Comparative Study on a Single Energy Recovery Circuits for Plasma Display Panels (PDPs)

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Abstract

Comparative study on a low cost sustaining driver with single and dual path energy recovery circuits for plasma display panels (PDPs) is shown in this paper. The cost of PDPs has been still high and about half of the cost has been occupied by driving circuit. A simple sustaining driver is proposed to reduce the cost and size of driving circuit. The proposed driver has small number of devices and reactive components and there are two methods for charging and discharging PDPs such as single and dual path energy recovery circuits. A comparative research on two-types of energy recovery path is practiced to evaluate performance. As a result, the dual energy recovery path circuit has low power consumption, low surge current and high performance. To verify those results, experiment will be shown with 42-inch HD panel.

I. INTRODUCTION

Plasma display panels (PDPs) are expected to be the best display for high definition (HD) television among flat panel display (FPD) due to wide view angel, large screen size, high contrast ratio, thinness, lightness. However, PDPs has been still expensive so there is new approach to reduce the cost such as reducing the address voltage [1], a single-scan method [2] and decreasing the number of electrical parts.

Generally, PDPs have been driven by the address display separation (ADS) method. The driving operation is divided into three periods: reset, addressing, and sustaining periods as shown Fig 1. During the reset period, a high voltage is forced between electrode X and electrode Y to initialize all the cells in order to obtain the same conditions for all the cells. In the addressing period, wall charges are accumulated in the cells which display the image. In the last period, sustaining, the discharges occur in the cells addressed previously and the desired image can be obtained on the panel. There are many power circuits to make three steps such as resetting, addressing and sustaining in driving the PDP.

During the sustaining period of Fig. 1, the panel voltage waveform is a rectangular pulse from V_S to 0 in electrode X and Y, alternatively. When the electrode X or Y becomes V_S, the light is emitted by the gas discharge. Therefore, most of the electrical power is consumed in sustaining period because a gray scale is made by the number of sustaining pulse [3]. Also, since the PDP is regarded as a capacitive load (C_p), minimizing the considerable energy loss of $2C_pV_s^2$ and electromagnetic interference (EMI) noise for each cycle, and

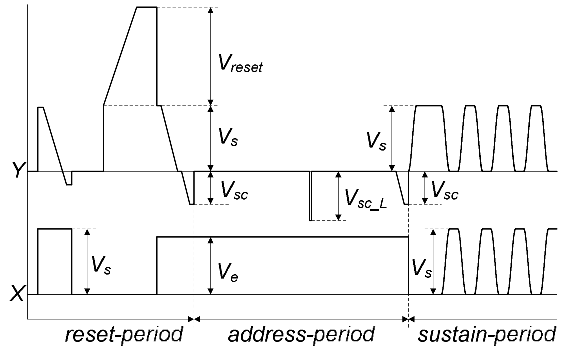


Fig. 1. Voltage waveforms applied to X and Y electrodes in ADS driving method

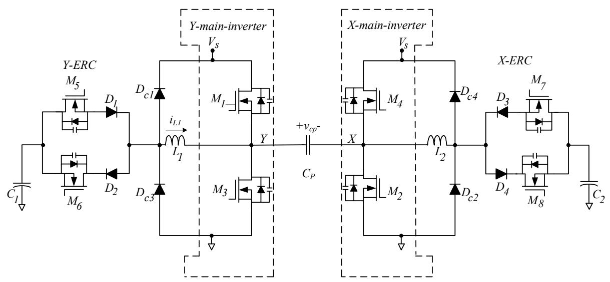


Fig. 2. Circuit diagram of the conventional sustaining driver

reducing the reactive power loss for charging or discharging the panel capacitor through an energy recovery circuit (ERC) [4-11] are much demanded. The best well-known sustaining driver is Weber & Wood circuit which has been composed H-bridge inverter to make high frequency rectangular pulse and series resonant type ERC in recent PDPs as shown in Fig. 2 [10]. This circuit has good performance, high efficiency and flexibility. However, many MOSFET switches, power diodes and reactive components such as inductors and capacitors make the structure of the sustaining driver and series resonant ERC complex and bulk. Above all, the worst demerit of the conventional driver comes from the high cost.

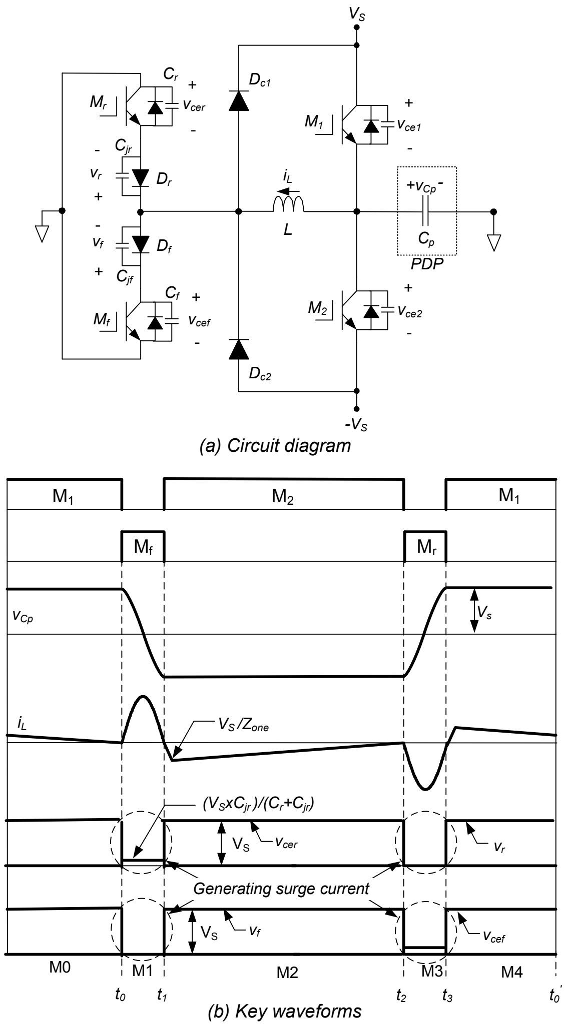


Fig. 4. Circuit diagram and key waveforms of the sustaining driver with single path ERC

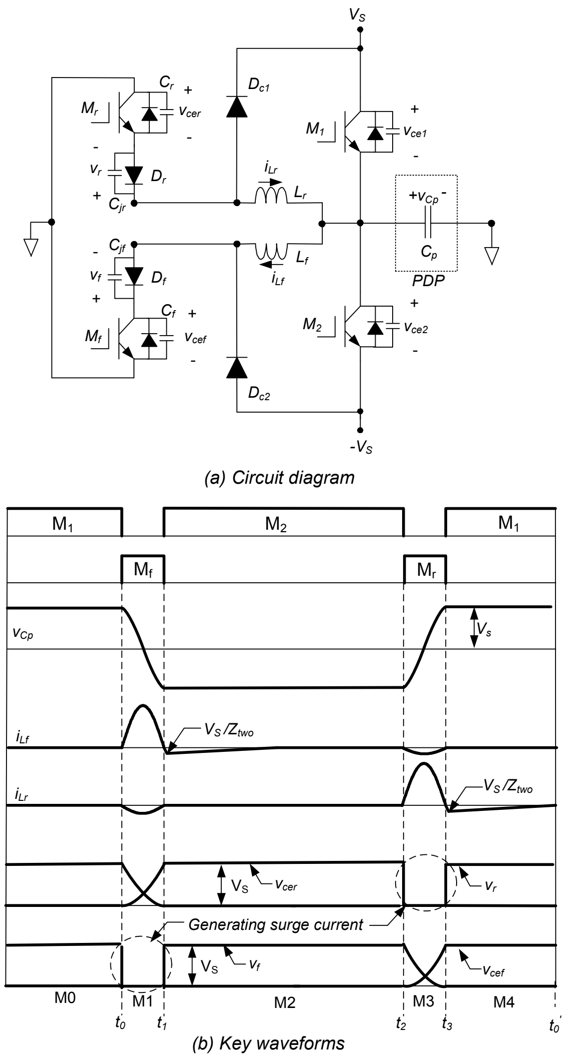


Fig. 5. Circuit diagram and key waveforms of the sustaining driver with dual path ERC

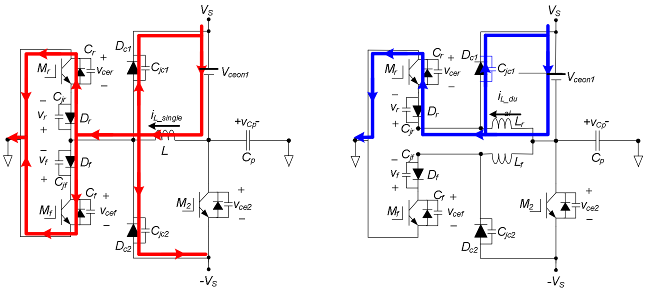
To capture the TV consumer marker and maintain a lead over other FPD, a new sustaining driver with a half-bridge inverter and a parallel resonant type ERC [11] are favorable due to the simple structure and small number of components: half the number of components in the conventional sustaining driver is used in the proposed. Furthermore, it can be driven with single and dual path ERCs. In this paper, a comparative study on the single and dual path ERCs is shown to obtain desirable performance and feasibility to commercialize the proposed driver. The mostly focused is the performance compared between the single and dual path ERCs with respect to power consumption and heat dissipation in ERC components. The dual path ERC achieves superiority over the single path ERC in efficiency and performance. To verify this result, experiment for the comparison of two circuits is performed with 42-inch HD PDP.

II. COMPARATIVE STUDY ON SINGLE AND DUAL PATH ERCS

Regarding to achieving energy recovery action, the operation of the two circuits, single and dual path ERCs, is almost the same. Fig.4 and Fig. 5 shows the circuit diagram and key waveforms of the two circuit. However, effects by parasitic components of ERC devices between single and dual path ERCs are some different after finishing energy recovery.

A. *The quantity of free-wheeling current*

After completing the charging the panel capacitor, additional current is needed to charge parasitic capacitors of switching components by ERC inductors. Remained current is free-wheeling through clamping diode such as D_{C1} and D_{C2} as shown in Fig 4, (b) and Fig. 5 (b). This free-wheeling current results in additional conduction loss. Fig. 6 is a visualized example of the current path for charging the parasitic capacitor of ERC device after the panel voltage becomes V_S. Compared with six parasitic capacitors for charging in the single path ERC, there are small numbers of parasitic capacitors for charging in dual path ERC. As results, there are larger current for charging additional capacitors in the single



(a) The single path ERC (b) The dual path ERC

Fig. 6. The current path for charging the parasitic capacitor in the single and dual path ERCs

path circuit than that of dual path it. The peak value of free-wheeling current in single path circuit can be obtained as follows:

$$I_{L\text{-}free\text{-}one}=V_S\,/\,Z_{ONE} \qquad (3)$$

where $Z_{ONE}=\sqrt{L/(C_{oss}+C_j+2C_{jc})}$, output capacitance of ERC switches, $C_{oss}=C_r=C_f$, junction capacitance of diodes, $C_j=C_{jr}=C_{jf}$ and junction capacitance of clamping diodes, $C_{jc}=C_{jc1}=C_{jc2}$. In the same manner, the peak value of free-wheeling current is obtained in dual path circuit as follows:

$$I_{L\text{-}free\text{-}two}=V_S\,/\,Z_{TWO} \qquad (4)$$

where $Z_{TWO}=\sqrt{L/\left(C_j+C_{jc}\right)}$, $L=L_r=L_f$, junction capacitance of clamping diodes, $C_{jc}=C_{jc1}=C_{jc2}$. As it is shown in equations, (3) and (4), the peak value of current for charging the parasitic capacitor is smaller and free-wheeling current is lower in dual path ERC as shown in Fig. 5 (b).

B. *Heat dissipation and size of ERC inductors*

In the commercialized driving circuit, air-cored inductor has been used as ERC inductors. The inductance of air-cord inductor can be designed as follows

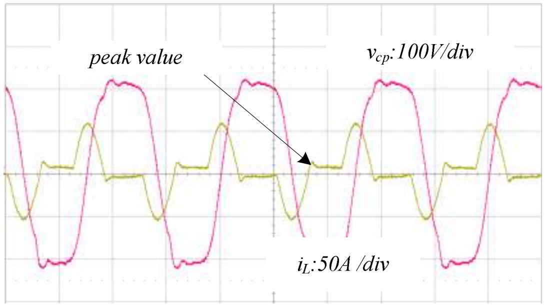
$$L=\frac{(d^2\ \times\ n^2\ )}{18d+40l} \qquad (5)$$

where L is inductance in micro Henrys and d is coil diameter in inches, l is coil length in inches, and n is number of turns. In conventional ERC inductors like the single path ERC, the ERC inductor has been used in parallel to release heat dissipation. Therefore, the ERC inductance has to be designed as two times greater than the desired inductance. However, since the dual path ERC can use a single inductor, the size of the ERC inductance can be reduced compared with that of the single path ERC.

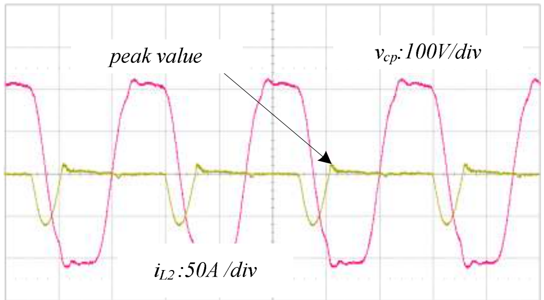
Also, power loss is observed in ERC inductor because the ERC inductor has a resistive component. The resistance of ERC inductor can be obtained in aired core inductor with copper material wire as follows:

$$R=1/\sigma\times\left(1\,/(\pi^2\times(D\varepsilon-\varepsilon)^2\right)[\Omega] \qquad (6)$$

where conductivity of copper, σ , length of wire, l and skin depth , $\varepsilon=6.62/\sqrt{f}$[cm] in f=frequency. In case of dual path ERC, since the wire length of the ERC inductance is shorter, smaller resistance can be obtained and the ERC currents are flowing with two inductors, the power consumption in the ERC inductors can be reduced and heat in inductor is distributed. In addition, since the smaller free-wheeling current is flowing in ERC inductor, the power loss in ERC inductor can be minimized in dual path ERC.



(a) The single path ERC



(b)The dual path ERC

Fig. 7. Waveforms of panel voltage and ERC inductor currents

C. *The number of generating surge current*

Additional, there are four times of generations of excessive surge current in single path ERC during one switching cycle as shown in Fig. 4 (b) because the ERC switches can not be achieved zero voltage switching. However, the excessive surge current is generated as two times in dual path ERC during one switching cycle as shown in Fig. 5 (b). The collector-emitter voltage of turned-off switch and diode voltage of junction capacitor are charged or discharged by resonance of parasitic capacitors and another ERC inductor without surge current. Comparing with single path ERC, it results in smaller surge current and lower power consumption in dual path ERC.

III. Experimental Results

The experiment shows the comparisons between the two circuits, single and dual path ERCs, 42-inch HD PDP according to the number of sustaining pulse in 1 TV-field (per 16.6ms) without gas discharge. Table 1 shows the component list in the experimental circuit. Fig. 7 shows waveforms of panel voltage in two circuits. While the energy recovery action is almost same in two circuits, the peak value of free-wheeling current is 11.2A in dual path circuit and it is 15.4A in single path circuit. The conduction loss by free-wheeling current is greatly reduced in dual path circuit. According to the number of sustaining pulse, the power consumptions are measured as shown in Fig. 8. The number of sustaining pulse can be 1033 to obtain the brightest image. As mentioned above, since the

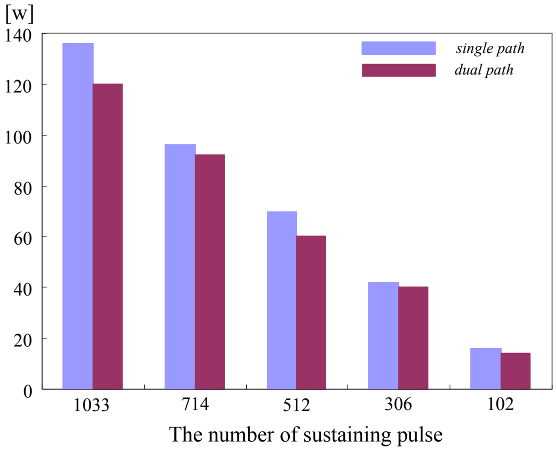


Fig.8. Power consumption

dual path ERC has low surge current and free-wheeling current, it can be obtained higher efficiency than that of single path ERC as shown Fig. 8. The temperature in components is very important in terms of reliability of PDP. Fig. 9 shows temperature of ERC components such as inductor, switches and diodes when the number of sustaining pulse is same in two circuits. Temperature of all components is lower in dual path ERC. Since ERC inductor has small resistive component in dual path circuit, the temperature of that is much lower than that of single path circuit. Also, reliability of switches and diodes can be guaranteed in two-path circuit. Through these experiment results, the detailed analyses on the comparison between the two circuits are successfully done.

IV. CONCLUSION

The low cost sustaining driver is discussed in this paper to reduce the cost and to get high performance with single path and dual path energy recovery circuits in this paper. The power consumption is analyzed in respect to parasitic effects in two ERCs. The experimental tests show difference and comparison of two circuits well. Due to lower surge current, smaller free-wheeling current and lower power consumption in dual path ERC, the dual path ERC shows better performance. The proposed sustaining circuit with dual path ERC can be expected to be suitable for the low cost and high performance sustaining driver for PDPs.

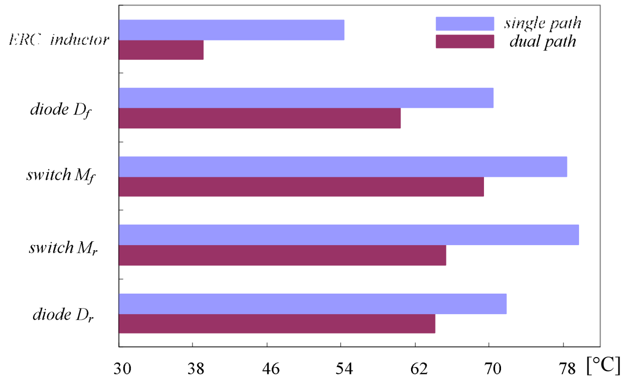


Fig.9. Temperature in ERC components

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