High Efficiency AC Power Control Circuit using a Soft-switching Technique

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Abstract. This paper proposes the high efficiency AC power control circuit using a soft-switching technique. The proposed control circuit uses a classic switching power amplifier circuit that consists of one switch and achieves high efficiency using the soft-switching technique. The proposed control circuit can control the AC power of nonlinear load such as the cold-cathode fluorescent lamp. The driver circuit of the proposed control circuit is very simple. In this paper, the proposed control circuit is introduced, briefly, and experimental results of the prototype circuit shows good performance for the AC power controller.

Keywords: AC power, control circuit, switching power amplifier, soft-switching.

1 Introduction

The cold-cathode fluorescent lamp (CCFL) has nonlinear load characteristics. However the nonlinear load such as the CCFL needs an AC power being able to drive itself. The best method of controlling AC power for the CCFL is to use a power source of the current source type [1]-[3]. The AC power control circuit controlling a nonlinear load such as the CCFL is powered by a DC battery or an AC-DC adaptor. The controller converts input DC power to AC power. The CCFL needs high voltage to be fired, and its system efficiency and size are important. The lamp typically is operated by AC sinusoidal voltage of 700-800 V and a current of 7-10 mA rms. The operation frequency is normally recommended between 25-85 kHz, and a sinusoidal voltage waveform is preferable. Additionally, the dimming control function is another desirable feature for such applications. These formidable requirements demand a highly efficient conversion circuit [4]-[7]. Therefore, to satisfy the above various requirements, this paper presents the high efficiency AC power control using a soft-switching technique.

2 Operational principles

The resonant inductor in the conventional switching power amplifier is in series
with the primary winding of the transformer. This allows the absorption of the leakage inductance of the transformer in the resonant network, which leads to a reduction in overall cost. The analytic model of the proposed AC power control circuit is shown in Fig. 1.

![Fig. 1. Analytic model of the proposed control circuit with integrated magnetic structure](image1)

![Fig. 2. Simplified model of the proposed control circuit for analysis](image2)

![Fig. 3. Theoretical operational waveform of the proposed AC power controller](image3)

![Fig. 4. Operational modes of the inverter](image4)

The basic operation of the proposed control circuit is analyzed by considering the simplified equivalent model of Fig. 2. Fig. 3 shows its theoretical operational.
waveform. As shown in Fig. 4, the AC power controller has two operational modes: the boost mode and the resonance mode. During the boost mode in Fig. 4(a), either the switch or the diode is conducting. In this time interval, the capacitor is shorted to ground and the reflected load current $n_{\text{load}}$ at the reflected branch increases exponentially. During the resonance mode in Fig. 4(b), the switch is turned off, and the inductive branch and the capacitor form a resonant network, which forces the voltage $v_r$ across the switch to follow a sinusoidal waveform. In a properly designed AC power controller, the sinusoidal waveform eventually returns to the zero level after the anti-parallel diode catches. The gate-source voltage $v_{gs}$ can then be applied to turn on the switch under the ZVS condition. The resonant capacitor $C_r$ reduces the $dv/dt$ across the switch at turn-off, which reduces switching losses and allows high frequency operation.

3 Prototype implementation

![Control Block Diagram](image)

**Fig. 5.** Total control block diagram of the proposed control circuit

In order to show that the proposed control circuit operates effectively driving the CCFL, a prototype control circuit is implemented as shown in the control block diagram in Fig. 5. The proposed control circuit is very simple.

4 Experimental results

![Lamp Current Waveforms](image)

(a) 25-% dimming  (b) 80-% dimming

**Fig. 6.** Lamp current waveforms at each dimming state
Figs. 6 and 7 exhibit that the proposed control circuit has good performance as an AC power controller.

Fig. 7. Experimental waveforms of the lamp voltage $v_{\text{lamp}}$ and the lamp current $i_{\text{load}}$

5 Concluding remarks

In this paper, the high efficiency AC power control circuit using a soft-switching technique has been proposed, and the operational principle and the experimental result have been described, briefly. It is shown through experimental results that the proposed circuit has good performance as an AC power control circuit for driving the CCFL.

References