Simulation Analysis of Ac/Dc Adapter Under Zero No-Load Power Consumption using Simulink Process

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ABSTRACT

The burst-mode control is generally used to regulate the output voltage of the ac/dc adapter under light or no-load condition. Although the burst-mode control reduces the switching loss, the control-IC and the feedback circuit at the output side still consume a large amount of power. In order to further reduce the power consumption at no-load condition, a zero no-load power (ZNP) ac/dc adapter for electronic equipment with an embedded battery is proposed in this paper. When the proposed adapter is load connected, the operation is same as that of the conventional adapter. At no-load condition, the adapter is totally turned off. As a result the adapter can reduce the no-load power consumption to less than 1mW. Simulation of a 65 W adapter is presented in order to verify its validity

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1. 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 adapter is a 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 often operated without the attached load system. It is generally called as no-load condition. The power consumption during the no-load condition is called as no-load power or standby power [2]. The 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].To meet standby power regulation, many standby techniques have been proposed. Among several techniques burst mode control is commonly used [6]-[15]. Moreover, the CAP Zero is adopted to reduce the power consumption at discharging resistor for electromagnetic interference (EMI) filter [9]. A no-load power consumption of the conventional ac/dc adapter with these techniques is over several hundred milliwatts [10]-[15]. Although the conventional ac/dc adapter with these techniques meets the no-load requirement [4], [5] with margin, some countries are gradually tightening no-load requirement and some computer manufactures are asking for more stringent no-load requirement, even as low as 30 mW.

In this paper, to meet the no-load power requirement, a zero no-load (ZNP) ac/dc adapter with embedded battery is proposed. It requires an embedded battery for the detection of load and additional wire between adapter and battery. During load condition, by using the signal the operation is same as that of conventional adapter. When load is disconnected, there is no signal for the primary control circuit. Therefore, overall adapter will be turned off. As a result, the adapter can reduce no load power consumption less than 1mW. The block diagram of new adapter is shown below Figure 1.

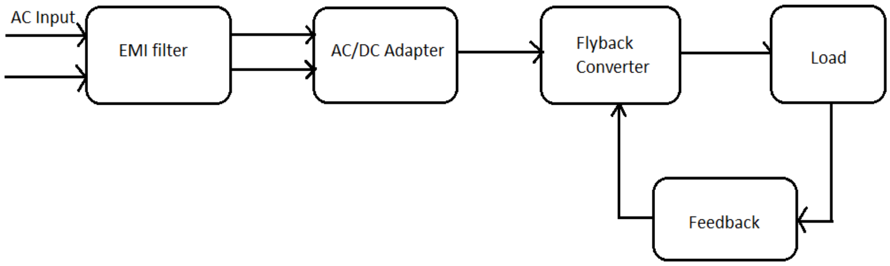


Figure 1. Block diagram of proposed adapter

2. CONVENTIONAL AC/DC ADAPTER

Figure 2 shows the conventional ac/dc adapter under 65W and the ac/dc adapter is composed with the following parts: electromagnetic interference (EMI) filter is equipped to meet the EMI requirements.EMI is disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. These effects can range from a simple degradation of data to a total loss of data. For the safety reason, the discharging resistor R_{dis} for the X-capacitor C_X in EMI filter has to be obtained. Since there is no power-factor requirement for nonlighting equipment with input power 75W or less, diode bridge and link capacitor rectifies ac input source to dc. Flyback converter is employed because of simple structure and low cost.

Control-IC regulates V_0 in accordance with the feedback signal from the feedback circuit. Control-IC adopts high-voltage start-up circuit to reduce the power consumption of conventional startup circuit. Secondary switch, microcontroller and sensing resistor are used for the protection purposes.

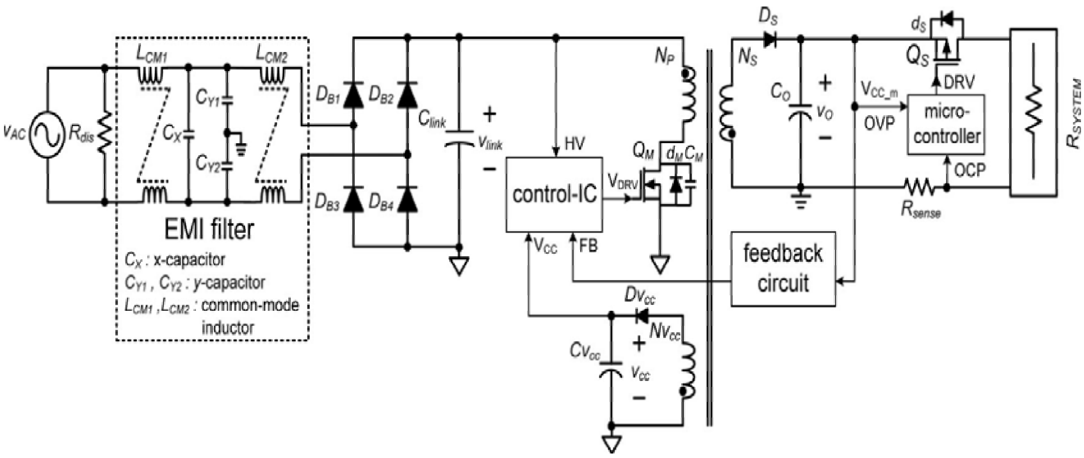


Figure 2. Structure of conventional adapter

Under no-load condition turning-off the ac/dc adapter is the simplest method for reducing the no-load power consumption. No-load power of the common adapter is several hundred mill watts. Since the burst mode control reduces the switching loss, it only captures 5.8% of the measured total input power $P_{Measured}$. On the other hand, the control-IC loss and the feedback circuit loss now account for 85% of $P_{Measured}$.

Therefore, the no-load power consumption can be reduced by decreasing the control-IC loss and the loss of feedback circuit. Normal waveform of conventional adapter is showing below in Figure 3.

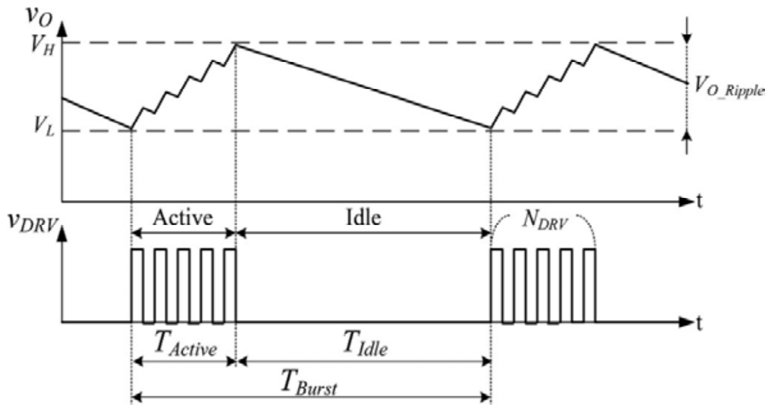


Figure 3. Normal waveform of conventional adapter

3. PROPOSED ZNP AC/DC ADAPTER

The structure of the ac/dc adapter is shown in Figure 3. To realize the 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 ac/dc 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 V_0 even under the no-load condition. Thus, no-load power consumption of the conventional adapter is over several hundred milli watts. In the ZNP adapter, an embedded battery of the load system V_{BAT} is used as a signal source for load-connection signal V_{DET} to monitor the connection of the load system. The operation of the adapter depends on V_{DET}. The adapter is composed with following parts: a rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Rectifiers have many uses, but are often found serving as components of DC power supplies and high-voltage direct current power transmission systems. The flyback is used in both AC/DC and DC/DC conversion with galvanic isolation between the input and any outputs. More precisely, the flyback converter is a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation. When driving for example a plasma lamp or a voltage multiplier the rectifying diode of the buck-boost converter is left out and the device is called a flyback transformer.
Details about the additional parts are described below:

3.1. Monitoring of Load–Connection Block

The MOLB is used to monitor whether the load system is connected or disconnected. The MOLB can be realized by using comparator and several resistors. When load is connected, MOLB generates v_{C1-ON} and it sends to the CIOB. The structure of proposed adapter is shown in Fig.4. When load is connected, v_{DET} and v_{C1-ON} are "ON". And also optocoupler1 and optocoupler2 are turned ON. When HV pin and V_{CC} pin are connected, then control-IC starts its function.

3.2. Control-IC ON/OFF Block

Under no-load condition, the CIOB adjusts the connection of supply voltage v_{cc} and V_{CC} pin of the control-IC for managing the control-IC ON/OFF operation. When the $v_{control-ICON}$ is "OFF", the CIOB cuts v_{cc} from V_{CC} pin of the control-IC. Then opto1 and opto2 are turned off.Q1 and Q3 are turned off. Q2 turned on when voltage of v_{c1} reaches threshold voltage of Q2. Then the entire control-IC is turned OFF. There by eliminating the power consumption of the control-IC. When $v_{control-ICON}$ is “ON” CIOB reconnects v_{cc} to V_{CC} pin of the control-IC, control-IC starts its operation again. Opto1 and opto2 are turned on. Q1 is turned ON by R_1 and V_z . Based on the approximated circuit as shown in Figure 4 and components list in Table I and Table 2.

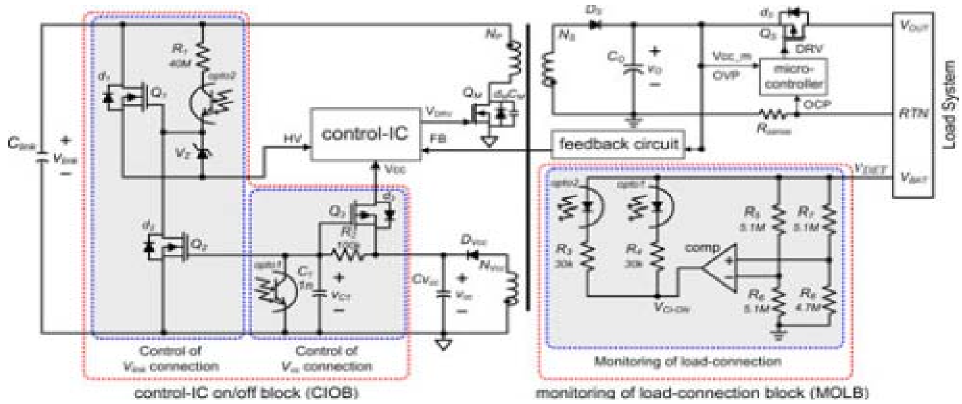


Figure 4. Zero No Load power adapter

Table 1. Specification of the adapter

Specifications	**Value**
Input voltage	90V~264V
Output power(Po)	62.5W(Vo=12.5V,Io=5A)
Resistance, R_1	1Ω
Resistance, R_2	1Ω
Capacitance, C_1	1μF
Capacitance, C_2	1μF
Output capacitor ,Co	1mF
Battery	Lithium-Ion
R_{SENSE}	0.1Ω

Table 2. Specification of EMI filter and rectifier

Specifications	**Value**
Discharging resistor (R_{dis})	0.001Ω
Link capacitor(C_{link})	1mF
X-Capacitor(C_X)	C_X =2.2mF $C_{Y1} = C_{Y2}$ =1μF
Inductor	L1=L2=2μH L3=L4=36μH
Switching Frequency	65kHz
Control-IC	NCP1237
Transformer turns ratio	48:8:7(core=RM10)

3.3. Power consumption of the CIOB and MOLB

These are the additional parts of new adapter. So power consumption of these additional parts can reduce the efficiency of the proposed adapter. The power consumption of CIOB block is about 2.25mW that can be expressed as:

$$P_{CIOB} = V_{CC}^{2} / R_{2} \tag{1}$$

Then the power consumption of the MOLB block is 14.1mW.It can be expressed as:

$$P_{MOLB} = \frac{V_{DET}^{2}}{(R_5 + R_6)} + \frac{V_{DET}^{2}}{(R_7 + R_8)} + \frac{V_{DET}(V_{DET} - V_{F2})}{R_3} + \frac{V_{DET}(V_{DET} - V_{F1})}{R_4} \tag{2}$$

Where V_{F1} and V_{F2} are the forward voltage drop of opto1 and opto2.When load is not connected, the CIOB and MOLB completely turned off. Thus the power consumption of additional blocks is ideally zero.

4. SIMULATION AND EXPERIMENTAL RESULTS

To verify the validity of the proposed ZNP ac/dc adapter, the simulation circuit is implemented. The MOCB monitors whether the load system is connected or not and manages the output voltage under no-load condition. For these functions, the MOCB generates the signal that Vcontrol-IC ON is "ON" and sends it over to the CIOB when either the load system is connected or V_0 reaches $V_{LNO-LOAD}$.The overall circuit diagram of ac/dc adapter is shown in Figure 5.

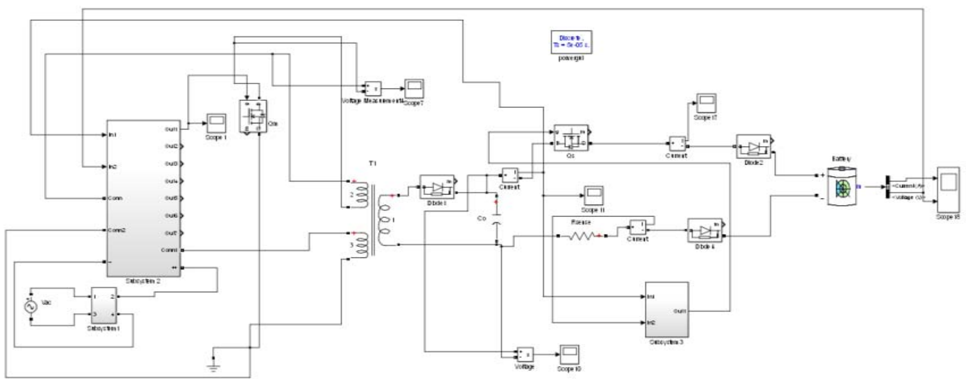


Figure 5. Simulation diagram of ZNP adapter

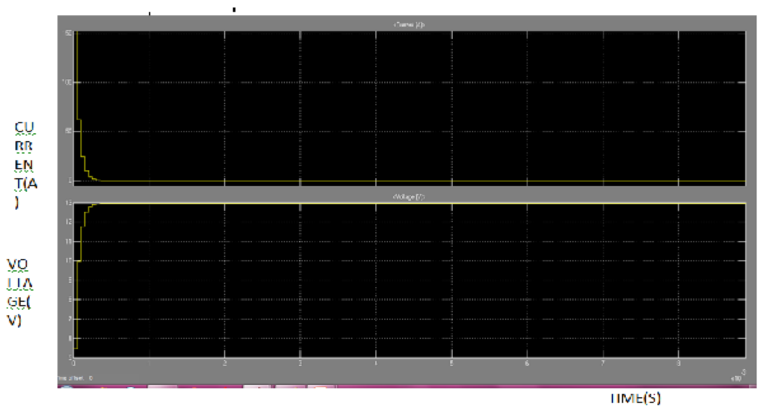


Figure 6. Current and voltage of a battery

The output current and voltage are shown in Figure 6. It considers the changes in load condition (i.e.) full load to no load condition. The rapid changes in the current and voltage values are plotted here. To realize the ZNP adapter we can simulate the circuit by using logical operators. The simulation diagram and corresponding waveforms are given below in Figure 7.

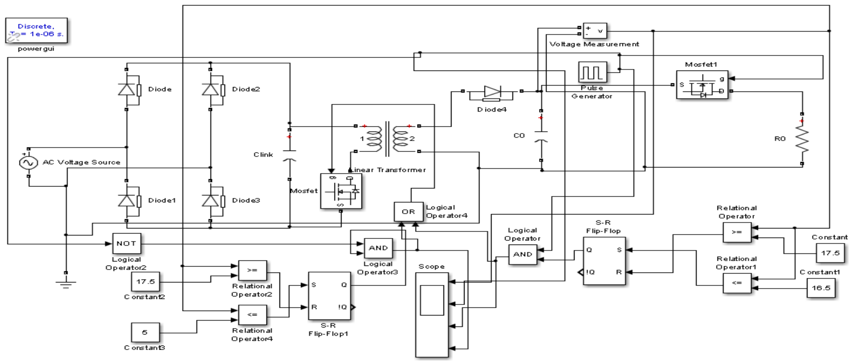


Figure 7. ZNP adapter using logic operators

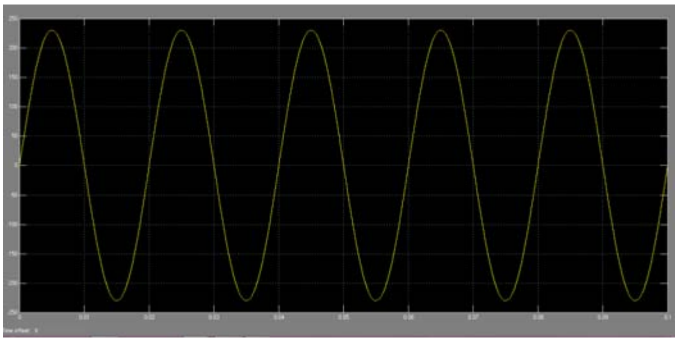
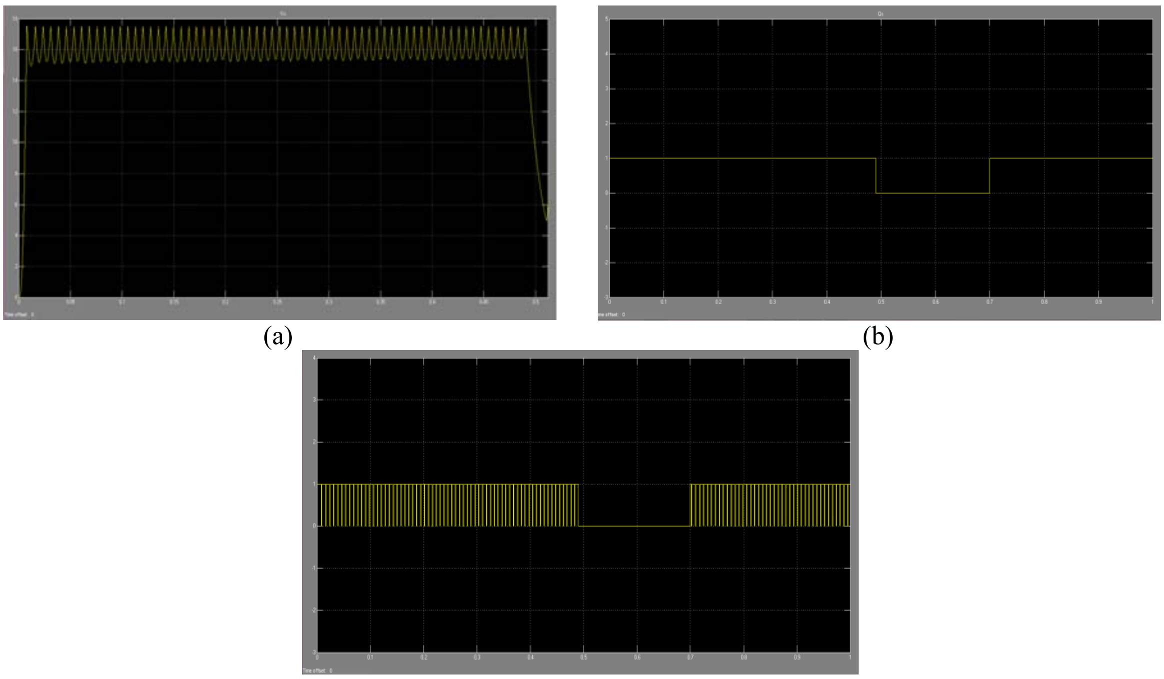


Figure 8. Input voltage of ZNP adapter



(a) (b)

(c)

Figure 9. (a) Voltage across the capacitor (b) Gate pulse of Qs (c) Gate pulse of Qm

5. CONCLUSION

A Zero No-Load power consumption technique for ac/dc adapter was presented in this paper. Here, the detection of the load connection was carried out using an embedded battery, which acts as a signal source. From the simulation results, it is clear that this technique can easily be applied to any commercial control-IC using simple auxiliary circuits such as CIOB and MOCB. Therefore, the reduction of No-Load power consumption can be achieved widely.

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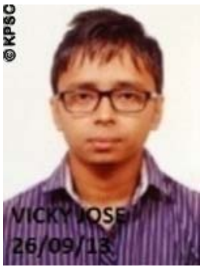

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