Study on High Efficiency EEFL Backlight inverter for 32-inch LCD TV

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ABSTRACT

As the screen size of LCD increases, EEFL(External Electrode Fluorescent Lamp) has been suggested to be applicable as backlight source for LCD . Since the electrodes of EEFL are outside of the tube, EEFL enhances the lifetime compared with CCFL(Cold Cathode Fluorescent Lamp), and a single inverter can drive multiple EEFL tubes of which luminance is uniform. Therefore, a compact design can be realized and the cost of EEFL application would be much lower than that of CCFL. Moreover, EEFL inverter has higher efficiency per unit power than CCFL inverter. In this paper, a complementary full-bridge PWM(Pulse Width Modulation) inverter was designed for 32-inch LCD TV backlight which has 20 EEFL tubes and adapted two different driving methods to the EEFL inverter. The validity of this study is confirmed from the experimental results.

1. Introduction

Modern display panels are large and thin, and require a high voltage for the backlight lamp. As the demand for large display screens is high, the inverter needs to be small, high-powered, and high efficient. Generally, one or two CCFLs have been used for backlight of LCD of which size is smaller than 19-inch. However, 10~20 CCFLs are needed for backlight of LCD of which size is bigger than 32-inch and 10~20 inverters are also needed for driving 10~20 CCFLs.

Recently, EEFL have been suggested to be applicable as backlight sources for LCD. EEFL is similar as a CCFL, however it has external electrodes as shown in Fig 1. Therefore, EEFL enhances the lifetime and has higher efficiency per unit power than CCFL. Moreover, EEFL inverter has simple structure in comparison with CCFL, since EEFL inverter does not need a ballast circuit as shown in Fig 2, and as a single inverter can drive multiple EEFL tubes, a compact design can be realized and the cost of EEFL application would be much lower than that of CCFL.[1]

In this paper, the characteristics of the EEFL were investigated and two different methods are adapted to a complementary full-bridge EEFL inverter.

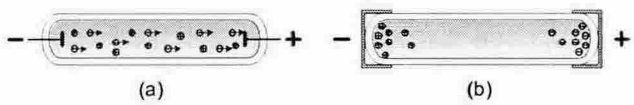

Fig. 1 Structures of Fluorescent (a) CCFL, (b) EEFL.

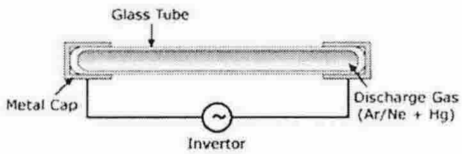

Fig. 2 Structure of EEFL inverter.

2. Operational Principles

2.1 Circuit Operation

EEFLs are operated with capacitive coupled external electrodes at the glass barrier, thereby not inserting electrode materials into the discharge space. The electrical current in conventional CCFLs flows directly through the metal electrode inside the tube, which is therefore a direct current discharge as shown in Fig. 1 (a). On the other hand, plasma current does not flow through electrodes in EEFLs; instead, charged particles are alternatively accumulated on the inner surface of glass tube ends as shown in Fig (b). Thus, EEFLs are alternating current discharge systems with an alternating voltage. The wall charge makes it possible to operate the backlight with a single inverter system, with the backlight arrayed with the multi-EEFLs connected in parallel.[2]

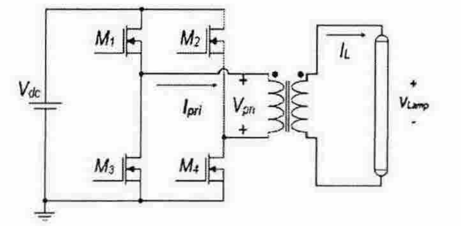

Fig. 3 Full-bridge inverter for EEFL.

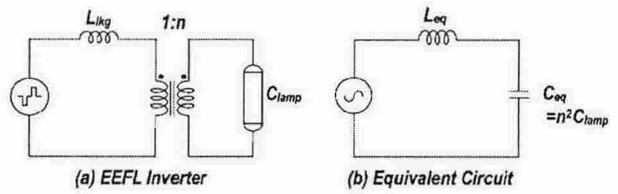

Fig. 4 EEFL inverter and Equivalent Circuit

To drive 20 EEFLs for 32-inch LCD TV, full-bridge inverter can be adapted, since it can change the duty of the powering and handle high power application. EEFL needs high voltage about 1~ $2kV$ to be excited and high voltage transformer is used to raise from the low input voltage to high output voltage of the lamp. Therefore, full-bridge EEFL inverter can be expressed a simple LC resonace inverter, a equivalent circuit as shown in Fig. 4 (a) and (b) respectively and its resonant frequency, (f_r) is decided by L_{eq} and C_{eq}.

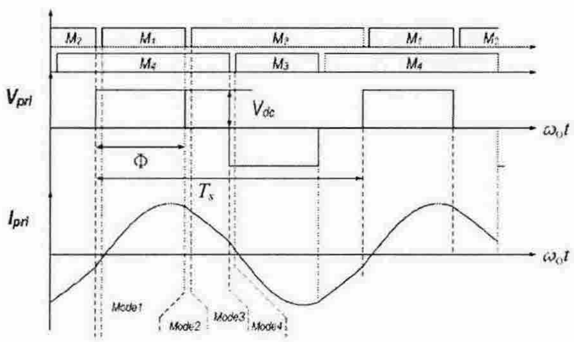

Fig. 5 Key waveforms of sinusoidal driving method

2.1.1 Sinusoidal Driving Method

EEFLs can be operated with a sine wave generated from an LC resonance inverter like conventional CCFLs. When the square wave is applied to the primary side of the transformer, the resonance occurs between the leakage inductance, L_{eq}, of the transformer and the capacitance of the lamp, (C_{eq}) in Fig 4 (b). The inverter is operated in above resonant mode if its switching frequency, (f_s), is higher than its resonant frequency, (fr), and the high sinusoidal voltage is applied to the EEFLs. Fig. 5 shows the key wave form of above resonant method.

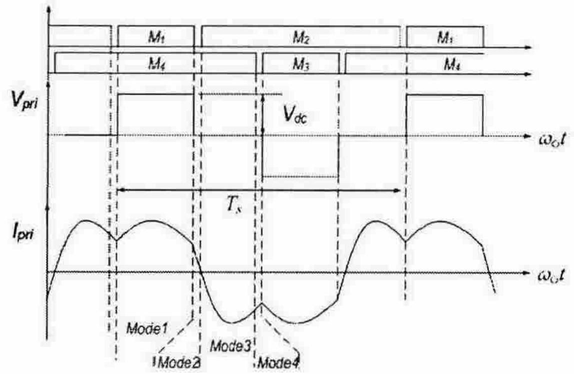

Fig. 6 Key waveforms of self-discharge driving method

2.1.2 Self-discharge Driving Method

EEFLs don't have negative resistance characteristic, and, the discharge current is self-restricted in EEFLs due to the dielectric barrier discharge, where a wall charge is accumulated on the glass tube inside the area where the external electrodes enter of the glass tube ends, it can be driven by self-discharge of which switching frequency(f_s) is almost half of the resonant frequency (f_r). Fig. 6 shows the key waveforms of self-discharge driving method.

2.2 Design of Inverter

There are many constraints such as the output power which the secondary winding must be capable of delivering to the load within specified regulation limits, minimum efficiency of operation which is dependent upon the maximum power loss, the maximum permissible temperature rise for the transformer, the volume , weight and cost of the transformer, and so on.

In EEFL inverter for 32-inch LCD TV backlight system, its output power is about $120W$, the maximum permissible temperature is under 60℃, the height of transformer is under 15mm. Moreover, a separated bobbin should be used since its output voltage is over $1.6kV_{rms}$ which is the firing voltage of EEFL. Therefore, two EFD 3030 cores are proper for designing.

If we know the maximum average voltage of the transformer primary side, ($V_{t,max}$), the number of primary turns, (N_p) can be calculated by Faraday's law expressed as

$$N_p = \frac{V_{t.max} \times 10^4}{K_f B_m A_c f}$$

where, *Vt,max* is maximum average voltage of the transformer primary side, *Kf* is 4.0 for square waveform, and 4.4 for sinusoidal waveform, *Bm* is flux density of core and *f* is operating frequency.

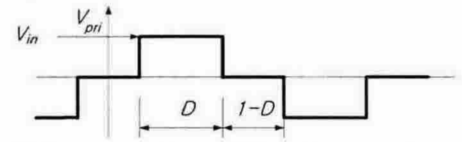

Fig. 7 Voltage wave form of transformer primary side

From fig. 7, the average voltage of transformer primary side can be calculated and expressed as

$$V_{t.max} = \frac{V_{in.max}}{2} \times D$$

The number of secondary turns can be also calculated by the average of transformer and expressed as

$$N = \frac{N_s}{N_p} \geq \frac{V_{firing,rms}}{V_{t,min}}$$

$$N_s \geq \frac{V_{start,rms}}{V_{t,min}} \times N_p \quad .$$

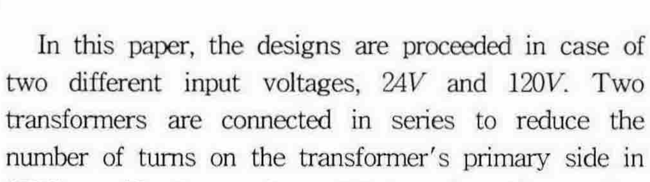

Fig. 8 Full-bridge inverters with two transformers.

3. Experimental Results

In this paper, the designs are proceeded in case of two different input voltages, *24V* and *120V*. Two transformers are connected in series to reduce the number of turns on the transformer's primary side in 120V specification, and parallel to reduce the number of wire strings in *24V* specification as shown in Fig. 8. Table 1 shows the system parameters as results of calculating transformer. In this table, we can notice that the resonant frequency of *120V* spec. is less than that of *24V* specification. The optimal operating frequency of EEFL is between *60kHz*~*100kHz*. The resonant frequency in *120V* specification is about *95kHz*, it is better to drive in sine wave form due to the optical efficiency of EEFL and the resonant frequency in *24V* specification is over *133kHz*, it is better to drive in self-discharge wave form.

Table 1 System parameters of EEFL inverter.

V_{dc}	L_{lkg}	C_{lamp}	n	L_{eq}	C_{eq}	f_r
120V	70uH	100pF	38	140uH	20nF	95kH
24V	5uH	100pF	14	2.5uH	577nF	133kH

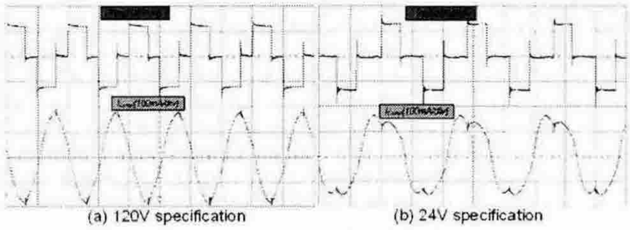

Fig. 9 Experimental Results (5us) (a) V_{pri}(100V/div), I_{Lamp}(100mA/div) (b) V_{pri}(20V/div), I_{Lamp}(100mA/div)

Fig. 9 shows the result of its experimental results. The luminances of each EEFL backlight systems are both over *7,000cd/m²*.

4. Conclusions

the characteristics of the EEFL were investigated and two different methods, sinusoidal driving method and self-discharge driving method, are adapted to EEFL inverter. The validity of this study was confirmed from the experimental results.

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참 고 문 헌

[1] Y. Takeda, M. Takagi, T. Kurita, Y. Watanabe, M. Amano, and H. Nakano, "The characteristics of the external-electrode mercury fluorescent lamp for backlighting liquid-crystal-television displays", Journal of the SID, 11/4, 2003.

[2] G. S Cho, N.O. Kwon, Y. M. Kim, S. J. Kim, T. S. Cho, B. S. Kim, J. G. Kang, E. H. Choi, U. W. Lee, S. C. Yang, and H. S. Choi, "Self-discharge synchronizing operations in the external electrode fluorescent multi-lamps backlight", J. Phys. D: Appl. Phys. 36, pp. 2526-2530, 2003