produces a current which both increases the ultracapacitor’s discharging time and reduces the socket’s average power consumption $P_{ave}$. We both increase the illumination intensity and measure the average power consumption with different PV array areas. The results are shown in Fig. 11 where the power produced by the PV array is equal to $P_{ave}$ when there is sufficient illumination. Thus the total power consumed by the socket is 0 W at zero standby state. In our measurement the illumination unit is lx and 1 lx=1.46 mW/m$^2$. In general, the indoor illumination is about 200 to 500 lx.

![Fig. 11. Socket power consumption in respect to the illumination with different PV array areas.](image)

The threshold value 7 is selected according Table I. The load current sensor circuit makes an accurate judgment as to whether a specific appliance is working or not.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Work power</th>
<th>Socket operation voltage</th>
<th>$x(k)$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVD player</td>
<td>5.5 W</td>
<td>3.1 V</td>
<td>15</td>
</tr>
<tr>
<td>Microwave oven</td>
<td>1.4 kW</td>
<td>3.1 V</td>
<td>106</td>
</tr>
<tr>
<td>LCD TV</td>
<td>212 W</td>
<td>3.1 V</td>
<td>106</td>
</tr>
<tr>
<td>PC</td>
<td>98 W</td>
<td>3.1 V</td>
<td>15</td>
</tr>
<tr>
<td>No work</td>
<td>0 W</td>
<td>3.1 V</td>
<td>2</td>
</tr>
</tbody>
</table>

![TABLE I](image)

### E. Implementation

Fig. 12 depicts our circuit design of the zero standby power socket. Fig. 13 shows the implementation of a zero standby power socket. The PV array area used is $15 \times 15$ cm$^2$. Our design requires the use of DC 3.1-4.2 V from the AC/DC converter as the socket operation voltage. For this prototype we have chosen an AC/DC converter with low power consumption.
III. MEASURING THE POWER CONSUMPTION OF THE ZERO STANDBY POWER SOCKET

When the illumination is 0 lx, the zero standby power socket as shown in Fig. 13 still requires electricity to work. Its average power consumption is 7 mW when no user approaches, the appliance is not working. This consumption is lower than the general standby power of home appliances. We measure the power consumption of the socket with a home appliance load in standby state when the illumination is 0 lx. Table II compares the standby power of appliances both with and without our design both when no user is approaching and when the appliance is not in use. When the illumination is 350 lx and the PV array area 15x15 cm², the power consumed is 0 W.

<table>
<thead>
<tr>
<th>Appliance type</th>
<th>Appliance only</th>
<th>With our design Illu.=0 lx</th>
<th>With our design Illu.&gt;=350 lx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microwave oven</td>
<td>2.8 W</td>
<td>7 mW</td>
<td>0 W</td>
</tr>
<tr>
<td>TV</td>
<td>1.2 W</td>
<td>7 mW</td>
<td>0 W</td>
</tr>
<tr>
<td>DVD player</td>
<td>1.5 W</td>
<td>7 mW</td>
<td>0 W</td>
</tr>
<tr>
<td>Washing machine</td>
<td>1.4 W</td>
<td>7 mW</td>
<td>0 W</td>
</tr>
</tbody>
</table>

IV. MATHEMATICAL VERIFICATION

Home appliances have two power states: standby state and work state. An appliance with a zero standby power socket has two additional power states which we call “ultra low standby state” and “zero standby state”. Fig. 14 shows the power state in the finite state machine and Fig. 15 shows the power consumption of state transition in a microwave oven with the zero standby power socket having a PV array area of 15x15 cm².
We now turn our discussion to the power consumption of an appliance with our design in ultra low standby state, standby state and work state when the illumination is 0 lx. The zero standby state power consumption is 7 mW from the socket. This amount is much less than the standby power of an appliance without our design. An appliance with the socket increases its power consumption when it is in either the standby state or the work state. This result is because if either the user approaches or the appliance is working, as the main power SSR then turns on, the socket will consume more power. According to our measurement, the average power consumption of the socket is 0.12 W in the standby state and work state. The power is added to the original power that an appliance consumes in the standby state and work state without utilizing our design. Thus the zero standby power socket saves power in both the ultra low standby state and the zero standby state but consumes more power in the standby state and work state. If an appliance in the zero standby state and ultra low state standby state is in daily use over a long period of time, the socket saves power; otherwise the socket consumes more power. Below we discuss the total power saving of our design with an appliance load.

First we define the probabilities of an appliance both in the standby state, work state, without the zero standby power socket.

\[ P_{\text{standby}} = \frac{T_{\text{standby}}}{T_{\text{work}} + T_{\text{standby}}}, \quad P_{\text{work}} = \frac{T_{\text{work}}}{T_{\text{work}} + T_{\text{standby}}} \]  
(5)

\[ P_{\text{standby}} + P_{\text{work}} = 1 \]

Then we define the probabilities of an appliance with a zero standby power socket both in the standby state, work state, and ultra low standby state when the illumination is 0 lx.

\[ P_{\text{socket standby}} = \frac{T_{\text{socket standby}}}{T_{\text{socket work}} + T_{\text{socket standby}} + T_{\text{socket ultra low standby}}} \]

\[ P_{\text{socket work}} = \frac{T_{\text{socket work}}}{T_{\text{socket work}} + T_{\text{socket standby}} + T_{\text{socket ultra low standby}}} \]

\[ P_{\text{socket ultra low standby}} = \frac{T_{\text{socket ultra low standby}}}{T_{\text{socket work}} + T_{\text{socket standby}} + T_{\text{socket ultra low standby}}} \]

\[ P_{\text{socket ultra low standby}} + P_{\text{socket standby}} + P_{\text{socket work}} = 1 \]

We denote the power consumption of each state as measured by a power meter as follows.

\[ P_{W_{\text{standby}}}, \quad P_{W_{\text{work}}}, \quad P_{W_{\text{socket standby}}}, \quad P_{W_{\text{socket work}}}, \quad \text{and} \quad P_{W_{\text{socket ultra low standby}}} \]

For an appliance with or without the zero standby power socket the work state time is the same.

\[ T_{\text{work}} = P_{\text{work}} \quad \text{and} \quad T_{\text{standby}} = P_{\text{standby}} + P_{\text{ultra low standby}} \]

Thus \[ P_{\text{work}} = P_{\text{socket work}} \quad \text{and} \quad P_{\text{standby}} = P_{\text{socket standby}} + P_{\text{ultra low standby}} \]

\[ P_{W_{\text{socket work}}} = P_{W_{\text{work}}} + 0.12 \text{ W} \]

\[ P_{W_{\text{standby}}} = P_{W_{\text{standby}}} + 0.12 \text{ W} \]

\[ P_{W_{\text{socket ultra low standby}}} = 7 \text{ mW} \]  
(7)

The power consumption of an appliance without the zero standby socket is greater than the one with the zero standby socket.

\[ P_{\text{work}} \times P_{\text{work}} + P_{\text{standby}} \times P_{\text{standby}} > P_{\text{socket work}} \times P_{\text{work}} + P_{\text{socket standby}} \times P_{\text{standby}} + P_{\text{ultra low standby}} \times P_{\text{ultra low standby}} \]

\[ P_{\text{standby}} \times P_{\text{standby}} > \]

\[ P_{\text{work}} \times 0.12 \text{ W} + P_{\text{socket standby}} \times (P_{\text{socket standby}} + 0.12 \text{ W}) + P_{\text{socket ultra low standby}} \times 7 \text{ mW} \]

\[ P_{\text{work}} \times 0.12 \text{ W} + P_{\text{socket work}} \times (P_{\text{work}} + 0.12 \text{ W}) + P_{\text{socket ultra low standby}} \times 7 \text{ mW} \]

\[ P_{\text{socket low standby}} \times P_{\text{work}} \text{ > } \]

\[ (P_{\text{work}} + P_{\text{socket low standby}} + P_{\text{socket ultra low standby}}) \times 0.12 \text{ W} - P_{\text{socket ultra low standby}} \times 0.113 \text{ W} \]

\[ P_{\text{socket ultra low standby}} \times (P_{\text{work}} + 0.113 \text{ W}) > 0.12 \text{ W} \]

\[ P_{\text{socket ultra low standby}} > \frac{0.12 \text{ W}}{P_{\text{work}} + 0.113 \text{ W}} \]

Equations (5) to (12) define the power saving of the zero standby power socket. (13) presents the power saving limit of the socket. \( P_{\text{socket ultra low standby}} \) represents the state probability of an appliance with our socket in the ultra low standby state. The value must be larger than \((0.12 / (P_{\text{work}} + 0.113))\) in order to save power. For example, the standby power of a microwave oven is 2.8 W. To save power, a microwave oven with a zero standby power socket must have a probability both of no user approaching and of the appliance not working which is more than 4.1% when the illumination is 0 lx. As most family members are occupied both with 8 hours at either work or school and with 8 hours of sleep, the probability of no user approaching is higher than 67%. Thus the zero standby power socket is useful in most situations. Table III shows a comparison between our design as shown in Fig. 13 and similar products.

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>COMPARISON OF OUR DESIGN AND OTHER PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product A</td>
<td>Recharger</td>
</tr>
<tr>
<td>Product B</td>
<td>PC peripherals</td>
</tr>
<tr>
<td>Product C</td>
<td>Electric home appliances with standby power</td>
</tr>
<tr>
<td>Our design</td>
<td>Electric home appliances with standby power</td>
</tr>
</tbody>
</table>

V. CONCLUSION

Although the standby power of electric home appliances is not great, it affects the user’s electricity bill in the long run. In this paper we propose a design which reduces the standby power substantially. In our design, the zero standby socket consumes...
less than 7 mW from the local electric power company when the illumination is 0 lx. When the illumination is 350 lx, the home power consumed is 0 W with a 15x15 cm$^2$ PV array. In the long run our design saves more power. Furthermore, our design, which is equipped not only with a load current sensor circuit and an MCU to control both an SSR and a PIR module, is easily modified by programming and can then be applied to a new generation of appliances to save even more power.

REFERENCES


BIOGRAPHIES

Cheng-Hung Tsai is currently working toward the Ph.D. degree in Electronic Engineering at National Taiwan University of Science and Technology, Taiwan. He received his M.S. degree in electronic engineering from Fu Jen Catholic University in 2006. His research interests include low power system design and embedded computer systems.

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