New Energy Recovery Circuit with Asymmetric Inductance for AC Plasma Display Panel

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ABSTRACT

A new energy recovery sustain-circuit (ERC) using asymmetric inductance is proposed to reduce the power consumption of an ac-PDP. The proposed ERC uses different inductors in the energy recovery circuits of the Y- and X-boards, respectively, to compensate for the dissymmetric phenomenon of the sustain waveforms in the Y- and X-boards. Consequently, the proposed ERC is able to reduce the total system current, resulting in a higher luminous efficiency under the same luminance conditions.

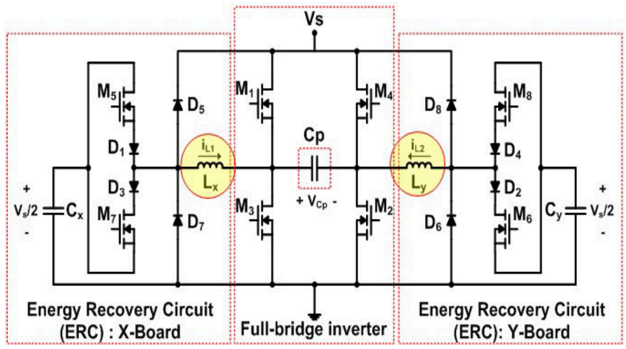

Fig. 1. Electrical equivalent circuit diagram, including energy recovery circuit during sustain period.

INTRODUCTION

The plasma-TV has become a competent flat TV in the commercial TV market, thanks to its large screen size, wide view angle, high dynamic contrast ratio, and fast response suitable for various dynamic motions.

To implement the aforementioned operation successfully, a sustaining circuit is needed to generate ac high-voltage and high-frequency square-wave pulses. In general, this sustaining circuit has a well-known full-bridge configuration to convert a dc voltage to an ac high-frequency square-wave voltage [1]–[6].

As mentioned, since the three electrodes of PDPs are covered by the dielectric and MgO layers, the PDP panel can be regarded as an equivalent inherent capacitor *C*p. Therefore, when applying the ac high-voltage square-wave pulses with an amplitude of *V*s between the X and Y electrodes, an undesirable energy loss of $2C_pV_s^2$ for each switching cycle is generated in the nonideal parasitic resistance of circuits and PDP during the charging or discharging interval without an energy-recovery circuit (ERC). Furthermore, the excessive surge charging and discharging currents will give rise to electromagnetic interference (EMI) noises and increase the surge current ratings of switches [1]–[6].

In the conventional ERC for a plasma display panel (PDP), the inductance L_x in the X-board is exactly the same as the inductance L_y in the Y-board, even though the Y-board, which includes the scan-board, has more electric components than the X-board. As a result, the use of identical inductors induces different LC resonance periods for the X- and Y-board ERCs. While increasing the inductance in the ERC extends the resonance period, thereby reducing the power consumption, this also produces difficulties as regards controlling the discharge in the PDP cells. Conversely, when decreasing the inductance in the ERC, the resonance period is shortened, thereby increasing the power consumption due to a current increase. Thus, if the resonance periods can be properly controlled using asymmetric inductors (i.e., $L_x \neq L_y$) in the ERCs for each board, the luminous efficiency of the PDP is expected to be improved by considerably reducing the total current.

EXPERIMENTAL SETUP

The pixel-pitch of the 50-in full-high definition (full-HD) ac-PDP used in this experiment was 576 x 192 ㎛. The discharge gas composition was He+Ne+Xe (11 %) and gas pressure was 420 Torr. The test panel had a conventional ac-PDP structure with a stripe barrier rib and three electrodes such as two sustain electrodes and one address electrode.

The circuit in Fig. 1, proposed by Weber, is completely symmetrical and there are no coupled circuit components in the X- and Y- boards [7]. A resonance structure is formed with the panel capacitance, C_p and external inductors, L_x and L_y. Additional capacitors, which are considerably larger than the panel capacitance, are used as an external source to exchange the reactive energy with the panel capacitor. Activating M_5 and M_7 on the X-side results in energy injection to the panel and energy recovery from it, respectively. Additional diodes, D_5, D_6, D_7, and D_8 are required to protect the circuit from a voltage surge caused by possible parasitic resonance in the inductors. Although this driver shows several advantages, such as a high energy recovery and decoupled structure, its major drawbacks include a high cost and considerable number of circuit components. In the typical LC resonance, a large inductor extends the resonance period, thereby reducing the power consumption, yet also causing an uncontrollable state in the discharge cells. In contrast, a small inductor increases the current, thereby increasing the power consumption [8-10]. Thus, to solve these problems, a circuit is proposed with a different inductor in the Y- and X-board energy recovery circuits, respectively. For example, an inductor (L_1) with 0.38 μH is used in the Y-board, while another inductor (L_2) with 0.47 μH is used in the X-board. Alternatively, an inductor (L_1) with 0.47 μH is used in the Y-board, while another inductor (L_2) with 0.38 μH is used in the X-board. Thus, the important point is that different inductors are employed in each board.

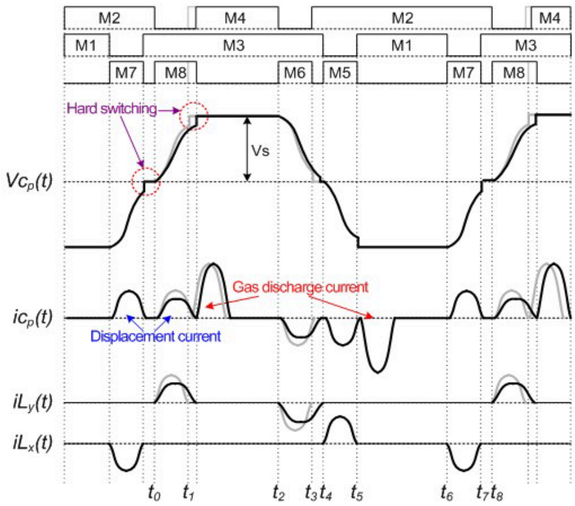

Fig. 2. Key operation waveforms of proposed circuit with asymmetric inductance in relation to reference circuit with symmetric inductance.

RESULTS & DISCUSSIOIN

Fig. 2 shows the key operation waveforms of the proposed circuit with asymmetric inductance in relation to the reference circuit with symmetric inductance. As shown in Fig. 2, the changes in the values of $i_{Ly}(t)$, and $i_{Cp}(t)$ were investigated as a function of inductor Ly, where the sustain voltage was V_s, the panel capacitance was C_p, and the resonance angular frequency was $\omega = 1/\sqrt{LC}$.

The panel current was expressed as,

$$i_{c_p}(t) = \frac{Vs}{\sqrt{L_{x,y}/C_p}} \sin(\omega t) \quad \cdots \quad (1)$$

The inductor current was expressed as,

$$i_{L_{x,y}}(t) = \frac{Vs}{\sqrt{L_{x,y}/C_p}} \sin(\omega t) \quad \cdots \quad (2)$$

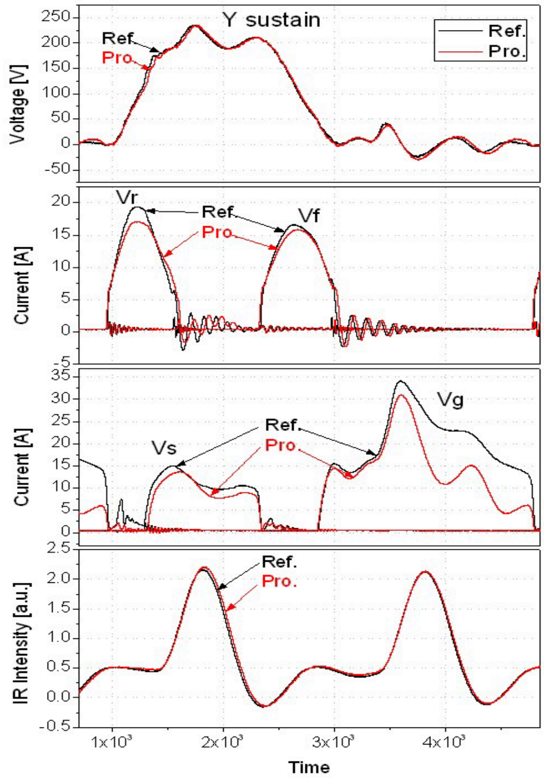

Fig. 3. Comparison of voltage, currents, and IR intensity when adopting reference and proposed circuit under full-white (100 % display) load.

In general, if $L_x = L_y$, $i_{Lx}(t) = i_{Ly}(t)$. However, if $L_x << L_y$, the current was reduced, as $i_{Lx}(t) >> i_{Ly}(t)$ Moreover, when comparing the panel current, $i_{Cp}(t)$, with symmetric (identical) inductors, i.e., $L_x = L_y$, and asymmetric (different) inductors, i.e., ($L_x >> L_y$), the panel current with the asymmetric inductors was less than that with the symmetric inductors.

As shown in Fig. 3, only the currents were reduced without lessening the infrared (IR) emissions when displaying the full-white pattern (=a 100 % display-load) as a result of adopting the proposed ERC. In this case, the increase in the LC resonance period caused by the asymmetric inductance L caused the currents (i.e., V_f, V_r, V_s, and V_g) to be reduced. In particular, the current reductions in the periods of V_s and V_g were mainly due to the decrease in the hard switching induced by the enlarged resonance period of V_r and V_f.

Fig. 4 shows the changes in the luminous efficiencies of the 50-in.full-high definition (Full-HD) PDP modules when the display-load is varied from

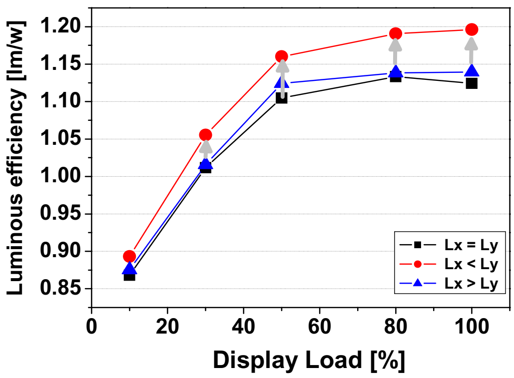

Fig. 4. Changes in luminous efficiencies of 50-in. full-HD ac-PDP modules with display load ranging from 10 to 100 % when adopting three different ERC scenarios: case 1, Ref. ERC with L_x (0.21 H) = L_y (0.21 H), case 2, Pro. ERC with L_x (0.21 H) < L_y (0.25 H), and case 3, Pro. ERC with L_x (0.25 H) > L_y (0.21 H).

10 to 100 % when adopting the three different ERC cases: case 1 is Ref. ERC with L_x (0.21 H) = L_y (0.21 H), case 2 is Pro. ERC with L_x (0.21 H) < L_y (0.25 H), and case 3 is Pro. ERC with L_x (0.25 H) > L_y (0.21 H)]. As shown in Fig. 4, the luminous efficiency was improved when using the ERC with asymmetric inductance instead of the symmetric inductance. In particular, when adopting the ERC with L_y greater than L_x, the higher luminous efficiencies were obtained by about 4 and 6 % in the ranges of the display-load from 1 to 40 % and from 40 to 100 %, respectively. This result meant that the use of larger inductance in the Y-board with ramp set and scan-board (*i.e.*, the circuit board having more electric driving components) was more effective in reducing the power consumption.

CONCLUSION

A new energy recovery circuit using asymmetric inductance was proposed to reduce the consumption power of a 50-in. full-HD ac-PDP. As a result, the proposed ERC was shown to reduce the power consumption by about 10 W. In particular, an ERC using a larger inductance for the Y-board with the ramp reset and scan-board was more effective in reducing the power consumption.

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