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Cost-effective Single Board PDP Sustaining Driver with Dual Resonant Method

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ABSTRACT

A new plasma display panel sustaining driver using single side sustaining technique with a dual resonant method is proposed in this paper. Since this circuit enables to keep device voltage stress same as the prior circuit, it can be a low cost circuit compared to a conventional driver. To integrate the sustaining function into one side with a single power source in the driver, a charge pump method is adopted to make negative sustaining voltage and to achieve dual resonant energy recovery on the sustaining modes.

Keywords: Single Board Sustain Driver, Dual Resonant Energy Recovery

1. Introduction

Digital broadcasting and the infrastructure of digital networks such as the Internet is progressing quickly in many nations [1]. 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 panels (PDP) have advantages over other flat panel displays (FPDs), including wider view angle, larger screen, higher brightness, and thinness. Thanks to these advantages, the PDP is expected to widen its market share in the digital display market[2]. Thus, to attract many consumers, the development of a low-cost driving technology for the PDP is required [3]. Fig .1 shows the simplified PDP structure with three electrodes. It consists of two glass plates with chemically stable rare gases filled between them. The scanning(Y) and sustaining(X) electrodes are built on the front glass, which is coated with a dielectric layer (MgO) and the addressing electrode is on the rear glass. A desired color light can be obtained by exciting the phosphors on the addressing electrode to emit visible light with the ultraviolet photons generated by gas discharge [5].

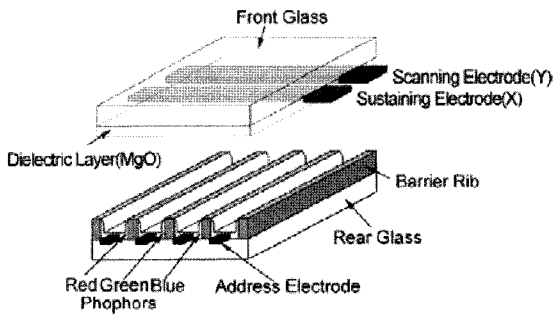

Fig. 1 Simplified PDP structure with three electrodes

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Generally, PDPs have been driven by the address display separation (ADS) method. Fig .2 shows conventional PDP driving waveform applied with the ADS driving method. The driving operation is divided into three periods of reset, addressing and sustaining periods. During the reset period, all of the PDP cells are erased and prepared to perform addressing by making proper wall charge condition to do so. After that, selective write discharges to form an image are ignited by applying data and scanning pulses to the addressing and scanning electrodes, respectively [5][6]. Since addressing discharge itself emits an insufficient visible light, high-voltage AC square pulses are continuously applied between sustaining(X) and scanning(Y) electrodes for strong light emission of selective cells [5]. Fig. 3 is a circuit that realizes conventional sustaining waveforms. 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, and the sustaining circuit is designed to generate sustaining pulse at both sides of the panel (C_p).

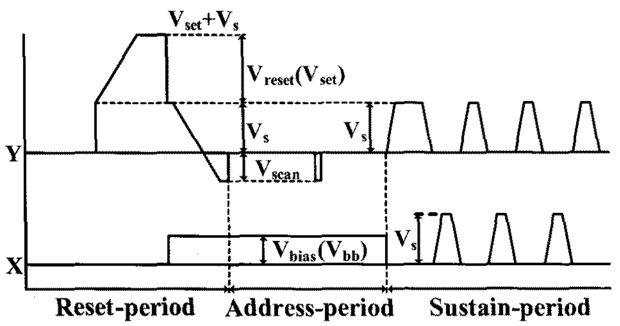


Fig. 2 Conventional PDP driving waveform in ADS driving method

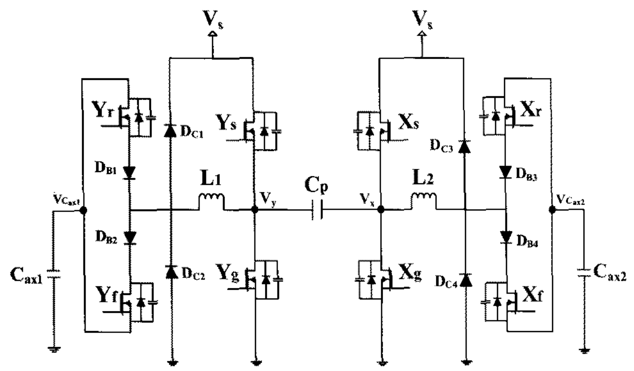


Fig. 3 Conventional PDP sustaining driver

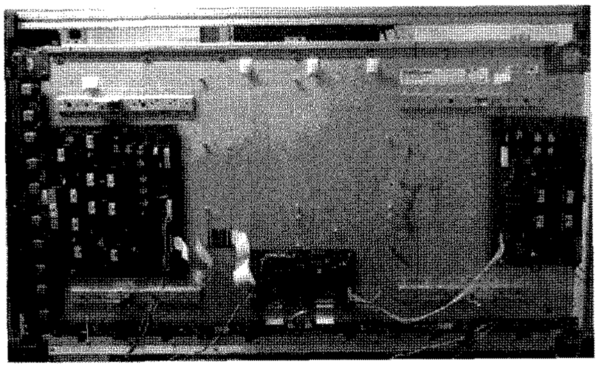
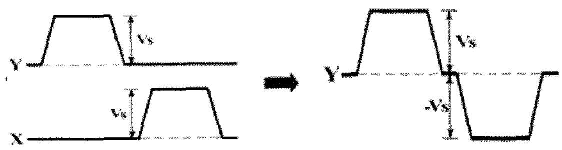
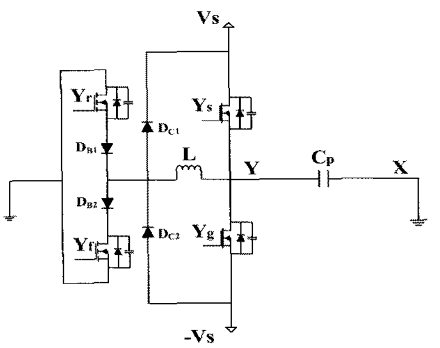


Fig. 4 Conventional PDP driving module

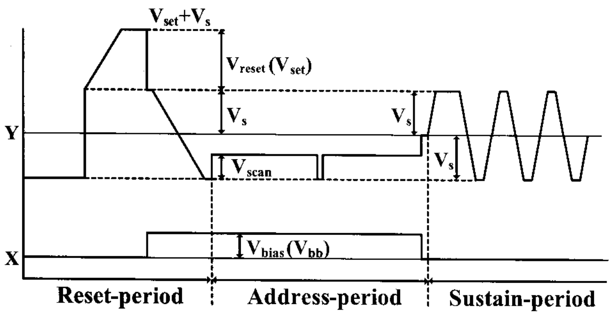
In particular, the sustaining waveform is alternately applied to the X and Y electrodes. If the two sustaining pulses which are separated into two electrodes(X,Y) are merged to one sustaining pulse which has both positive and negative voltage levels, that is to say, a sustaining waveform is applied only to the Y electrode without applying any sustaining driving waveform to the X electrode, the driving cost can be considerably reduced due to the elimination of the sustaining driving circuit block on the X electrodes. Fig .5 shows a concept of a single sustaining pulse, single side sustaining driver which is modified using conventional driver to apply the merged waveform and overall single-board driving waveform. If the driver is actually implemented, the PDP driver cost can be considerably decreased because the sustaining circuit block is removed on the X electrodes [3].



(a) Basic concept of merged sustain waveform



(b) Conventional single sustaining driver



(c) Single-board PDP driving waveform in ADS method

Fig. 5 Single-board driving waveform and its driver

However, this method has a defect which increases voltage stress of sustaining and energy recovery switches into double compared with a conventional driver due to the reduction of all switches by half. Moreover, a switch which connects panel(C_p) to GND is additionally needed when we consider not only the sustaining period but overall period driving. Thus, expensive high voltage switching devices are required, which contribute to an increase of the PDP cost [2].

In this paper, a low-cost sustaining driver integrated sustaining function into one side is proposed. Although sustaining switches are minimally increased, this driver is able to maintain the voltage stress of energy recovery switches the same way as a conventional driver despite reduction of an energy recovery switch by using a dual resonant energy recovery technique. In addition, a charge pump concept is adopted to achieve not only dual resonant energy recovery but also to decrease the voltage stress in sustaining switches by using a single power source.

2. Proposed Driver

2.1 Circuit Description

Fig. 6 shows the proposed PDP driver adopting the dual resonant method. According to Fig.1, capacitance between two electrodes exists innately because of the dielectric layer which is encrusted on X and Y electrodes. This is modeled by C_p. The Y sustaining driver is composed of two switching blocks, respectively. Y_s, Y_h are for applying a positive sustaining voltage pulse to Y electrode and a negative sustaining voltage pulse is applied by Y_g, Y_L to the 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.

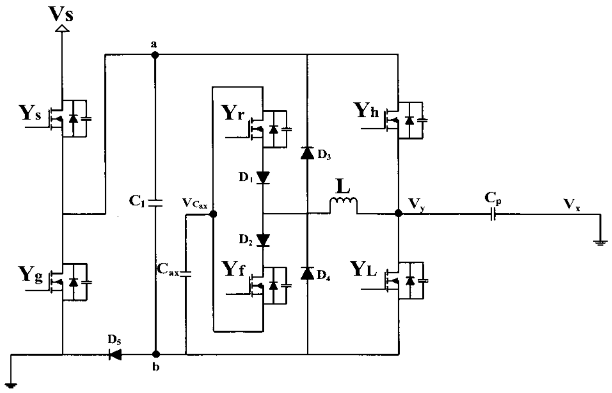


Fig. 6 Proposed single board PDP sustaining driver

2.2 Operational Principles

The operation can be divided into three modes and mode analysis is performed at 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_g, Y_L are turned on. In addition, C_1 and C_{ax} are charged to V_s and $1/2V_s$, respectively.

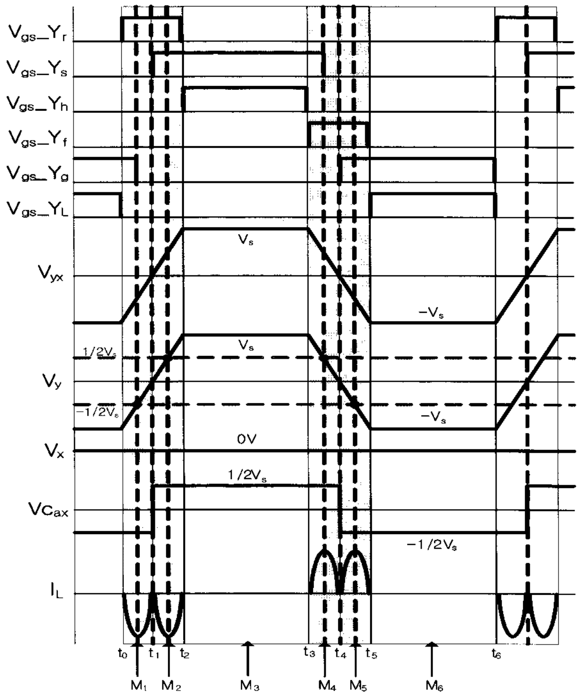


Fig. 7 Operational waveform of proposed driver

Mode 1(t_0~t_1): Mode 1 begins at t_0 when Y_L is turned off and Y_r is turned on. A current path is formed including Y_g, C_1, C_{ax}, and Y_r, L at Y electrode. Accordingly, a resonance occurs between L and C_p to recover energy of the panel until V_y becomes GND level. During this mode, the 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 and has been turned on, so D_5 is blocked and Vc_{ax} becomes $-1/2V_s$. Moreover, it can generate negative sustaining voltage without an external power source. Referring to Figure 8(a), the voltage stress of Y_f which does not conduct is $1/2V_s$. In this mode, a voltage recovered from C_p and the current that flows to C_p can be expressed as follows:

$$V_{yx} = \left(-\frac{V_s}{2} - V_{D1}\right)\left[1 - e^{-\frac{t}{\tau}}\left(\cos\omega t + \frac{R}{\omega L}\sin\omega t\right)\right] \quad (1)$$

$$I_{C_p} = \frac{1}{L\omega}\left(-\frac{V_s}{2} - V_{D1}\right)e^{-\frac{t}{\tau}}\sin\omega t \quad (2)$$

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

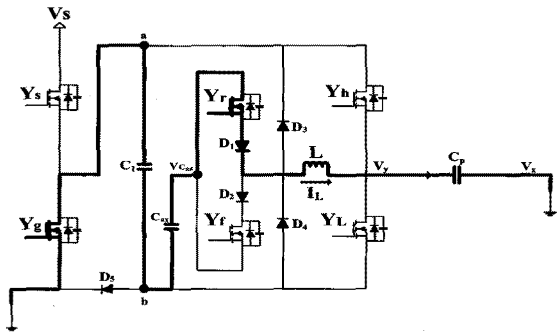
(R : equivalent series resistance on energy recovery path)
(V_{D1}: on drop voltage of the diode)

Mode 2(t_1~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 Vc_{ax} is varied from $-1/2V_s$ to $1/2V_s$ because Y_s, D_5 are turned on respectively. Therefore, the resonance takes place once more until V_y becomes V_s level with maintaining the voltage of Y_f as $1/2V_s$ equal to the previous mode. For that reason, the dual resonant energy recovery can be accomplished, which keeps the voltage stress of the energy recovery switch the same as a conventional driver. In this mode, as in mode 1, the parameters can be expressed as follows:

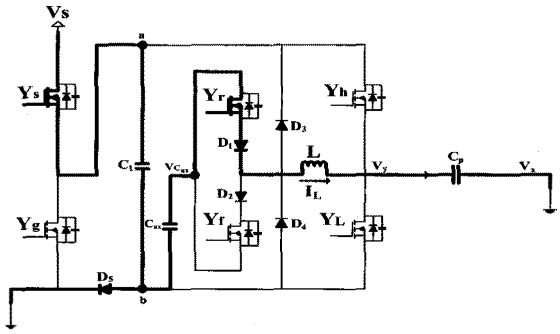
$$V_{yx} = \left(\frac{V_s}{2} - V_{D1}\right)\left[1 - e^{-\frac{t}{\tau}}\left(\cos\omega t + \frac{R}{\omega L}\sin\omega t\right)\right] \quad (3)$$

$$I_{C_p} = \frac{1}{L\omega}\left(\frac{V_s}{2} - V_{D1}\right)e^{-\frac{t}{\tau}}\sin\omega t \quad (4).$$

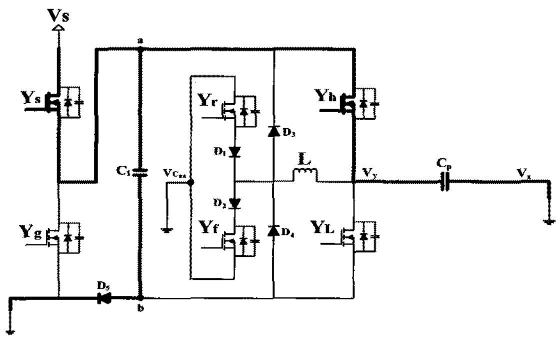
Mode 3(t_2~t_3): At mode 3, Y_r is turned off and Y_h is turned on, so the sustaining pulse is applied to C_p while charging C_1 to perform the charge-pump operation.



(a) Mode 1 (t_0~t_1)



(b) Mode 2 (t_1~t_2)



(c) Mode 3 (t_2~t_3)

Fig. 8 Operational modes of proposed driver

2.3 Block Diagram of Overall Driver

Fig. 9 is a total block diagram of the proposed driver. In the driver, major functions exist on the Y board, while the X board only performs applying bias and GND to panel(C_p). Furthermore, rising ramp(Y_{rr}) and falling ramp(Y_{fr}) circuits are on the Y board in order to carry out reset function, and scan function (Vscan) consistently exists on the Y board.

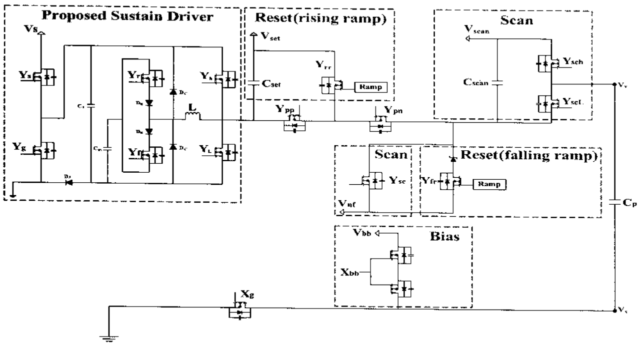
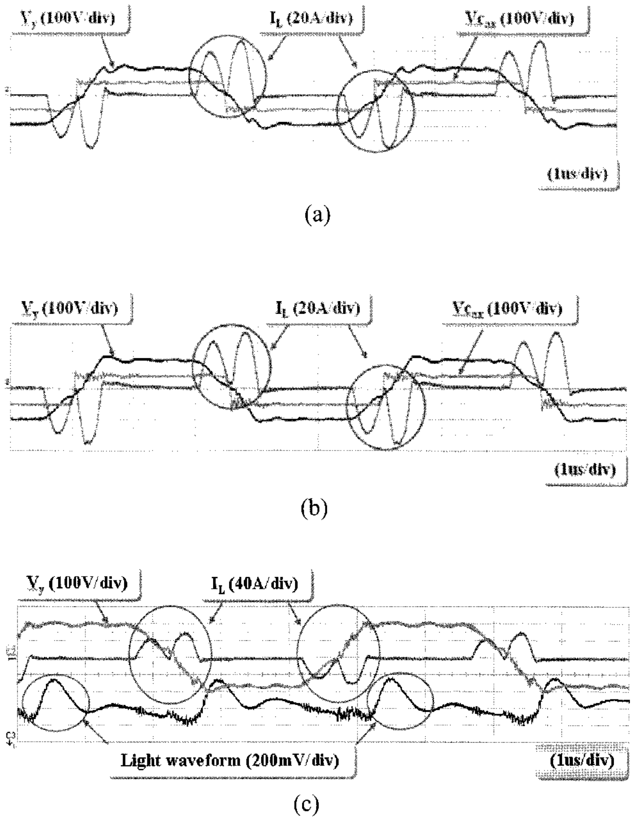


Fig. 9 Total circuit of proposed driver

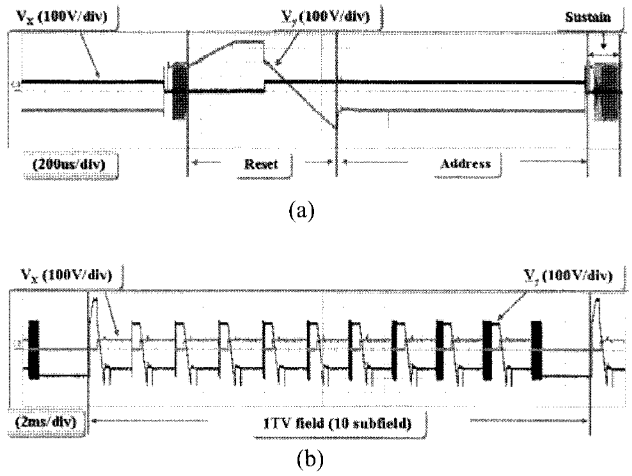
3. Experimental Results

An experiment was performed about the proposed driver to realize the dual resonant method and to prove its usefulness of that by applying it to a 42 inch HD PDP panel, and the dual resonant waveform is shown in Fig 10 as a result of the experiment. Fig 10(a), (b) is a magnified waveform of the sustaining field, and it shows Y electrode voltage(V_y), resonant current of inductor(I_L), and auxiliary capacitor voltage(Vc_{ax}). Sustaining voltage was applied by 180V to discharge the panel completely. While V_y is changed between V_s and $-V_s$, I_L that is a resonant current between L and panel capacitance(C_p) occurs twice according to invert Vc_{ax}. The first current takes place while V_y rises from $-V_s$ to 0V like the mode1 in the Fig 8(a) and the second current occurs while V_y rises from 0V to V_s like mode 2 in Fig 8(b). In this period including a duration kept at V_s level, Vc_{ax} is always kept at a half voltage level of sustaining voltage, so the voltage stress of the energy recovery switches can be maintained as $1/2V_s$. Moreover, according to this waveform, we can find that the peak point of the second resonance current is higher than that of first resonance current, which is based on the length of the second resonance path longer than the first resonance path on a real driving board. This affects the resonant frequency by changing the inductance value on the path. For that reason, such a waveform can appear. Fig. 10(b) is the undischarged waveform, so the displacement current only exists in the panel. We can find that the dual resonant operation occurs in any condition from these waveforms. Fig. 11 shows every period as well as the sustaining period. We can see that not only the sustaining function but also the other functions are driven well.



(c)

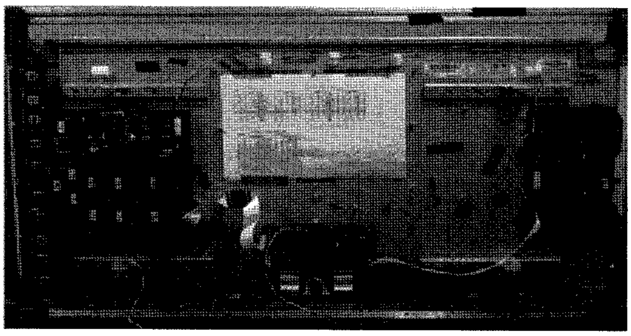
Fig. 10 Sustain period waveforms of dual resonant method
(a) Waveforms of V_y, Vc_{ax} and I_L with discharge
(b) Waveforms of V_y, Vc_{ax} and I_L without discharge
(c) Waveforms of V_y, I_L and light waveform



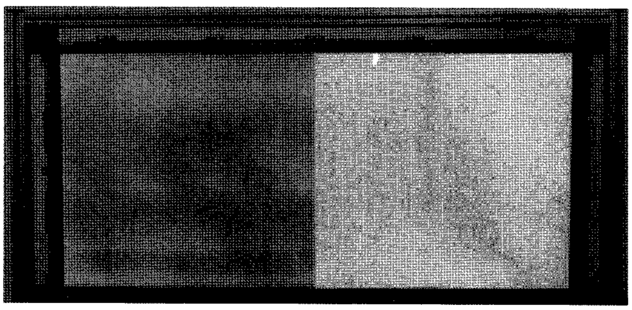
(b)

Fig. 11 Total period(reset, address, sustain)waveforms of the proposed driver
(a) One subfield waveforms of V_x and V_y
(b) One TV field waveforms of V_x and V_y

Fig 12 shows the PDP module and its discharge picture applied to the proposed method. In Fig 12(a), the Y board circuit is located on the left side of the module and the X board circuit is located on the opposite side. According to this picture, most of the function including the sustained function is concentrated on the Y board, while the X board only has minimum functions without the sustained function. Moreover, the different discharge status of both sides of the panel is found in Fig 12 (b). The single sustaining drive has a serious defect which is an interruption by address electrode, so misfiring occurs between the Y electrode, which has a sustaining function and address electrode. Thus, a synchronized pulse with the sustaining pulse is applied to address electrode in the sustaining period to minimize interference by the electrode. It is defined as data switching, and fig 13 clearly shows a concept of the data switching. Accordingly, the right side of the discharge picture is much brighter than the left side because data switching is only applied to the right side. Fig 14 shows the waveform which applies the data switching method in the sustained period.



(a) PDP module applied proposed method



(b) Discharge using proposed method

Fig. 12 Prototype of the proposed method built in 42-inch HD PDP and its discharge

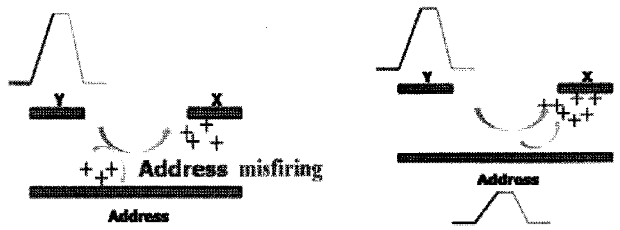


Fig. 13 A concept of data switching

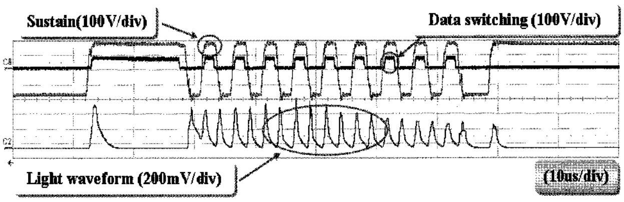


Fig. 14 Sustain waveform applied data switching

4. Conclusions

In this paper, a single board PDP sustaining circuit applied dual resonant method is proposed, and the circuit is verified through a driving experiment with an actual 42 inch HD PDP panel. To realize a single side sustaining circuit without increase of voltage stress of the energy recovery switch, a dual resonant energy recovery concept using a charge pump method is adopted. Accordingly, this circuit has an important merit in that it can maintain voltage stress of the energy recovery switch the same as that of a conventional circuit, though the switch is reduced. To understand the voltage stress objectively, we compared it to a single resonant method which performs energy recovery through just one resonance, and is realized by replacing the auxiliary capacitor to the GND in the proposed circuit. Fig.15 shows the single board PDP sustaining driver using the single resonant method. In table 1, we find that the voltage stresses of Y_r and Y_f are half of the single resonant method.

Table 1 Comparing voltage stress with single resonant method

	Dual resonant	Single resonant
Y_s	Vs	Vs
Y_g	Vs	Vs
Y_h	Vs	Vs
Y_L	Vs	Vs
Y_r	Vs/2	Vs
Y_f	Vs/2	Vs

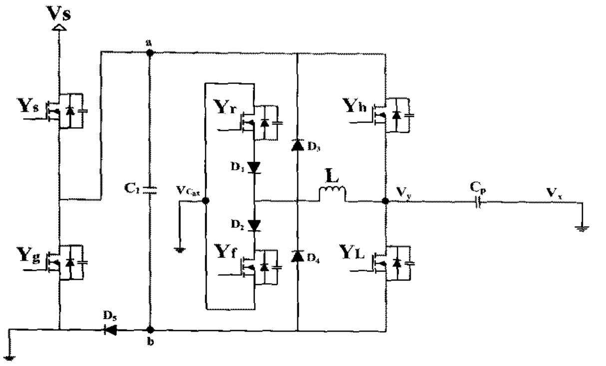


Fig. 15 Single resonant single board PDP sustaining driver

In addition, despite an increase of a sustaining switch count above a conventional single sustaining driver(Fig.5), by applying the charge pump concept, this circuit enables a single power source to be used as well as a reduced voltage stress of sustaining switches. Therefore, the proposed driver is expected to be suitable for a low-cost PDP sustaining driver.

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