대형 액정디스플레이패널의 백라이트용 외부 전극 형광램프의 구형파 구동 방법에 대한 휘도, 방전 특성 연구

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A Study on Luminescence and Discharge Characteristics of EEFL (External Electrode Fluorescent Lamp) Driven by Square Wave for Large sized-LCD panel

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ABSTRACT

EEFL can be driven by square wave driving method. A square wave is applied directly to both ends of EEFL by cascaded multi-stage full-bridge inverter. The various current shapes of lamp are achieved by various inductors between lamp and inverter. In this paper, it is newly investigated that the area of current directly influences the luminance. Furthermore, the 3-level square wave is considered to drive EEFL with self-discharge characteristics. The highest luminance efficiency is achieved by properly controlling the rate of self-discharge usage.

1. Introduction

Since thin film transistor-liquid crystal display (TFT-LCD) is not a self-luminescence device, TFT-LCD has to use back light unit (BLU). Therefore, cold cathode fluorescent lamp (CCFL) has been mainly used for backlight source during the past years. Due to the development of large size LCD TV, the number of lamps is increased. The 32-inch LCD TV needs about 20~40 CCFLs and corresponding inverters. Recently, external electrode fluorescent lamp (EEFL) has been suggested to be applicable as backlight sources for LCD. The structure of EEFL is simpler than that of CCFL. The EEFL consists of a plasma lamp and two external electrodes. The EEFL system has longer lifetime, higher light efficiency (lm/W), higher brightness, lower price and higher uniformity of brightness than those of CCFL system. For the wall charges the discharge occurs when the voltage is changed from negative to positive direction and vice versa. Ions and electrons are accumulated as the wall charges on the both walls inside of the glass tube edge if the voltage is applied across the EEFL. When the applied voltage polarity is switched, both accumulated charges on the each side of glass tube move to the opposite electrode side and are accumulated again.

In this paper, 2-level and 3-level square wave driving methods of EEFL are introduced. The purpose of this study is to analyze the relation between the current and the luminance of EEFL. It is found that the area under the lamp current is related with the lamp luminance. In addition, the current shape of the highest luminance is shown.

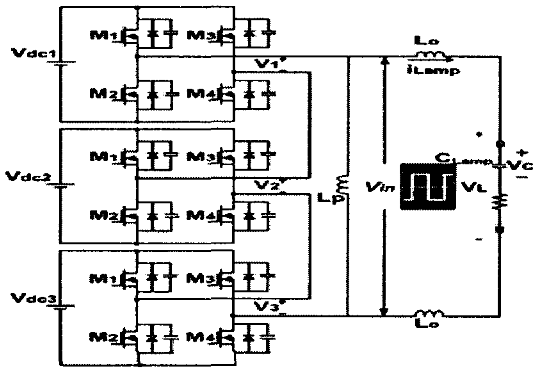

Fig. 1 Square wave driving circuit used in the experiment

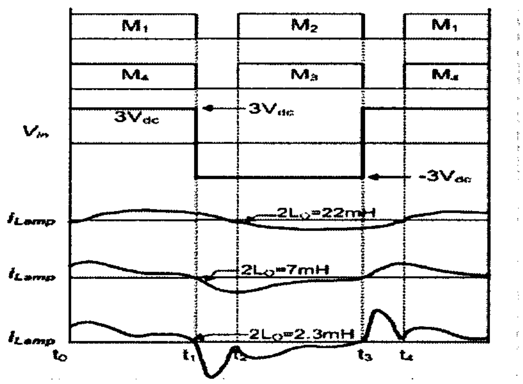

Fig. 2 Key waveform of 2-level square wave driving method

2. Circuit Operation

2.1. 2-level square wave driving method

The 2-level square wave is applied to both ends of EEFL by cascade multi-stage inverter. 3-stages full-bridge inverters are used to reduce the voltage stresses of switches in an inverter stage. This square wave driving circuit is shown in Fig. 1. To change the current shape, various inductors are added between the inverter and EEFL such as LO=1.15mH, 1.45mH, 3.5mH, and 11mH. Since these inductors cannot always guarantee the ZVS condition of switches, the additional inductor LP is connected in parallel to the inductors and EEFL. The operation can be divided into 4 processes in Fig.2. To explain the operational principles of square wave driving

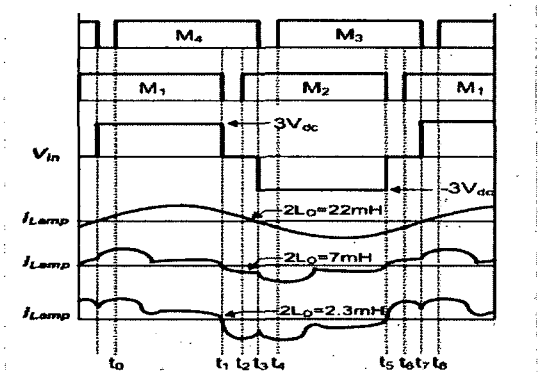

Fig. 3 Key waveform of 3-level square wave driving method

method, several assumptions are made as follow:

The power switches such as M1, M2, M3 and M4 of each full - bridge stage are ideal except for their internal diodes and output capacitors. The values of input voltage for each full-bridge inverter are same as Vdc1=Vdc2=Vdc3=Vdc.

Mode 1 (t0~t1): The switches M1 and M4 of each stage are turned on and the input voltage, 3Vdc, is applied across 2LO and EEFL. The EEFL can be modeled as the R-C series. Thus, the R-L-C series resonance is occurred. The equivalent circuit in Mode1 is simply the R-L-C series with voltage source, Vin=3Vdc, initial current, iLamp(t0), and initial capacitor voltage, VC(t0). To obtain the lamp current, the 2nd order differential equation is solved.

Denote lamp current as iLamp(t), lamp capacitor voltage as VC(t) and series of inductors 2Lo as L.

$$L\frac{di_{Lamp}(t)}{dt}+V_c+Ri_{Lamp}(t)=Vin \qquad (1)$$

Therefore, the lamp current $i_{Lamp}(t)$ can be expressed as

$$i_{Lamp}(t)=e^{-\frac{R}{2L}t}\sqrt{\alpha^2+\beta^2}\,sin(\gamma t+\psi) \qquad (2)$$

$$Where,\psi=\tan^{-1}(\frac{\beta}{\alpha}),\alpha=\frac{Vin-V_c(t_0)-0.5Ri_{Lamp}(t_0)}{\sqrt{\frac{L}{C_{Lamp}}-\frac{R^2}{4L^2}}}$$

$$\beta=i_{Lamp}(t_0),\gamma=\sqrt{\frac{1}{LC_{Lamp}}-\frac{R^2}{4L^2}}$$

Mode2 (t1~t2): The switches M1 and M4 are turned off. The remaining current, iLamp(t1) is used for charging output capacitors of M1 and M4 and discharging output capacitors of M2 and M3. The process of charge and discharge of switches is completed by the resonance of the capacitors of switches and the inductors. After M2 and M3 are discharged, anti-parallel diodes of M2 and M3 are turned on. Thus, in Mode3, M2 and M3 can be turned on by zero voltage switching (ZVS) condition.

Since the operation of remained half cycle is symmetric except the current direction and initial condition, the next half cycle is not considered.

2.2. 3-level square wave driving method

The 3-level square wave can be also made by the circuit in Fig. 1. The operation can be divided into 8 processes in Fig. 3. Because two half cycle are symmetric except the change of the current direction, the first half cycle is considered only.

Mode 1(t0~t1): The switches M1 and M4 are turned on and the input voltage, 3Vdc is applied across 2LO and EEFL. The equivalent circuit in Mode1 is the R-L-C series with voltage source (Vin=3Vdc), initial current iLamp(t0), and initial capacitor voltage Vc(t0). iLamp(t) can be acquired by solving the 2nd order differential equation which is expressed in (1).

Mode 2(t1~t2): After the switch M1 is turned off, mode 2 begins. Using the remained current, the output capacitor of M1 is charged and that of M2 is discharged. When the output capacitor of M2 is completely discharged, the current flows through the body diode of M2. Thus, switch M2 is switched under ZVS condition.

Mode 3(t2~t3): When the switch M2 is turned on, mode 3 begins. The direction of current is not changed.

Mode 4(t3~t4): The switch M4 is turned off. Using the remained current, the output capacitor of M4 is charged and that of M3 is discharged. When the output capacitor of M3 is completely discharged, the current flows through the body diode of M3. Thus the M3 shows zero voltage switching.

3. Experimental Results

3.1 2-level square wave driving method

The circuit is implemented with the following parameters: input voltage, Vdc1=Vdc2=Vdc3 =Vdc = 365V, lamp output power, Pout = 100W, switching frequency, fsw = 87 kHz, switches, M1~M4 = FQP7N80 (Cout = 120pF), 2Lo (2Lo=2.3mH, 3mH, 7mH, and 22mH) The experiment waveforms of 2-level square wave driving method are shown in Fig. 4. To change the current shape, the values of inductors, 2LO, are varied from 2.3mH to 22mH. Fig. 4(a) shows the voltage and current of the series of EEFL and 2LO when the 2LO is 22mH. The RMS value of the lamp current is 109.5mA. The luminance in case of 2LO=22mH is 8820[cd/m2]. Fig.4 (b), (c), and (d) are the voltages and currents of the series of EEFL and 2LO when 2LO is changed with 7mH, 2.9mH, and 2.3mH, respectively. The RMS current values of each circuit are 114mA, 122mA and 124.9mA, respectively. The corresponding luminances are 8776, 8536 and 8508[cd/m2]. In fact, when the current shape is sinusoidal, it shows that the luminance is proportional to the RMS current. However, in the other current shape, RMS current is inversely proportional to luminance. Using the measure current data for each 2LO, the area under the current of half cycle are calculated by MATLAB program. The current area of half cycle is proportional to luminance as shown in Fig. 5.

3.2 3-level square wave driving method

The circuit is implemented with the following parameters: input voltage, Vdc1=Vdc2=Vdc3 =Vdc = 435V, lamp output power, Pout = 100W, switching frequency, fsw = 87 kHz, switches, M1~M4 = FQP7N80 (Cout = 120pF), 2Lo (2Lo=2.3mH, 3mH, 7mH, and 22mH) The experiment waveforms of 3-level square wave driving method are shown in Fig.6 (a),(b),(c), and (d). In this Fig. 6 the voltages and currents of the series of EEFL and 2LO corresponding 22mH, 7mH, 3mH, and 2.3mH are shown. The corresponding luminance are 8834, 8910, 8810 and 8750(cd/m2). The calculated area under the current of half cycle is inversely

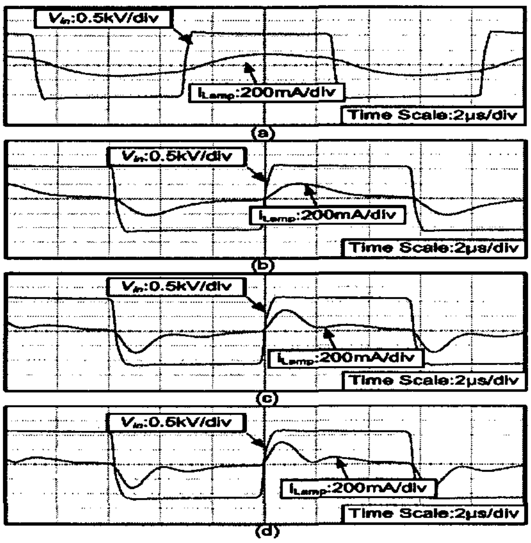

Fig.4 Waveforms of 2-level square wave driving method, Voltage and current of the series of EEFL and $2L_O$= (a) 22mH (b) 7mH (c) 3mH (d)2.3mH

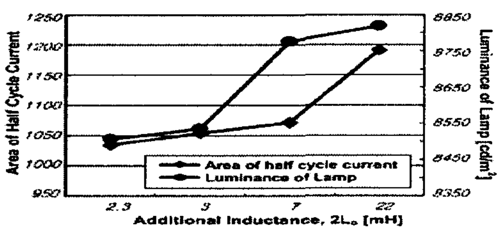

Fig.5 The characteristics between area of half cycle current and luminance of lamp for 2-level square wave driving method

proportional to luminance as shown in Fig.7. Summing up, the experiments will come to the following result. In plasma physics, if the number of electrons in plasma state is increased, the probability of inert gas gone to excited state is increased too. If the calculated area under the current of half cycle becomes larger, the luminance of lamp becomes higher. However, the upper feature is guaranteed in the case of constant lamp voltage. When the area of current is increased in the circuit with 100W output power, the voltage across the series of EEFL and 2LO should be decreased to make 100W power. As a result, the corresponding electric field is decreased too. The electron can be accelerated by electric field, and the gas temperature is increased by the collision between the accelerated electrons and the atoms. It is noted that increased electric field increases the probability of inelastic collision. When the electrons and atoms have an elastic collision, because of no energy transfer, the atoms cannot go to the excited state. However, when the electrons and atoms have an inelastic collision, the atoms can go to the excited state. Thus the increased probability of inelastic collision makes the luminance of lamp higher. The probability of inelastic collision between electrons and atoms is the function of number of charges in gas and electric field intensity. In the case of 2-level square wave driving method experiments, the number of charges is the dominant factor of probability of inelastic collision, because the difference of electric field intensity from 2LO=2.3mH to 2LO=22mH is

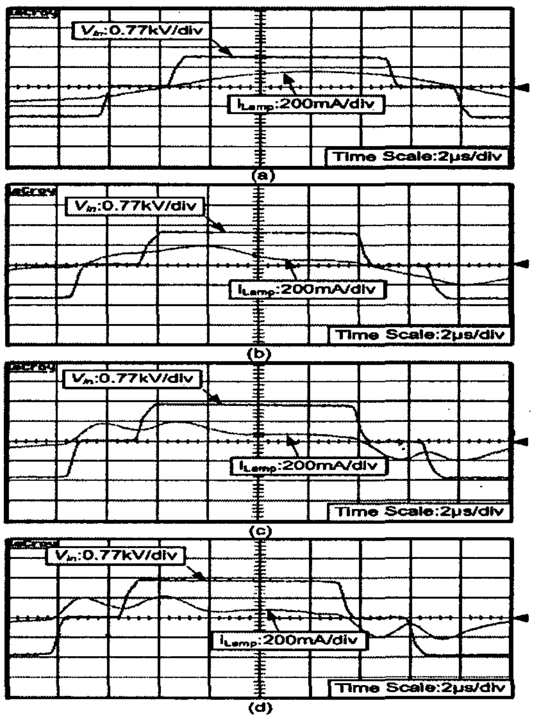

Fig.6 Waveforms of 3-level square wave driving method: Voltage and current of the series of EEFL and 2LO= (a) 22mH (b)7mH (c)3mH (d)2.3mH

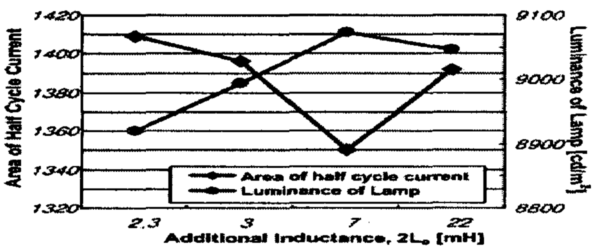

Fig.7 The characteristics between area of half cycle current and luminance of Lamp for 3-level square wave driving method

small. Thus the larger area of current has higher luminance. In the case of 3-level square wave driving method experiments, the number of charge is not the dominant factor of probability of inelastic collision because the electric field intensity varies enough to change the probability of inelastic collision. Thus in spite of the larger area of current, in 3-level square driving method experiments, the lower luminance is shown.

4. Conclusion

In this paper, 2-level and 3-level square wave driving method of EEFL are introduced. In the experiments, the 3-stage inverters are designed to apply the high voltage above 1000V to the EEFL. It is shown that the area of current is directly related with luminance. And, the electric field across the lamp is related with luminance too. As a result, the larger probability of inelastic collision makes the luminance of lamp higher.

Acknowledgment
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Reference

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