USING AN IR SENSOR MODULE TO REDUCE THE STANDBY POWER CONSUMPTION OF A PC MONITOR

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ABSTRACT

This paper presents a way to reduce the standby power consumption of a personal computer (PC) monitor in standby status. Although a PC monitor enters standby by means of the power management of the operating system (OS) after a preset idle time and awakens when the keyboard is hit or the mouse is moved, the monitor still consumes 0.3-1 W power in standby status. This design features a socket to plug-in the PC monitor, which consumes 0.01 W in standby status and is not only easy to set up but also inexpensive. This socket supplies the monitor with power when the user appears; when the user leaves it turns the monitor off, and the electric power is cut off to reduce the standby power. A micro control unit (MCU) receives signals from an infrared (IR) sensor module which detects the user approaching the monitor. The MCU controls the relay On/Off when used as a switch for cutting off the standby power.

Index Terms—IR sensor, standby power, relay, power consumption, PC monitor

1. INTRODUCTION

A typical office PC might consume 90 W when active, approximately 50 W for the base unit, 40 W for a typical liquid crystal display (LCD) monitor and 0.3 to 1 W when in standby status. The power management features are standard in common operating systems which are based upon an idle timer. If the PC is idle for longer than the preset timeout it may be configured to either standby or hibernate. The OS uses a combination of user activity and central processing unit (CPU) activity to determine when the PC is idle. The power management causes the monitor, the hard disk (HD) or the CPU to enter its low-power standby status individually after a preset idle time. By simply either hitting the keyboard or moving the mouse the computer or monitor awakens from its standby status in seconds. In standby status, these devices do not completely cut off; they continue to consume some power which is called standby power [1-2]. The HD and CPU need standby power to keep the necessary data needed for awakening. Based on the issues of cost and the complexity of engineering, it is hard to reduce the standby power of HD and CPU. The PC monitor not only temporarily stores display data, but also needs to get restarted quickly. Moreover, the monitor could be completely cut off while in standby status. Unfortunately for general PC monitors, the consumption of power is between 0.3 to 1 W when they are in standby status. The origin of the PC monitor standby power lies in an inside ac/dc converter which has no power-off switch [3-4]. This converter, which serves as a power supply for the monitor, converts ac voltage to dc voltage for the monitor display. The converter even still consumes power while in standby status [5], which the monitor does not display. However, this standby status power should be either reduced or eliminated. In this paper, a design called “ultra low standby power PC monitor socket” is proposed to reduce the standby power of the PC monitor, and which is plugged into the ac power. When the user appears the ac power is immediately supplied by the socket to the monitor, the monitor then shows a display, and when the user leaves, the ac power is cut off completely by the socket and the monitor becomes dark [6-9]. As the PC monitor standby power can be decreased to 10 mW with our socket of this design, the socket obviously will help save energy.

The organization of this paper is as follows. Section 2 presents the circuit designs of the socket. Section 3 presents the measurement of the power consumption of this design to verify the total power saved. Section 4 presents the implementation prototype of the socket. In Section 5 the conclusion is drawn.

2. CIRCUIT DESIGN OF THE ULTRA LOW STANDBY POWER PC MONITOR SOCKET

As described in the introduction, the PC monitor still consumes standby power in standby status. The standby power is consumed by the inside ac/dc converter which cannot be switched off. If the converter is switched off, the standby power is reduced to 0 W. However the ac source of
the converter can be switched off by means of the relay. Thus the main concept of this design is to cut off the ac source of the converter when there is no user, to reduce the standby power and to turn it on when the user appears [3]. Fig. 1 shows the state transition of the ultra-low standby power PC monitor socket.

![State transition of ultra-low standby power PC monitor socket](image)

Fig. 1. State transition of ultra-low standby power PC monitor socket.

The standby state in Fig. 1 means that if the user leaves, the PC monitor is not in use, the ac power source is completely cut off as if the unit had been unplugged to reduce the standby power consumption. The display state means that if the user is approaching, the PC monitor uses the ac power source provided by the socket as if the unit had been plugged into the ac socket. If the user stays in front of the monitor, the ac power source is provided by the socket continuously. Fig. 2 is the block diagram of this design.

![Block diagram of the ultra-low standby power PC monitor socket](image)

Fig. 2. Block diagram of the ultra-low standby power PC monitor socket.

The ultra low standby power PC monitor socket is composed of an MCU, an IR sensor module, a dc voltage module and a start button module. This design also includes an ac/dc converter to provide power for the socket operation. The converter still consumes power even without any load in the dc output. The dc voltage module is designed to reduce that power consumption. The start button module is designed to charge the dc voltage module at initialization. The IR sensor module is used to sense whether a user appears. When a user appears, the relay turns on the ac power to the monitor; when the user leaves, the ac power is cut off completely by the relay. The dc voltage module comprises an ultracapacitor voltage detector circuit, a boost circuit and a limiter circuit. The ultracapacitor (UC) is an energy storing element that stores the dc voltage energy provided by the converter. The \( V_{UC} \) detector circuit detects the UC voltage to determine when to charge or stop charging the UC. The operation voltage of the ac/dc converter is denoted as \( V_{dc} \), the UC voltage as \( V_{UC} \) and the output voltages of the boost circuit as \( V_{CC} \). The \( V_{dc} \) is the UC charge source, and the \( V_{UC} \) is both the UC voltage and the input of the boost circuit. The \( V_{CC} \) is the required operation voltage that supports the dc voltage module and the IR module operation voltage. The socket is installed on the monitor. The schematic installation is shown in Fig. 3.

![Schematic of the socket installation](image)

Fig. 3. Schematic of the socket installation.

### 2.1. IR sensor module

The IR sensor has an IR transmitter and an IR receiver pair. The basic concept is to transmit the IR signal in a specific direction, and it is then received at the IR receiver when the IR radiation bounces back from a surface of the object. The longer the distance from the object, the smaller the signal that is received. The MCU judges the received signal from the IR receiver to detect a user’s appearance and leaving, thus the IR sensor module is a proximity sensor to detect a user’s approach. The MCU causes the relay turned on whenever the IR sensor detects a user’s appearance, and turned off otherwise. When the relay is turned on it provides ac power to the monitor, if it is turned off, the ac power is cut off completely to reduce the standby power. For low power consumption the IR sensor is not always enabled to detect whether a potential user is approaching, because that user’s moves are not as fast as the electronic signal of this design. Hence the IR sensor is enabled for 100 ms every 1 sec by the MCU. During the 1 sec, the MCU is in sleep mode to save power. The circuit design of the IR sensor module is shown in Fig. 4. The MCU enables the IR sensor by turning on the \( Q_{IR} \), enables the IR transmitter and reads the IR receiver signal to detect whether a user is approaching. The maximum detection range is 60 cm. If a user approaches, the MCU causes the relay to be turned on. The signals of the IR sensor module are shown in Fig. 5. The power consumption in Fig. 5 is 1.32 \( \mu \)W when the IR sensor is disabled and the MCU is in sleep mode. When the
MCU wakes up from sleep mode to active mode in order to enable the IR sensor, the power consumption is 20.8 mW. If a user approaches, the MCU turns on the relay which has a power consumption of 155.1 mW. The power consumption is listed in Table I.

![Circuit design of IR sensor module.](image)

**Fig. 4. Circuit design of IR sensor module.**

**Table I**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Power consumption (V_{CC}=3.3 V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCU sleep mode</td>
<td>3.3 V×0.4 μA = 1.32 μW</td>
</tr>
<tr>
<td>IR sensor disabled</td>
<td>3.3 V×6.3 mA = 20.8 mW</td>
</tr>
<tr>
<td>MCU active mode</td>
<td>3.3 V×47 mA = 155.1 mW</td>
</tr>
</tbody>
</table>

2.2. dc voltage module

The dc voltage module supplies the V_{CC} to the socket design which consists of a boost circuit, a V_{UC} detector circuit, a limiter circuit and a UC. The MUC controls the V_{UC} detector circuit and the boost circuit to keep the V_{UC} and V_{CC} to the predefined voltage level. The UC thus functions as a battery supporting the boost circuit input. The

V_{UC} detector circuit supplies the normal V_{UC} to the boost circuit. The boost circuit outputs the regular voltage V_{CC} which supports the MCU and the operation of other modules. The limiter circuit limits the charge current to the UC.

2.2.1 Boost circuit

The boost circuit uses a dc-dc converter as the boost regulator. It provides an easy-to-use power supply solution for MCU applications powered by batteries. In this design the UC supports the boost regulator’s input voltage (V_{UC}) as a battery. Fig. 6 shows the boost circuit. The input voltage of a boost circuit is V_{UC} and the output voltage is V_{CC}. The input voltage V_{UC} must be kept to sufficient values between V_{UC\text{min}} and V_{UC\text{max}} that results in an output of V_{CC}=3.3 V. The values of V_{UC\text{min}} and V_{UC\text{max}} are determined by the method below. First the circuit is enabled, then the input voltage V_{UC} is increased from 0 V to 2.5 V, and then decreased from 2.5 V to 0 V by a programmable power supply.

Next we measure the output voltage V_{CC}. The result is shown in Fig. 7. The circuit operations of the MCU and the other modules require V_{CC}=3.3 V in the MCU active mode. Thus by means of the measurement curves the V_{UC\text{min}} is determined at 1.5 V. The V_{UC\text{max}} is determined at 2.4 V because the UC breakdown voltage is 2.7 V, and charging becomes inefficient when the V_{UC} is above 2.4 V. The boost regulator produces low voltage to support our design operation by a single UC. Without the boost circuit, previous designs needed two UCs to support operations, therefore by reducing the number of UCs needed in this design, the boost circuit reduces both manufacturing cost and volume size.

The MCU wakes up and enables the boost regulator for 100 msec, therefore enabling the boost every 1 sec to pump up the output voltage to V_{CC}=3.3 V to enable the IR transmitter to detect whether a user is approaching. In Fig. 7 (a) the V_{UC} is increased from 0 V to 2.4 V by the UC charged. The V_{UC} must be higher than 1.3 V to obtain V_{CC}=3.3 V. The MCU and other module circuit operations require V_{CC}=3.3 V in the MCU active mode. In Fig. 7 (b), the V_{UC} is decreased from 2.4 V to 0 V as the UC discharged. The V_{UC} is lower than 0.5 V the V_{CC} cannot stay at 3.3 V. For fixed operation voltage the V_{UC} must be kept to a sufficient value.
2.2.2 \( V_{UC} \) detector circuit and limiter circuit

As mentioned earlier, the ac/dc converter which is inefficient at low dc voltage still consumes power when the primary functions are provided by the power source without any load on the dc output. To overcome this problem this design includes the \( V_{UC} \) detector circuit and the limiter circuit which are shown in Fig. 8. The UC supports the \( V_{UC} \) as a battery for the boost circuit input voltage. The boost circuit’s output is the design’s dc operation voltage \( V_{CC} \). The ac/dc converter’s dc output \( V_{dc} \) is the power source that provides the UC with a current of a sufficient charge when its voltage \( V_{UC} \) is below a predefined value \( V_{UCmin} \) (1.5 V). The limiter circuit limits the charge current from the ac/dc converter to the UC to protect the circuit. The diode blocks the reverse current from the UC to the ac/dc converter. The latching relay is placed on the primary side of the ac/dc converter as a switch controlled by the MCU. The \( V_{UC} \) is connected to the ADC input channel 1 (AN1) of the MCU that digitizes the \( V_{UC} \) to an 8-bit binary representation. In this design the \( V_{UC} \) must be within a range of \( V_{UCmin} \) and \( V_{UCmax} \) sufficient for \( V_{CC}=3.3 \) V. The MCU detects the value representing the \( V_{UC} \) to judge when to charge and to stop charging the UC. When the \( V_{UC} \) has decreased to 1.2 V, the MCU causes the armature of the latching relay to move to the reset contact so that the ac/dc converter turns on to charge the UC, thus raising the \( V_{UC} \). After the converter has charged the \( V_{UC} \) to 2.4 V, the MCU causes the armature to move to the set contact that turns off the ac/dc converter, thus stopping the charge. The measurement results of the \( V_{UC} \) and the power consumption of the ac/dc converter with respect to charge and discharge times in standby state are shown in Fig. 10. The power consumption of the discharge time is 0 W and the discharge time is \( 9.55 \times 10^4 \) secs which is measured at the ac source. The converter is turned off most of the time and this design still works well. Only during the charge time does the converter consume power. In our measurement, the first discharge time is shorter than the discharge time, and after the first discharge the other discharge time is almost the same in standby state.

3. MEASURING THE POWER CONSUMPTION OF THIS DESIGN

The MCU controls the \( V_{UC} \) detector circuit and the boost circuit to keep the \( V_{UC} \) and the \( V_{CC} \) to the predefined voltage level. The UC thus functioning as a battery supports the boost circuit input. The \( V_{UC} \) detector circuit supplies the normal \( V_{UC} \) to the boost circuit. The boost circuit outputs the regular voltage \( V_{CC} \) which supports the MCU and other module operations. The latching relay is set on the primary side of the ac/dc converter as a switch controlled by the MCU. Fig. 10 shows the \( V_{UC} \) and the ac power consumption with respect to charge and discharge times.
3.1 **ac/dc converter standby power**

In this design the standby power of the ac/dc converter used in Fig. 2 is 1 W; the \( V_{UC} \) detector circuit is designed to reduce the power consumption of the converter. The power consumption of the discharge time is 0 W and that of the charge time is more than 8 W. The charge and discharge of the UC are a cycle whose time is

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

(1)

The average power is denoted in cycle \( T_{cycle} \) as

\[
P_{ave} = \frac{\sum P_{charge} + \sum P_{discharge}}{T_{charge} + T_{discharge}}, \quad \sum P_{discharge} = 0
\]

(2)

Thus

\[
P_{ave} = \frac{\sum P_{charge}}{T_{cycle}} = 0.01 \text{ W}
\]

(3)

The improvement is 99.99 %. The socket reduces the power consumption of the PC monitor in standby status. There are several monitors of different brands in an electric appliance store. Four typical products denoted as monitors A, B, C and D measure the power consumption with and without the socket in standby status. The power consumption is shown in Table II.

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Standby power without the socket</th>
<th>Standby power with the socket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor A</td>
<td>15&quot;</td>
<td>1 W</td>
<td>0.01 W</td>
</tr>
<tr>
<td>Monitor B</td>
<td>17&quot;</td>
<td>0.5 W</td>
<td>0.01 W</td>
</tr>
<tr>
<td>Monitor C</td>
<td>19&quot;</td>
<td>0.5 W</td>
<td>0.01 W</td>
</tr>
<tr>
<td>Monitor D</td>
<td>22&quot;</td>
<td>0.3 W</td>
<td>0.01 W</td>
</tr>
</tbody>
</table>

Table II: Comparison of standby power consumption of this design and other PC monitors.

Generally the ac/dc converter inside the monitor consumes power when it is in standby status. Although the ultra low standby power PC monitor socket still includes an ac/dc converter which is not in use during most of the time, the latching relay is used to cut off the power from the ac source to the converter and causes the standby power with the socket to be greatly reduced.

3.2 **Start button module**

A latching relay is factory-set to the reset state for shipment. Thus the \( V_{UC} \) detector circuit could auto-charge when the oven is first plugged into ac power. However, it may set again while being transported, due to vibration or shock. If it is first plugged into ac power, there is no electric power in the UC and the latching relay connects to the set contact. Therefore the UC cannot be charged, the MCU does not work, and the socket is always in the cut-off state. To prevent such a situation, a start button is placed in the circuit to make sure that the latching relay is reset when the socket is first plugged into ac power and there is no electric power in the UC at the beginning of the operation. The start button module circuit design is shown in Fig. 11.

![Fig. 11. Start button module design.](image)

The start button circuit includes five contacts: three normal open (NO) and two normal close (NC). If the
latching relay connects to the set contact and there is no electric power in the UC, the user just presses the start button. The line power is then connected to the converter by the NO1, the UC charge path is turned off by the NC2 since the \( V_{dc} \) rises to 3 V immediately, and the \( V_{dc} \) is connected to the reset coil of the relay by the NO2 at the same time. The reset coil is enabled and the relay is reset. After the button release, the circuit in Fig. 11 is the same as that in Fig. 8. The UC is being charged at the beginning of the operation. The switching time from pressing the button to the relay reset is less than 20 msecs, and the user just needs to touch the start button once at the beginning. The signals of the start button module at first charge when there is no electric power in the UC are shown in Fig. 12.

3.3 Implementation result

The MCU, the UC, the relay, the latching relay, the dc voltage module and the start button module are integrated in a main PCB. The IR sensor module, the ac/dc converter are in other, separate PCBs. These PCBs are shown in Fig. 13.

![Implementation PCBs of this design.](image1)

4. CONCLUSION

Although the standby power of a PC monitor is not great, it affects the electricity bill in the long run. In this paper a new circuit design is proposed which reduces the standby power substantially. Also, the power consumption is much less than that without the socket. The design, including the ultra low standby power PC monitor socket, consumes 10 mW. It is both easy to set up and inexpensive and in the long run saves more power. This design is suitable for any PC monitor with standby power.

5. REFERENCES


