

ZERO NO-LOAD POWER AC/DC ADAPTER FOR ELECTRONIC EQUIPMENT WITH EMBEDDED BATTERY

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ABSTRACT

A zero no-load power (ZNP) ac/dc adapter for electronic equipment with an embedded battery is proposed in this letter. The embedded battery is used as a signal source for the detection of load connection. Depending on the signal of load connection, an operation of the proposed ZNP ac/dc adapter is determined. When the proposed adapter is connected with a load system, the operation of the proposed adapter is the same as that of the conventional ac/dc adapter. While the proposed adapter is disconnected from the load system, the overall proposed adapter is totally turned off. Therefore, the proposed adapter can achieve ZNP consumption. To verify the validity of the proposed adapter, loss analysis and experimental results of 65 W are presented.

Index Terms: AC/DC Adapter, Burst-Mode Control, No-Load Power Consumption, Standby Power.

I INTRODUCTION

As the number of electronic device increases such as notebook computer, smart-phone, and smart-pad, demand for the ac/dc adapter is also consistently increasing [1]. The ac/dc adapter is the device that converts universal voltage ac power from wall outlets into a desired voltage dc power needed by various electronic devices. The ac/dc adapter is usually connected to the wall outlets with no regard for connection state of the load system. In other words, the ac/dc adapter is often operated without the attached load system. It is generally called the no-load condition. Therefore, under the no-load condition, the ac/dc adapter just wastes power without any power transfer to the load system. This power consumption is called no-load power or standby power [2]. Standby power has been considered as a waste of electric power and it is typically 5–10% of residential electricity use in most developed countries [3]. Moreover, according to growing concerns about environment and strengthening CO₂ regulation, to reduce standby power consumption, all countries of the world impose legal restrictions on standby power consumption such as Energy Star Program [4] and 1 Watt Plan [5]. Among these, the Energy Star Program requires that the no-load power consumption should be less than or equal to 0.3 W at 0–50 W nameplate output power and less than or equal to 0.5 W at 50–250 W nameplate output power [4].

In this letter, to meet this requirement and further reduce the power loss under the no-load condition, a zero no-load power (ZNP) ac/dc adapter for electronic equipment with embedded battery is proposed. The proposed method requires an embedded battery in the load (electronic equipment) and an additional wire between the adapter and the load. The embedded battery is used as an independent signal source for the detection of load connection, which is transferred to the primary side to enable the control circuit. By utilizing the load-connection signal, an operation of the proposed adapter is the same as that of the conventional ac/dc adapter during load connection. While the adapter is disconnected from the load system, there is no enable signal for the primary control circuit. Therefore, the overall proposed adapter is completely turned off. As a result, the proposed adapter can reduce the no-load power consumption less than 1mW. Experimental results of 65 W ac/dc adapter are presented to verify the effectiveness of the proposed adapter.

II ZNP AC/DC ADAPTER

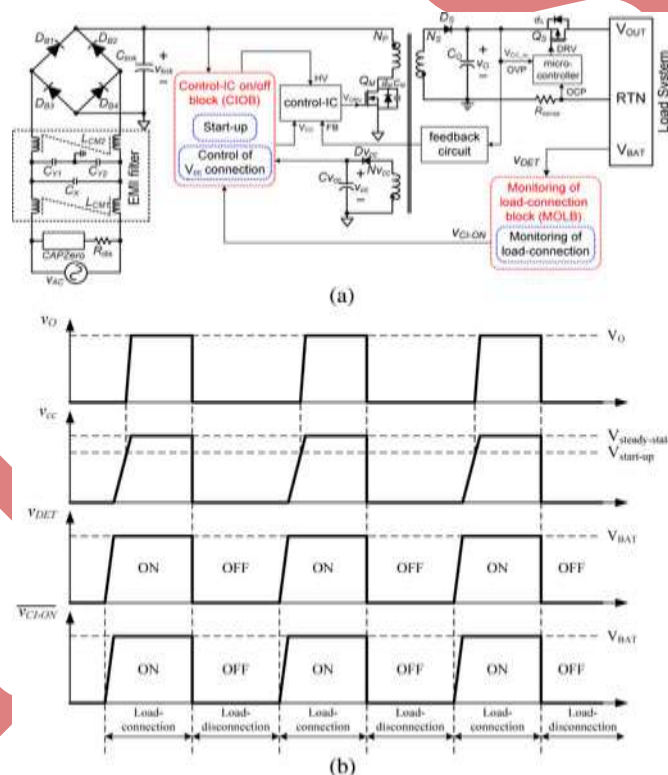


Fig. 1. (a) Structure of the proposed ZNP ac/dc adapter. (b) Operational waveforms of the proposed ZNP ac/dc adapter.

The structure and the operational waveforms of the proposed adapter are shown in Fig. 1(a) and (b), respectively. To realize the proposed adapter, a control-IC ON/OFF block (CIOB) and a monitoring of load-connection block (MOLB) are added to the conventional ac/dc adapter. The operation of the proposed adapter is described as follows.

Turning-off the adapter under the no-load condition is the simple method to reduce the no-load power consumption. However, since the conventional adapter may not recognize the connection of the load system, the conventional adapter regulates output voltage even under the no-load condition. Thus, no-load power consumption of the conventional adapter is over several hundred milli watts. In the proposed adapter, an embedded battery of the load system V_{BAT} is used as a signal source for load-connection signal v to monitor the connection of the load system.

Implementation example of the proposed ZNP ac/dc adapter is shown Fig. 2. The components list of additional parts, the CIOB and the MOLB, is described in Table I. Details about the functions of the additional parts are described in the following sections.

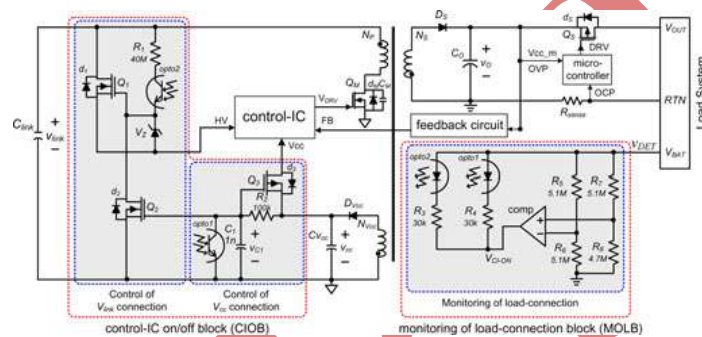


Fig. 2. Implementation Example of the Proposed Adapter

Part	Value
Comparator Comp	TLV3401
Optocoupler opto1	H11AV1M
Optocoupler opto2	AQV216
NMOS Switch Q_1 and Q_2	STN1HINK60 ($R_{DS(on)} = 8 \Omega$, $C_{OSS} = 23.5 \text{ pF}$, $V_{(BR)DSS} = 600 \text{ V}$)
PMOS switch Q_3	TP0202K ($R_{DS(on)} = 2.1 \Omega$, $C_{OSS} = 11 \text{ pF}$, $V_{(BR)DSS} = -30 \text{ V}$)
Zener diode V_Z	BZX84C15 ($V_Z = 15 \text{ V}$)

- **Monitoring of Load-Connection Block:** The MOLB monitors whether the load system is connected or not. The MOLB can be realized by using only one comparator and several resistors as shown in Fig. 2.
- **Control-IC ON/OFF Block:** The CIOB functions to control the connection of v and v link in accordance with v which comes from the MOLB. Implementation example of the CIOB is also shown in Fig. 2.

III MATLAB DIAGRAM AND RESULTS

To verify the validity of the proposed ZNP ac/dc adapter, experimental prototype of the proposed adapter and that of the conventional adapter with the burst-mode control are implemented. Referred to the design solution in [16], the flyback converter and the feedback circuit are designed.

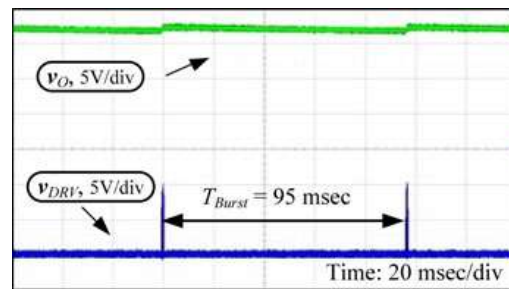


Fig. 4. Experimental waveforms of the conventional adapter with the burst mode control

Fig. 4 shows the experimental waveforms of the conventional adapter with the burst-mode control under the no-load condition. With the burst-mode control, V_O is regulated within 1V even during the no-load condition, because the conventional adapter cannot recognize whether the load system is connected or not.

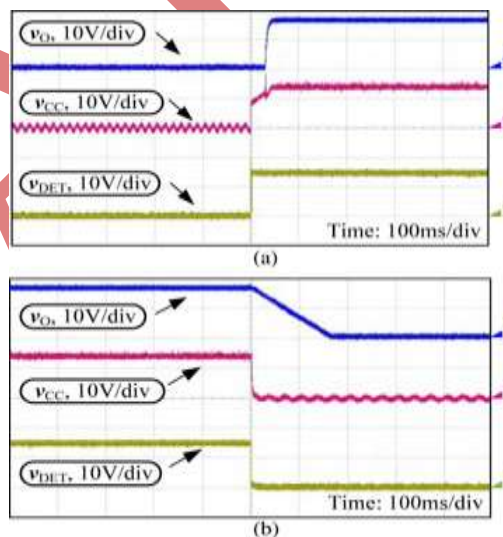


Fig. 5. Experimental waveforms of the proposed adapter (a) from load disconnection to load connection and (b) from load connection to load disconnection

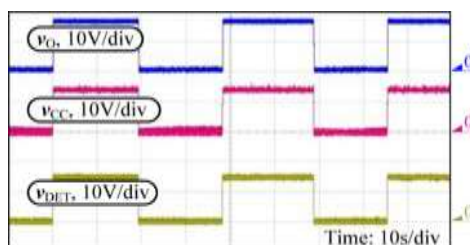


Fig. 6. Experimental waveforms with the repetition of load connection and load disconnection.

Fig. 5(a) and (b) shows the experimental waveforms of the proposed adapter, when the load system is connected with the full-load condition and when the load system is disconnected, respectively. Fig. 6 shows experimental waveforms with the repetition of load connection and load disconnection. As shown in those figures, the proposed adapter is totally turned on and turned off whenever the load system is connected and disconnected.

IV CONCLUSION

The ZNP ac/dc adapter for electronic equipment with embedded battery has been proposed in this letter. The embedded battery is used as the signal source for the detection of load connection. By using the load-connection signal, since the proposed adapter is totally turned off while the proposed adapter is disconnected from the load system, the proposed adapter can achieve zero no-load power. Experimental results of prototype show that the proposed adapter consumes less than 1 mW during the no-load condition. Moreover, the proposed adapter can be implemented with any general commercial control IC with the simple auxiliary circuits, the CIOB, and the MOLB. Therefore, the proposed ZNP ac/dc adapter is expected to be widely used for reducing the no-load power consumption of the ac/dc adapter.

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