in proportion to the average load current. The phase plane relating i_s to v_c is shown in Fig. 4, for a general case in which $V_p > 0$, which commonly occurs in the operation of Fig. 1. Numbers in the phase plane indicate the correspondence between the trajectories and the intervals of waveforms in Fig. 3. Point 4 (as well as C) indicates the dead time, or PWM width, in circuit operation. For a three phase load the pulses are distributed in the three output capacitors.

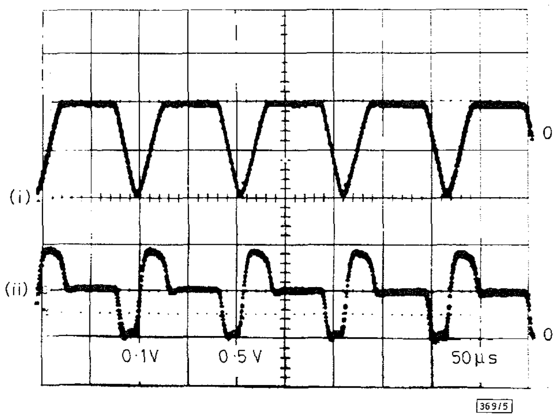

Fig. 5 *Experimental results for operation at 10kHz*

(i) capacitor voltage v_c, 100V/div
(ii) link current i_s, 5A/div

Experimental results: For verification of the operational principles, a prototype of the simplified version of the PWM-SRDCLC with a saturable reactor clamping circuit was designed and built. The prototype operated around 10kHz with an SCR having a turn off time of t_q = 15µs and a diode with a recovery time t_{rr} = 0.5µs. The other components used were C_0 = 0.2µF, L_d = 14mH and C_L = 25µF. Typical measured waveforms, with a winding factor k = 2, are shown in Fig. 4*a* and *b*, where the bias current is I_d = 5A.

Conclusions: This Letter presents a new series resonant DC link converter with PWM capability and current peak limiting function. Experimental results agree with the theoretical prediction and the circuit performance is satisfactory. The current limiting circuit is very simple and the clamping level is automatically adjusted by the load current. The circuit seems to be a good candidate for future industrial use.

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Single switch unity-power-factor dimmable fluorescent lamp ballast circuit

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Indexing terms: Fluorescent lamps, Lamps

The authors propose an electronic ballast circuit which is capable of achieving high power factor, high efficiency, dimming control, and freedom from lamp flickering. All these features are accomplished with a single-switch power circuit, and a low-cost control circuit. Experimental results are given.

Introduction: Single-switch ballasts are smaller in size and lower in cost than those of traditional two-stage ballasts [1]. However, most of the methods reported for single-switch ballasts [2 – 4] are subject to a 120Hz flicker on lamps, a high peak voltage across switching devices, and a high resonant circulating current in components. The lamp flicker is not only annoying but also shortens lamp lifetime and decreases lamp luminous efficacy. The need to use high voltage devices in these circuits increases device conduction losses and the device cost, and high resonant circulating current leads to low efficiency. Moreover, most of the circuits are unsuitable for light-dimming operation. In this Letter, a new single-switch high power factor electronic ballast is proposed in which these weakness of single-switch ballasts are eliminated. A low-cost constant frequency PWM control scheme is used to provide a simple but effective way of regulating lamp current for light dimming.

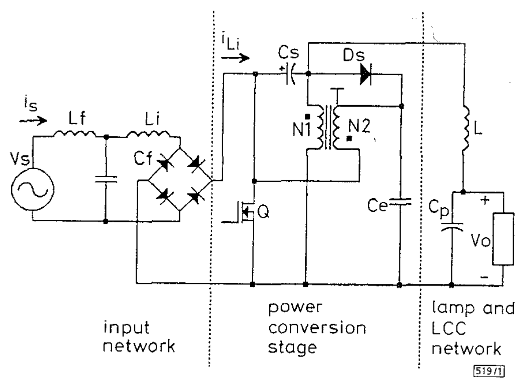

Fig. 1 *Circuit diagram of proposed ballast*

Ballast description: The proposed ballast topology, shown in Fig. 1, consists of input network, power conversion stage, lamp and LCC network. The clamp transformer T provides energy storage when Q is on, as well as a voltage clamp when Q is off. When switch Q is on, energy is stored in inductor Li and the transformer magnetising inductor. When Q is off, this inductive energy is transfered to the LCC network and capacitor Ce. As the line voltage *Vs* passes through zero, the input power also passes through zero, and the power conversion stage converts the energy stored in capacitor Ce to the LCC network, thus preventing the lamp from being turned off in each 120 Hz cycle and the lamp flicker is eliminated. During the off interval, the blocking voltage across Q is represented by V_{bk},

$$V_{bk} = V_{Ce} * \left(\frac{N1+N2}{N1}\right) \quad (1)$$

where V_{Ce} is the voltage on energy storage capacitor Ce, and *N*1 and *N*2 are the winding turns of transformer T. Note that the two windings have the same number of turns and that this limits the maximum duty factor of the switch Q to 50%. (The capacitor Cs and diode Ds are designed to absorb the device voltage spike caused by the transformer leakage inductance.) Assuming the voltage on capacitor Ce is as high as line voltage peak *Vm*, then the voltage stress on power devices is $2Vm$, from eqn. 1. Note that the required voltage rating of the power devices in the previous ballasts [2 – 4] is 4 times *Vm* or higher (see Table 1). High power factor is achieved because of constant duty-cycle discontinuous mode of operation [5]. Near unity power factor can be achieved. The control circuit is therefore very simple.

Table 1: Comparison between proposed ballast and previous works

Authors	Voltage rating on devices	Elimination of flickering	Dimming control operation	Unity-input-power factor
C. Licitra [2]	800V	no	yes	yes
H. Matsuo [3]	1kV	yes	no	yes
E. Deng [4]	800V	yes	no	yes
Proposed ballast	400V	yes	yes	yes

Input voltage of all compared ballasts is 115V, input power is 70W, and load is two Sylvania F40T12 fluorescent lamps connected in series

The switching frequency *fs* is an important factor for ballast converting efficiency [6]. Proper choice of *fs* minimises the circulating current in the LCC network, thus maximising efficiency. It can be proved that the maximum value of the efficiency occurs at a critical switching frequency f_{Scr}

$$f_{Scr} = \frac{f_O}{Q_L} \quad (2)$$

$$\text{where } f_O = \frac{1}{2\pi\sqrt{LC_p}} \qquad Q_L = R_p\sqrt{\frac{C_p}{L}}$$

and R_p is the equivalent resistance of the fluorescent lamp.

The ballast output power *Po* is controlled by the fundamental voltage v_f across the LCC network, v_f can be found from Fourier analysis of the voltage on switch Q;

$$v_f = \frac{2 - 2\cos 2\pi D}{\pi} V_{Ce} \quad (3)$$

$$Po = \frac{v_f}{\sqrt{2}}\frac{v_o}{\sqrt{2}}\frac{Q_L}{R_p} = \left(\frac{V_f}{\sqrt{2}}\right)^2 \frac{Q_L^2}{R_p} \quad (4)$$

Dimming of the lamp is easily achieved by changing the duty factor D of the transistor. When D changes, output power changes according to eqns. 3 and 4.

Experimental results: A ballast prototype based on the circuit described above was built and tested. The maximum input power was 70W. Two Sylvania F40T12 fluorescent lamps connected in series were used as the load and the equivalent resistance Rp measured was 600Ω. The component values used were Lf = 400 µ, Lj = 1.1 mH, L = 1.6 mH, and Cf = 1 µF, Cs = 0.5 µF, Ce = 44 µF, Cp = 9 nF, the magnetising inductance of transformer T was 2mH, and the switch Q was a MOSFET IRF740. From eqn. 2, switching frequency of 30kHz is chosen. Fig. 2*a* shows the waveforms of line input current and output voltage. The input current has very low harmonic distortion, and the measured power factor is 0.98. It is quite clear that the flicker is eliminated, because the output voltage is stable as the line voltage passes zero. Fig. 2*b* shows the waveform of input current i_{Li}, and the switching voltage on Q. It is seen that i_{Li} is discontinous and thus achieving a high power factor, and that low voltage stress on power devices was achieved. With dimming control and the feedback of the lamp current, the proposed ballast has a constant input power in the voltage range 95–130V. This feature increased the reliability by protecting the ballast from the damage of line voltage variation. The ballast efficiency is also compared. Two ballasts having the same input power leads to different light output. Experiment shows that the light level of the proposed ballast is 6% higher than that presented in [4].

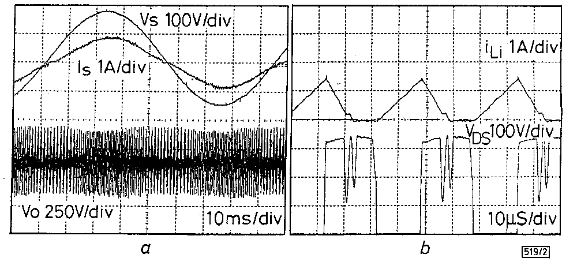

Fig. 2 *Experimental voltage and current waveform*

Line voltage: 115V rms
a Amplitude of load voltage with input current and voltage
b Switching voltage (V_{DS} of Q) and input current in Li

Conclusions: A novel single-switch, unity-power-factor electronic ballast is presented. The proposed ballast has higher efficiency, lower voltage stress on components, and is suitable for the operation of dimming control. The simplicity of the control circuit required to achieve a high power factor and dimming capability is particularly attractive for low cost integration.

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Technique for increasing switching speed in a MOSFET full bridge converter

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Indexing terms: MOSFET, Converters

Switching speed in a full bridge converter is limited by the time taken to turn off the MOSFET built-in diode. The authors describe a new technique for diverting the current away from the diode so that it never turns on, and hence never needs turning off.

Outline of the problem: A full bridge converter is commonly used where a bi-directional output is required, such as in motor drives and sinusoidal output inverters. Unless the load is noninductive a current will flow through a pair of MOSFETs in the reverse direction. Depending on the saturation voltage the built-in diodes may