A new plasma display panel sustaining driver using single side sustaining technique with the dual resonant method is proposed. Since this circuit enables to reduce switches in energy recovery circuit with keeping voltage stress like that of prior circuit, it can be low cost circuit comparing with a conventional driver. To integrate sustain function into one side with single power source in the driver, a charge pump method is adopted to make negative sustaining voltage and achieve dual resonant energy recovery on sustaining modes.

**1. Introduction**

Digital broadcasting and the infrastructure of digital networks represented by the Internet is progressing quickly in many nations. Moreover, many consumers are turning to a wide digital TV to equip their home theater systems. To meet these requirements, many kinds of digital displays have been developed and plasma display panel (PDP) has advantages over other flat panel displays (FPDs) such as the wider view angle, larger screen, higher brightness, and thinness. Thanks to these advantages PDP is expected to widen its market share in the digital display market. Thus, to attract many consumers, the development of a low-cost driving technology for PDP is required. The operation of PDP is divided into three periods: reset, addressing, and sustaining. The sustaining operation of PDP has been performed by applying sustain pulses to X,Y electrodes alternately. If the two sustain pulses are merged to one sustain pulse with both the positive and negative voltage levels, cost of PDP can be decreased because energy recovery and sustain switches are reduced. However, this method has a defect that is double voltage stress in these switches, so high voltage switching devices are required which contributes to an increase of PDP cost. In this paper, a low-cost sustaining driver integrated sustain function into one side is proposed. Although sustain switch blocks a few increase, this driver is able to maintain voltage stress same as a conventional driver despite reduction of energy recovery switch by using dual resonant energy recovery technique. In addition, charge pump concept is adopted to achieve not only dual resonant energy recovery but also decrease of voltage stress in sustain switches by using single power source.

**2. Proposed driver**

**2.1 Circuit description**

Fig. 1 shows the proposed PDP driver adopting the dual resonant method. Since the dielectric layer of MgO is encrusted on sustaining(X) and scanning(Y) electrodes, capacitance between two electrodes exists inherently. This is modeled by \( C_p \). The Y sustaining driver is composed of two switching blocks, respectively. \( Y_s \), \( Y_h \) are for applying positive sustaining voltage pulse to Y electrode and negative sustaining voltage pulse is applied by \( Y_g \), \( Y_L \) to same electrode. Capacitor \( C_1 \) charged to \( V_s \) while the electrode is maintained at \( V_s \) level has functions of applying the negative sustaining voltage and realizing the dual resonant energy recovery by switching operation of \( Y_s \), \( Y_g \).

![Fig. 1. Proposed single board PDP sustaining driver](image)

**2.2 Operational principles**

The operation can be divided into three modes and mode analysis is performed about the first half cycle because the operation of the two half cycles is symmetric. It is assumed that before the start of mode 1, the switches, \( Y_s \), \( Y_L \) are turned on. In addition, \( C_1 \) and \( C_{ax} \) are charged to \( V_s \) and \( 1/2V_s \), respectively.
Mode 1 \((t_0 \leq t < t_1)\)
Mode 1 begins at \(t_0\) when \(Y_L\) is turned off and \(Y_r\) is turned on. Current path is formed including \(Y_g\), \(C_1\), \(C_{ax}\), and \(Y_r, L\) at \(Y\) electrode. Accordingly, a resonance is occurred between \(L\) and \(C_p\) to recover energy of panel until \(V_y\) become GND level. During this mode, potential of point \(b\) at \(C_1\) is kept on \(-V_s\) potential since point \(a\) of \(C_1\) is connected with GND by \(Y_g\) it has been turned on, so \(D_5\) is blocked and \(V_{CAx}\) becomes \(-1/2V_s\). Moreover, it can generate negative sustaining voltage without external power source. Referring to Fig. 3, the drain–source voltage of \(Y_f\) which does not conduct is \(1/2V_s\).

In this mode, likewise mode 1, the parameters can be expressed as follows:

\[
V_{y_D} = \left(\frac{V_s}{2} - V_{JA}\right) \left[1 - e^{-\frac{t}{\tau}} \left(\cos(\omega t) + \frac{R}{\omega L} \sin(\omega t)\right)\right] \quad (1)
\]

\[
E_p = \frac{1}{L\omega} \left(\frac{V_s}{2} - V_{JA}\right) e^{-\frac{t}{\tau}} \sin(\omega t) \quad (2)
\]

where \(\tau = \frac{2L}{R}\) and \(\omega = \sqrt{\left(1/LC_p\right) - \left(R/2L\right)^2}\)

\(R\): equivalent series resistance on energy recovery path

\(V_{DO}\): on drop voltage of the diode

Mode 2 \((t_1 \leq t < t_2)\)
When \(Y_g\) is turned off and \(Y_s\) is turned on, mode 2 begins at \(t_1\). At this time, the point \(b\) of \(C_1\) rises from \(-V_s\) to GND, so \(V_{CAx}\) is varied from \(-1/2V_s\) to \(1/2V_s\) because \(Y_s, D_5\) are turned on respectively. Therefore, the resonance is took place once more until \(V_y\) becomes \(V_s\) level with maintaining the voltage of \(Y_1\) as \(1/2V_s\), equal to previous mode. For that reason, the dual resonant energy recovery can be accomplished, which keeps voltage stress of energy recovery switch same as conventional driver.

In this mode, likewise mode 1, the parameters can be expressed as follows:

\[
V_{y_D} = \left(\frac{V_s}{2} - V_{JA}\right) \left[1 - e^{-\frac{t}{\tau}} \left(\cos(\omega t) + \frac{R}{\omega L} \sin(\omega t)\right)\right] \quad (3)
\]

\[
E_p = \frac{1}{L\omega} \left(\frac{V_s}{2} - V_{JA}\right) e^{-\frac{t}{\tau}} \sin(\omega t) \quad (4)
\]

Mode 3 \((t_2 \leq t < t_3)\)
At the mode 3, \(Y_s\) is turned off and \(Y_h\) is turned on, so sustain pulse is applied to \(C_o\) with charging \(C_1\) to perform charge–pump operation.

\[
\text{Fig. 2. Operational waveform of proposed driver}
\]

\[
\text{Fig. 3. Current path of each mode in proposed driver}
\]
3. Experimental results

A experiment was performed about proposed driver to prove usefulness of that by applying to 42inch panel, and the waveform is shown to the Fig4 as a result of the experiment. The Fig4 is magnified waveform of sustain field, and it shows Y electrode voltage($V_y$), resonant current of inductor($I_L$), auxiliary capacitor voltage($V_{ca}$). Sustain voltage was applied by 180V to discharge the panel completely. While $V_y$ is changed between $V_s$ and -$V_s$, that is resonant current between L and panel capacitance($C_p$) occurs twice according to invert $V_{ca}$, the first current takes place while $V_y$ rises from -$V_s$ to 0V like the mode 1 and second current occurs while $V_y$ rises from 0V to $V_s$ like the mode 2 in the Fig 2. In this period, $V_{ca}$ is always keeping a half voltage level of sustain voltage, so voltage stress of energy recovery switches can be maintained as 1/2$V_s$. Besides, according to this waveform, we can find that the peak point of second resonance current is higher than that of first resonance current, it is based on a length of the second resonance path longer than the first resonance path on real driving board, and it effects resonant frequency by changing inductance value on the path. For that reason, such a waveform can be appeared. Fig5. is undischarged waveform, so displacement current only exists in the panel. We can find that the dual resonant operation is occurred in any condition from these waveforms.

![Fig. 4. Waveform of dual resonance with discharge](image)

![Fig. 5. Waveform of dual resonance without discharge](image)

4. Conclusions

In this paper, single board PDP sustaining circuit applied dual resonant method is proposed, and the circuit is verified through driving experiment to actual 42 inch PDP panel. To realize single side sustaining circuit without increase of voltage stress, dual resonant energy recovery concept using charge pump method is adopted. Accordingly, this circuit has so important merit that can maintain voltage stress of energy recovery switch same as that of conventional circuit though the switch is reduced. To understand the voltage stress objectively, we compared that with single resonant method which performs energy recovery through just once resonance, and it is realized by replacing auxiliary capacitor to GND in the proposed circuit. In the table 1, we can find that the voltage stresses of $Y_r$ and $Y_f$ are half of single resonant method.

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<td>$Y_f$</td>
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Table 1. Comparing voltage stress with single resonant method

In addition, despite increase of sustain switch count above simple single sustaining driver, by applying charge pump concept this circuit enables single power source to be usable and to reduce voltage stress of sustain switches. Therefore, the proposed driver is expected to be suitable for a low-cost PDP sustaining driver.

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참 고 문 헌


