PDP을 위한 새로운 저가형 비대칭 전류 주입 에너지 회수 회로

김태성[1], 한상규[2], 문건우[1], 윤명중[1]
한국과학기술원[1], 국민대학교[2]

A new low-cost asymmetric current-fed energy-recovery circuit for a plasma display panel

Tae-Sung Kim[1], Sang-Kyoo Han[2], Gun-Woo Moon[1], and Myung-Joong Youn[1]
KAIST[1] and Kookmin University[2]

ABSTRACT

A new low-cost asymmetric current-fed energy-recovery circuit (ERC) for a plasma display panel (PDP) is proposed. LC resonant circuit biased by $V_s/2$ and composed of single switch is used as ERC on both sides of the PDP, slow discharging and fast charging times can be employed, and inductor currents are built up before the PDP is charged and discharged. Therefore, it features a low cost, fully charged/discharged PDP, zero voltage switching (ZVS), low electromagnetic interference (EMI), low current stress, no severe voltage notch, and high energy-recovery capability.

1. Introduction

The PDP is one of the most leading candidates for the large screen TVs due to advantages such as a wide view angle, lightness, thinness, high contrast, and large screen. The PDP can be equivalently regarded as the capacitance load Cp. Since a high sustaining voltage Vs is alternately applied across the PDP to cause gas-discharge current, there exist a large amount of energy loss of 2CpVs2 per each cycle, excessive surge current, severe EMI noise, and serious heat problem without ERC [1].

To solve these problems, Weber's circuit shown in Fig. 1 has been proposed in [2]. It features a good energy-recovery performance. However, it has several drawbacks. The insufficiently charged and discharged PDP due to a parasitic resistance and forward voltage drop of diode causes the serious hard switching, power dissipation, excessive surge current, and EMI problem. A large gas-discharge current causes the serious voltage notch. In particular, four auxiliary switches used for energy-recovery action increase the cost of production. Moreover, since gas-discharge occurs just after the PDP is charged to Vs, the fast charging time of the PDP is necessary to produce more stable light emission. On the other hand, since there is no gas-discharge after the PDP is discharged to zero, the discharging time of the PDP is not important to the light emission. However, since the discharging time is equal to the charging time in prior circuit, two same resonant inductors are used for energy-recovery so that the peak current of resonant inductor discharging the PDP increases inevitably, which results in a higher cost.

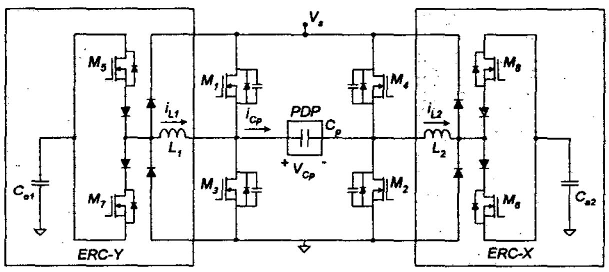
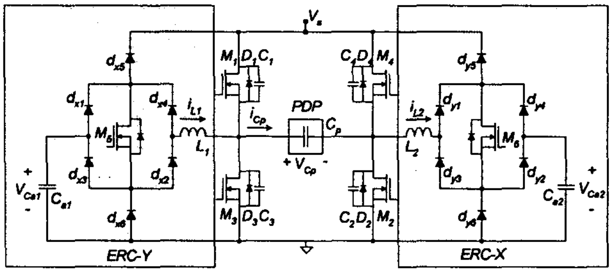
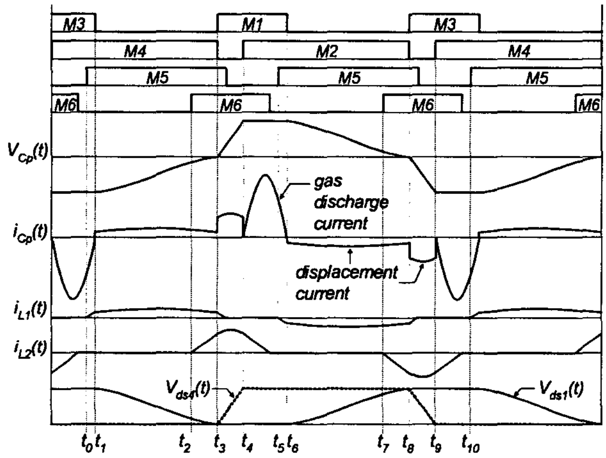


Fig. 1 Prior circuit

To solve these problems of prior circuit, A new low-cost asymmetric current-fed ERC for a PDP is proposed as shown in Fig. 2a. Two ERCs composed of single switch and different resonant inductors are used for both sides of the PDP. The ERC-Y discharging the PDP to zero and ERC-X charging the PDP to Vs employ slow discharging and fast charging times, respectively, resulting in more stable light emission and lower current stress on ERC-Y compared with ERC-X. Also, since, in the proposed circuit, only two auxiliary switches for the energy-recovery compared with four auxiliary switches of the prior circuit is used as well as the current stress on ERC-Y compared with the prior circuit is reduced, the cost of the production can be effectively reduced. Furthermore, the inductor currents are built up before the PDP is charged and discharged. These built-up inductor currents help to fully charge and discharge the PDP, achieve ZVS of main switches, and reduce the EMI noises. Also, since it compensates for a large gas-discharge current, there is no severe voltage notch as well as the current stress on main switches is reduced. Therefore, the proposed circuit features the high energy-recovery capability.



(a) Proposed circuit



(b) Key waveforms

Fig. 2 Proposed circuit and its key waveforms

2. Operation of the proposed circuit

Fig. 2(b) shows key waveforms of the proposed circuit. One cycle operation is divided into ten modes. It is assumed that C1, C2, C3, and C4 are equal to Coss, and VCa1 and VCa2 are equal to 0.5Vs.

Mode 1(t0~t1): Before t0, vCp is clamped to -Vs and the gas-discharge current flows through M4 and M3. When M5 is turned on at t0, mode 1 begins. In this mode, since 0.5Vs is applied across L1 through dx1, M5, dx2, and M3, iL1 increases linearly with the slope of 0.5Vs/L1.

Mode 2(t1~t2): When iCp is equal to zero at t1, M3 is turned off and mode 2 begins. In this mode, L1 begins to discharge Cp and C1, and charge C3 with initial conditions of iL1(t1)=IL1=0.5Vs(t1-t0)/L1 and vCp(t1)=-Vs as follows:

$$v_{Cp}(t) = -\frac{V_s}{2} - \frac{V_s}{2}\cos\omega(t-t_1) + I_{L1}\sqrt{\frac{L_1}{C_p+2C_{oss}}}\sin\omega(t-t_1) \quad (1)$$

where ω=[1/{L1(Cp+2Coss)}]0.5.

Mode 3(t2~t3): When M6 is turned on at t2, mode 3 begins. Since 0.5Vs is applied across L2 through M4, dy1, M6, and dy2, iL2 increases linearly with the slope of 0.5Vs/L2. In this mode, L1 still discharges Cp through dx1, M5, dx2 and M4. When vCp becomes zero, iL1 freewheels through dx1, M5, dx2 and D1. Therefore, M1 can be turned on under ZVS, and Cp is fully discharged to zero in spite of the parasitic resistance and forward voltage drop of diode.

Mode 4(t3~t4): When M1 is turned on and M4 is turned off at t3, mode 4 begins. In this mode, L2 begins to charge Cp and C4, and discharge C2 with initial conditions of iL2(t1)=IL2=0.5Vs(t3-t2)/L2 and vCp(t3)=0 as follows:

$$v_{Cp}(t) = \frac{V_s}{2} - \frac{V_s}{2}\cos\omega(t-t_3) + I_{L2}\sqrt{\frac{L_2}{C_p+2C_{oss}}}\sin\omega(t-t_3) \quad (2)$$

where ω=[1/{L2(Cp+2Coss)}]0.5. When vCp is clamped to Vs, the gas-discharge begins, and iL2 freewheels through D2, dy1, M6, and dy2. Therefore, M2 can be turned on under ZVS, and Cp is fully charged to Vs in spite of the parasitic resistance and forward voltage drop of diode. When iL1(t) decreased linearly with the slope of -0.5Vs/L1 is equal to zero, M5 is turned off.

Mode 5(t4~t5): When M2 is turned on at t4, mode 5 begins. In this mode, since iL2 compensates a large part of the gas-discharge current through M2, its current stress can be considerably reduced and the voltage notch across the PDP can be effectively overcome. When iL2(t) decreased linearly with the slope of -0.5Vs/L2 is equal to zero, M6 is turned off. The next circuit operation of t5~t10 is symmetric to that of t0~t5.

3. Design considerations

Since the brightness of the PDP depends on the operational frequency and the charging time, the charging time, Tc= t4-t3, is required to be as fast as possible. However, since this brightness is irrelevant to the discharging time, Td= t3-t1, it is good for the discharging time to be as slow as possible in the given operational frequency in order to reduce the current stress on ERC-Y. The built-up times, Δt_{L1} =t1-t0 and Δt_{L2}=t3-t2, of L1 and L2 can be determined from equations (1) and (2) as follows:

$$\Delta t_{L1} = \frac{\sqrt{L_1(C_p+2C_{oss})}}{\tan[T_d/(2\sqrt{L_1(C_p+2C_{oss})})]} \quad (3)$$

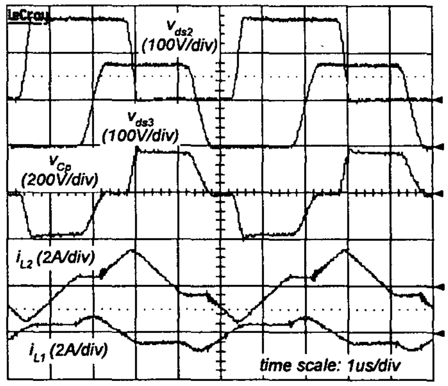
$$\Delta t_{L2} = \frac{\sqrt{L_2(C_p+2C_{oss})}}{\tan[T_d/(2\sqrt{L_2(C_p+2C_{oss})})]} \quad (4)$$

4. Experimental results

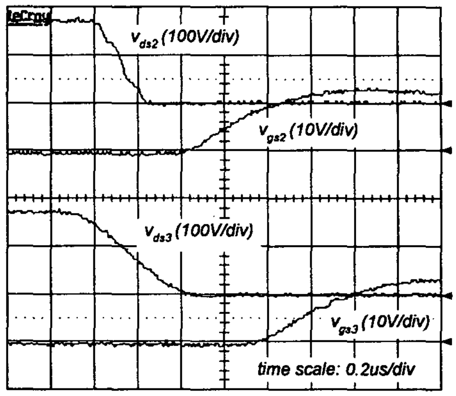
To verify the behavior and analysis of the proposed circuit, the prototype ERC is implemented with specifications of fs=200kHz, Cp=2nF (6-inch PDP), L1=73H, L2=51H, Td=t3-t1≤1.1s, Tc=t4-t3≤0.4s, and M1~M6=2SK2995. Fig. 3 shows the experimental results of the proposed circuit. As shown in Fig. 3(a), Cp is fully charged to Vs and discharged to 0 V without a hard switching due to built-up inductor currents. Also, the current stress in ERC-Y is considerably reduced compared with ERC-X due to the slow discharging time. Moreover, since iL2 compensates for the large amount of the gas-discharge current, the current stress of M2 and M4 and the voltage notch are effectively reduced. M2 and M3are turned on under ZVS due to built-up inductor currents as shown in Fig. 3(b).

5. Conclusions

A new low-cost asymmetric current-fed ERC for the PDP has been proposed. The ERC-Y discharging the PDP to zero and the ERC-X charging the PDP to Vsemploy slow discharging and fast charging times, respectively. The slow discharging time makes the current stress on ERC-Y compared with ERC-X. Also, two auxiliary switches in the proposed circuit compared with four auxiliary switches for an energy-recovery action in prior circuit and the reduced current stress on ERC-Y reduce the cost of the production. The built-up inductor currents fully charge and discharge the PDP in spite of a parasitic resistance, achieve ZVS of main switches, and reduce the EMI noises. Furthermore, due to the gas-discharge current compensation, there is no severe voltage notch as well as the current stress on main switches is reduced. The proposed circuit features the high energy-recovery capability. Therefore, it is expected to be suitable for the low-cost PDP.



(a) Key waveforms



(b) ZVS turn on M2 and M3

Fig. 3 Experimental Results

References

[1] Weber, L. F.: 'Measurement wall charge and capacitance variation for a single cell in AC plasma display panel', IEEE Trans. Electron Devices, 1997, 24, (7), pp. 864-869

[2] Weber, L. F., and Wood. M. B.: 'Energy recovery sustain circuit for the AC plasma display', Proc. S. I. D., 1987, pp. 92-95