PDP을 위한 새로운 고성능 에너지 회수 회로

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A new high performance energy-recovery circuit for a plasma display panel

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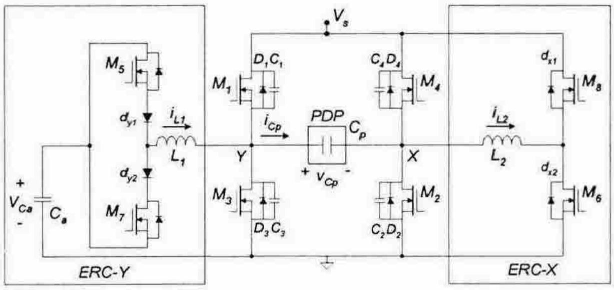
ABSTRACT

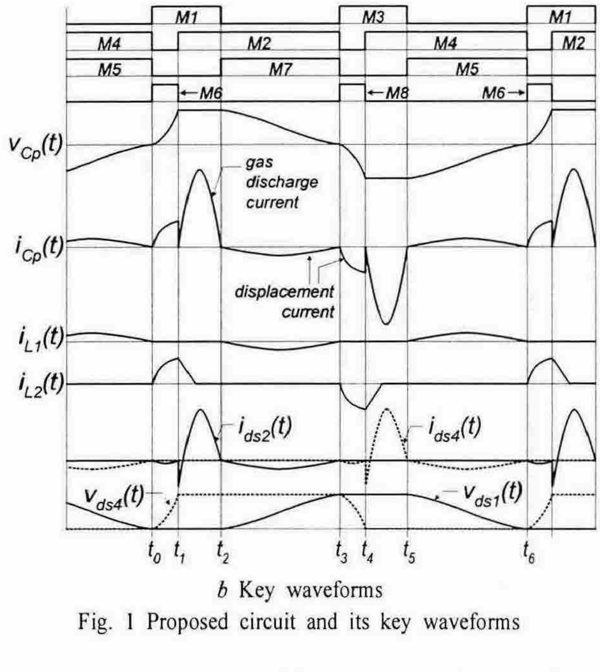
A new high performance energy-recovery circuit (ERC) for a plasma display panel (PDP) is proposed. Two different ERCs are employed on both sides of the PDP, and slow falling and fast rising times are applied. It features a zero voltage switching (ZVS), low electromagnetic interference (EMI), low current stress, high efficiency, no severe voltage notch, reduced sustaining voltage, and high energy-recovery capability.

1. Introduction

Since the PDP has advantages such as a wide view angle, lightness, thinness, high contrast, and large screen, it is one of the most leading candidates for large screen TVs. Since the PDP can be equivalently regarded as a capacitance load C_p, there are the considerable energy loss of $2C_pV_s^2$ per each cycle, excessive surge current, and severe EMI noise without ERC. To solve these problems, Weber's circuit using a LC resonance biased by $0.5V_s$ and Han's circuit using a LC resonance biased by V_s and 0 V have been proposed in [1] and [2], respectively. These circuits feature a good circuit flexibility and high energy-recovery performance. Moreover, since the PDP is charged and discharged by a half cycle resonance in Weber's circuit, there is ideally no resonant current except the rising and falling times of the PDP. Therefore, it has the advantage of low conduction loss. Han's circuit has advantages of no severe voltage notch due to the gas-discharge current compensation and the fast rising time with the PDP fully charged due to a quarter cycle resonance. However, they have several drawbacks. Generally, since the gas-discharge occurs immediately after C_p is charged to V_s, the rising time of the PDP is required to be fast enough to ensure the stable light emission (i.e. below about 400 nsec). On the other hand, since the falling time of the PDP does not affect the gas-discharge characteristics, it is neither important nor critical to the light emission. Nevertheless, these circuits are composed of two same ERCs on both sides, and each ERC helps to both charge and discharge the PDP. Thus, the same falling and rising times must be applied so that the current stresses of two ERCs are equivalent, which results in a high cost. Moreover, the fast rising time decreases a resonant inductance. The smaller a



a Proposed circuit



b Key waveforms

Fig. 1 Proposed circuit and its key waveforms resonant inductance is, the higher the peak current of a resonant inductor is. Therefore, in Weber's circuit, the fast rising time increases a parasitic voltage drop caused by a parasitic resistance, which results in the serious hard switching, excessive surge current, serious power dissipation, severe EMI noise, and poor energy-recovery capability. In particular, a large gas-discharge current causes a serious voltage drop across a parasitic resistance, which results in a serious voltage notch across the PDP. This serious voltage notch reduces an effective voltage applied across the PDP and the accumulated amount of the wall charge. In Han's circuit, even when there is no gas-discharge current, a very large inductor current without any energy-recovery action is fed back to an input voltage source so that excessive conduction loss occurs, which degrades the overall system efficiency.

To overcome these drawbacks, a new high performance ERC for the PDP is proposed as shown in Fig. 1a in this paper. In the proposed circuit, two different ERCs are employed on both sides of the PDP, and the slow falling and fast rising times are applied. ERC-Y for discharging C_p to zero utilizes a LC resonance biased by $0.5V_s$ to reduce conduction loss. The slow falling time reduces a parasitic voltage drop so that there are no severe hard switching of M_1 and M_3, power dissipation, surge current, and EMI noise. Also, it helps to discharge C_p to 0 V without severe hard switching in spite of a parasitic resistance, and makes the current stress of active devices in ERC-Y lower than it in ERC-X. Since ERC-X for charging C_p to V_s utilizes a LC resonance biased by V_s for the fast rising time and large gas-discharge current compensation, there are no severe voltage notch due to a large gas-discharge current, and the current stress of M_2 and M_4 and the sustaining voltage for emitting light waveforms are effectively reduced. Also, it helps to fully charge C_p to V_s, achieve the ZVS of M_2 and M_4, and reduce EMI noise. Moreover, the proposed circuit features the high efficiency and high energy-recovery capability.

2. The operation of the proposed circuit

Fig. 1b shows key waveforms of the proposed circuit. One cycle operation is divided into six modes. It is assumed that C_1, C_2, C_3 and C_4 are equal to C_{oss}, and V_{Ca} is equal to $0.5V_s$.

Mode 1(t_0~t_1): Before t_0, L_1 discharges C_p and C_1, and charges C_3. When M_4 and M_5 are turned off, and M_1 and M_6 are turned on at t_0, mode 1 begins. With initial conditions of $v_{Cp}(t_0)=0$ V and $i_{L2}(t_0)=0$ A, L_2 begins to charge C_p and C_4, and discharge C_2 as follows:

$$v_{Cp}(t)=V_s[1-e^{-(t-t_0)/\tau} \times((\cos\omega(t-t_0)+1/(\omega\tau)\times\sin\omega(t-t_0))] \quad (1)$$

where $\tau=2L_2/R_{esr}$, R_{esr}=parasitic resistance, and $\omega=1/\{L_2(C_p+2C_{oss})-1/\tau^2\}^{0.5}$. After a quarter resonant cycle, v_{Cp} is clamped to V_s and i_{L2} freewheels through D_2 and M_6. Therefore, M_2 can be turned on under ZVS, and C_p is fully charged to V_s in spite of a parasitic voltage drop, resulting in no severe hard switching, power dissipation, surge current, and EMI noise and higher energy-recovery capability.

Mode 2(t_1~t_2): When M_2 is turned on and M_6 is turned off at t_1, mode 2 begins. In this mode, since i_{L2} fed back to an input voltage source through M_2 and d_{x1} compensates for a large part of the gas-discharge current through M_2, the current stress of M_2can be considerably reduced, and the voltage notch across the PDP can be effectively overcome, which results in a reduced sustaining voltage.

Mode 3(t_2~t_3): When i_{Cp} becomes zero at t_2, M_1 is turned off, M_7 is turned on, and mode 3 begins. With initial conditions of $v_{Cp}(t_2)=V_s$ and $i_{L1}(t_2)=0$ A, L_1 begins to discharge C_p and C_3, and charge C_1 as follows:

$$v_{Cp}(t)=V_s[1+e^{-(t-t_2)/\tau} \times((\cos\omega(t-t_2)+1/(\omega\tau)\times\sin\omega(t-t_2))] \quad (2)$$

where $\tau=2L_1/R_{esr}$, and $\omega=1/\{L_1(C_p+2C_{oss})-1/\tau^2\}^{0.5}$. In this mode, lengthening falling time t_2~t_3 increases the value of L_1 so that the value of $\omega\tau$ is increased, which reduces the parasitic voltage drop, the peak current of i_{L1}, and the current stress of active devices in ERC-Y. Therefore, it features no severe hard switching, power dissipation, surge current, and EMI noise, and higher energy-recovery capability. The circuit operation of t_0~t_3 is symmetric to that of t_3~t_6.

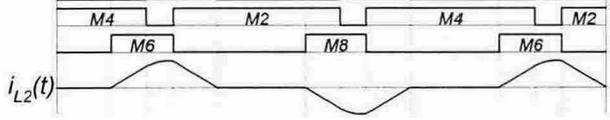
3. Design considerations

The voltage across the PDP is charged from 0 to V_s during the rising time t_0~t_1, and discharged from V_s to 0 during the falling time t_2~t_3. If parasitic components are neglected, L_1 and L_2 can be determined as follows:

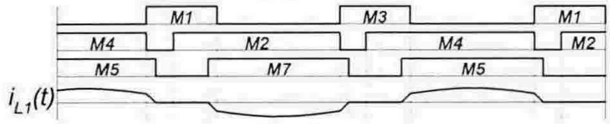
$$L_1=\frac{1}{C_p+2C_{oss}}\left(\frac{t_3-t_2}{\pi}\right)^2 \quad (3)$$

$$L_2=\frac{4}{C_p+2C_{oss}}\left(\frac{t_1-t_0}{\pi}\right)^2 \quad (4)$$

Since the brightness of a PDP is proportional to the operation frequency and the rising time, t_0~t_1 is required to be as fast as possible. However, since the brightness of a PDP is irrelevant to the falling time,

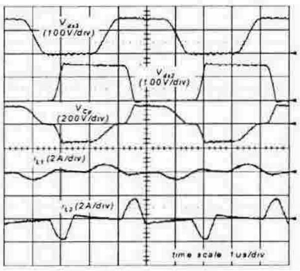


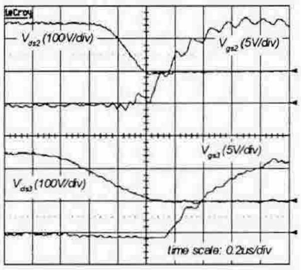
a ERC-X



b ERC-Y

Fig. 2 Other operations of proposed circuit





a Key waveforms *b* ZVS turn on M2 and M3

Fig. 3 Experimental Results

it is good for t_2~t_3 to be as slow as possible in the given operation frequency in order to reduce the current stress of ERC-Y and parasitic voltage drop.

4. Other operations of the proposed circuit

Fig. 2a and 2b show other possible operations of ERC-X and ERC-Y in the proposed circuit, respectively. When ERC-X is operated as shown in Fig. 2a, the quantity of the gas-discharge current compensated by i_{L2} is increased compared with the operation shown in Fig. 1b so that the current stress of M_2 and M_4, and the voltage notch are more improved. Also, since the peak current of i_{L2} is reduced, the current stress of M_6 and M_8 is more reduced. When ERC-Y is operated as shown in Fig. 2b, C_p is fully discharged to zero in spite of a parasitic voltage drop, which achieves the ZVS of M_1 and M_3, reduces the EMI noise and severe surge current, and improves energy-recovery capability compared with the operation shown in Fig. 1b. However, these operations have the disadvantage that conduction loss is higher compared with the operation shown in Fig. 1b, which can reduce the overall system efficiency and deteriorate heat problems.

4. Experimental results

To verify the behavior and analysis of the proposed circuit, the prototype circuit is implemented with specifications of f_s=200 kHz, C_p=2 nF (6-inch PDP), L_1=49 uH, L_2=26 uH, falling time=1100 ns, rising time=400 ns, M_1~M_8=2SK2995, and d_{y1}~d_{y2}=F10KF40.

Fig. 3 shows the experimental results of the proposed circuit in displaying the white image. Fig. 3a shows key waveforms. C_p is fully charged to V_s without hard switching, and discharged to 0 V without severe hard switching due to the slow falling time and non-zero initial current of L_1 caused by a freewheeling current generated by parasitic capacitors in ERC. Since the slow falling time also makes the peak current of L_1 lower than it of L_2, the current stress of active devices in ERC-Y is considerably reduced compared with it in ERC-X. Since i_{L2} compensates for the large amount of the gas-discharge current, the current stress of M_2 and M_4 and the voltage notch are effectively reduced, which makes the panel light in a lower sustain voltage such as 146 V compared with about 165 V for Weber's circuit. Fig. 3b shows that M_2 is turned on under ZVS. M_3 is turn on under ZVS without severe hard switching due to the slow falling time and non-zero initial current of L_1. M_1 and M_4 are also turned on under ZVS.

5. Conclusions

A new high performance ERC with the slow falling and fast rising times has been proposed to overcome the drawbacks of prior circuits. Two different ERCs are employed in the proposed circuit. It features the low EMI, high efficiency and high energy-recovery capability. ERC-Y biased by $0.5V_s$ reduces a conduction loss, and ERC-X biased by V_s helps to fully charge C_p to V_s and achieve the ZVS of M_2 and M_4. The slow falling time makes the current stress of active devices in ERC-Y lower than it in ERC-X and C_p discharged to 0 V without severe hard switching in spite of a parasitic resistance. Also, it enables M_1 and M_3 to be turned on without severe hard switching. Furthermore, there are no severe voltage notch, lower current stress of $M_2$and M_4, and reduced sustaining voltage due to the gas-discharge current compensation.

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References

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