A New Sustain Driving Method for AC PDP : Charge-Controlled Driving Method

Joon-Yub Kim*

Abstract - A new sustain driving method for the AC PDP is presented. In this driving method, the voltage source is connected to a storage capacitor, this storage capacitor charges an intermediate capacitor through LC resonance, and the panel is charged from the intermediate capacitor indirectly. In this way, the current flowing into the AC PDP when the sustain discharge occurs is reduced because the current is indirectly supplied from a capacitor, a limited source of charge. Thus, the input power to the output luminance efficiency is improved. Since the voltage supplied to the storage capacitor is doubled through LC resonance, this method can drive an AC PDP with a voltage source of about half of the voltage necessary in the conventional driving methods. The experiments showed that this charge-controlled driving method could drive an AC PDP with a voltage source of as low as 107V. Using a panel of the conventional structure, luminous efficiency of 1.28 lm/W was achieved.

Keywords: Plasma Display Panel(PDP), low voltage driving, low power consumption, high efficiency driving method, energy recovery circuit

1. Introduction

Because the Plasma Display Panel (PDP) has merits such as light weight, thin volume, wide viewing angle and manufacturability for large screen, it has been receiving attention as a next generation large screen display device. Nevertheless, some of its characteristics such as power consumption, picture quality and cost should be improved before it can be more widely used. Also, an efficient driving method for high-resolution display should be developed [1-4]. Many contributions for improving the power efficiency of the AC PDP have been made [5-12]. However, the low power efficiency is still one of the major problems of the present PDP. Most power in AC PDP is consumed during the sustain period [10-13]. The major current into the AC-PDP during the sustain period is the current that flows into the PDP at the moment when the discharge is fired [13].

There are several energy recovery circuits that have been proposed to improve the energy efficiency of the PDP by Weber [8], Sakai [9], Takahiro [10], and Yang [11]. These energy recovery circuits for the AC PDP utilize the LC resonance in common. The energy recovery circuit by Weber is composed of inductors, capacitors, and switches. When the voltage of one side of the panel goes down, the charge from the panel is stored in a storage capacitor. When the voltage of the same side of the panel goes up at the next period, the charge stored in the storage capacitor is reused to charge up the panel.

The energy recovery circuit by Sakai is composed of inductors and switches, but it does not include any capacitor. When the voltage across the panel is reversed, the charge from one side of the panel is directly supplied to the other side of the panel.

The energy recovery circuit by Takahiro is similar to the energy recovery circuit by Sakai. At the beginning of the ramping voltage applied to the panel, the current supplied to the panel is limited by using larger inductance in the resonance circuit. Right before the ramping voltage reaches the discharge voltage, the inductance in the resonance circuit is reduced such that the resonance circuit can supply the large discharge current. On the other hand, Takahiro's method requires more components and the switching timing is complicated. The energy recovery circuit by Yang uses the charge from one half of the panel to charge the other half of the panel. This method improves the power efficiency by reducing the capacitance in the LC resonance circuit to 1/2.

It is noted that all the energy recovery circuits for the AC PDP discussed above are focused on reusing the charge that flows out of the panel when the voltage across the panel is decreased to zero. However, the large current that flows into the panel when the panel discharges does not flow out even when the voltage of the panel is reduced to zero. The major charge stored in the panel flows out

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when the panel discharges in the reverse direction at the next half period. Thus, the energy recovery circuits discussed above have limitation in the energy recovery efficiency.

2. Charge-Controlled Driving Method

The new sustain driving method, a charge-controlled driving method, is shown in Fig.1. The charge-controlled driving method utilizes the storage capacitor, C_{ss}, similar to that in Weber's circuit, but this driving method has an intermediate storage capacitor, C_s, in addition. The voltage source is connected to the storage capacitor. Once the storage capacitor is charged to V_{ss}, the intermediate storage capacitor is charged from the storage capacitor through LC resonance. Then the panel is charged from the intermediate storage capacitor indirectly. In this way, the ramping rate of the voltage applied to the panel can be controlled independently of the LC resonance circuit. Also, in the charge-controlled driving method, the charge supplied to the panel is controlled by the capacitance of the intermediate storage capacitor. The main cause of the low luminous efficiency of the PDP is the large current into the panel when the panel discharges. In the charge-controlled driving method, because this large discharge current is limited, the luminous efficiency should be improved. Furthermore, in the charge-controlled driving method, the power supply is connected to the storage capacitor and the voltage is doubled when the storage capacitor charges the intermediate capacitor. Thus, we can drive a PDP with about a half of the voltage necessary in the conventional driving methods.

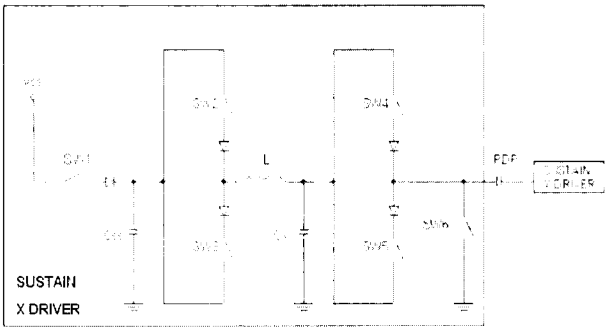


Fig. 1 Charge-Controlled Driving Method

After the panel completes the discharge, the charge in the intermediate storage capacitor, C_s, and the panel is recovered in the same way as in Weber's energy recovery circuit. Thus, principally the charge-controlled driving method should have about the same energy recovery efficiency as Weber's energy recovery circuit.

The switching sequence and the operation principle is as follows. First, C_{ss} is charged to V_{ss} by closing the switch SW1. Next, the charge stored in C_{ss} is supplied to the intermediate storage capacitor, C_s, through the inductor L by closing the switch SW2. If the capacitance of C_{ss} is much larger than the capacitance of C_s, the voltage across C_s will become twice V_{ss}. Next, by closing the switch SW4, the intermediate capacitor is connected to the panel and supplies charge to the panel. As the intermediate storage capacitor supplies the charge to the panel, the voltage across the PDP will increase and the discharge will be fired. However, in this new driving method, the supply of charge to the panel when the discharge occurs will be limited because the charge is supplied from the limited source of the charge, C_s. After the discharge of the panel, by closing the switches SW3 and SW5, the charge in the panel and the intermediate storage capacitor is restored into C_{ss} through LC resonance. Then the switch SW6 is closed to ground the side of the panel. In this way, switch SW4 can independently control the ramping rate of the voltage across the panel.

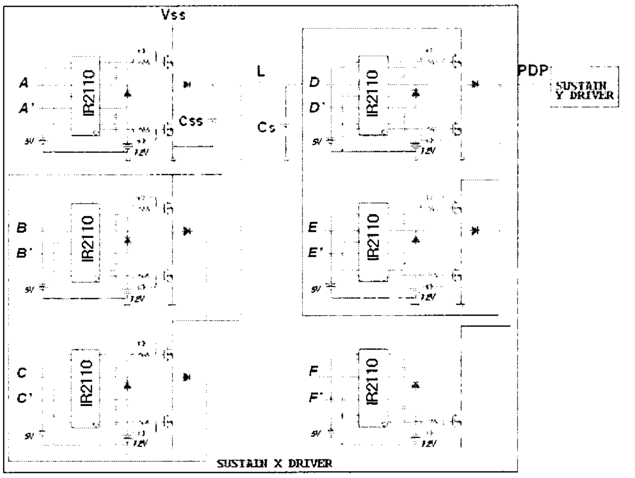


Fig. 2 Circuit Diagram for the Charge-Controlled Driving Method

3. Experimental Result

The charge-controlled driving method was realized with actual devices as shown in the circuit diagram of Fig.2. The switches were implemented using MOSFETs, IRF740 and the switch MOSFETs were driven by the driver ICs, IR2110. IR2110s generate the floating gate-source voltages for the switch MOSFETs.

The driver ICs are controlled by the pulse signals applied to the terminals A, B, C, D, E and F. Fig.3 shows the experimental setup for the measurements of power consumption and output luminance. A 4-inch panel was used in the measurement. By multiplying the voltage from the DC power supply and the average current measured with the digital multimeter, the input power to the system including the driving circuit and the panel was calculated. The out luminance was measured with luminance colorimeter, BM7.

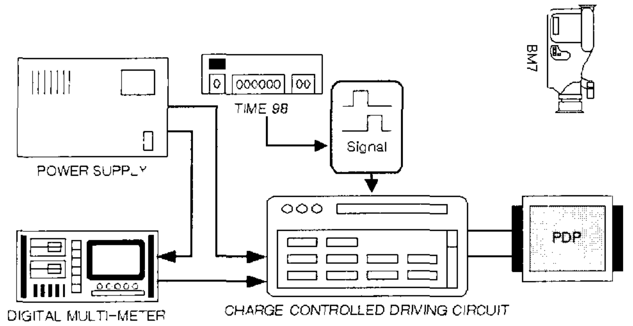
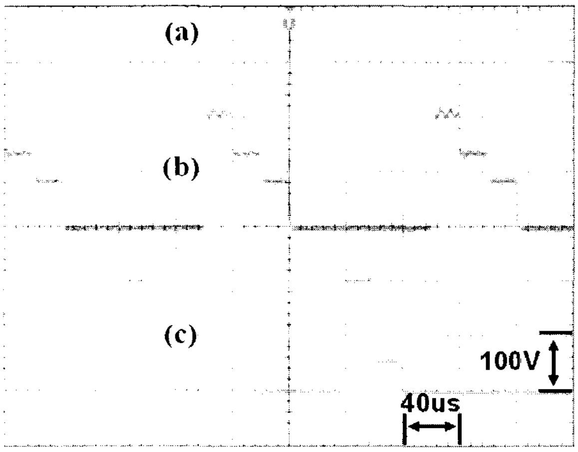


Fig. 3 Experimental Setup for measurement of power consumption and luminance



(a) Input voltage to C_{ss}, (b) Voltage of C_s, (c) Voltage at the panel

Fig. 4 The Oscilloscope Waveforms of the Charge-Controlled Driving Method

Fig.4 shows the waveforms observed on the oscilloscope. (a) is the input voltage supplied to the storage capacitor C_{ss}, (b) is the voltage of the intermediate storage capacitor, C_s, and (c) is the voltage at one side of the panel. Comparing the waveforms of (a) and (b), it is seen that the supply voltage is effectively doubled through LC resonance and transferred to the intermediate storage capacitor. This means that the charge-controlled driving method can drive AC PDPs with a power supply of about a half of the voltage necessary in the conventional sustain driving circuits.

First, to find the most suitable value for the storage capacitor C_{ss}, we fixed the capacitance of the intermediate storage capacitor C_s to 50nF, 100nF and 150nF, the inductance of the inductor L to 11uH, and measured the minimum power supply voltage necessary for different values of C_{ss}. The result is shown in Fig. 5. From Fig. 5, we can see that the necessary minimum power supply voltage reduces until C is increased to 47uF. Thus, 47uF was selected for the capacitance of C_{ss}. Next, to select the values for the inductor L and the intermediate capacitor C_s, the minimum necessary power supply voltage was measured for different values of L and C_s. Fig.6 shows the results. Generally speaking, as the inductance is increased, the minimum supply voltage decreases. Also, as the capacitance of the intermediate storage capacitor C_s is increased, the minimum power supply voltage decreases. Specifically when 47uF is used for C_{ss}, 11uH for L, and 150nF for C_s, the charge-controlled driving method can drive the panel with 107V. This voltage is half of the 213V that is necessary when the conventional sustain driving method is used.

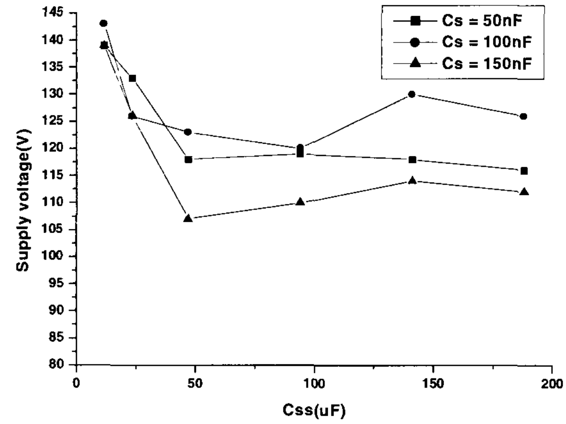


Fig. 5 Supply voltage as a function of Css

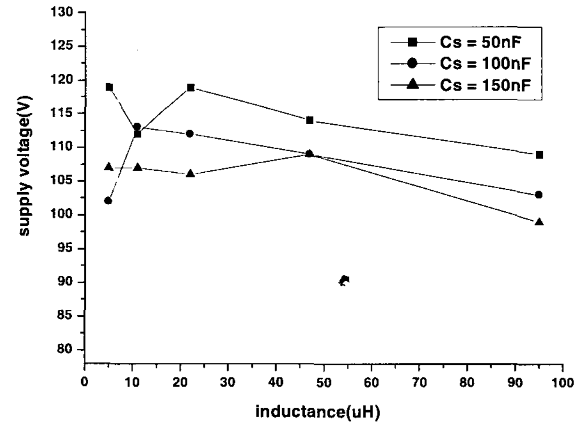


Fig. 6 Supply voltage as a function of Inductance

The luminous efficiency is expressed as

$$\eta = \frac{\pi BS}{P_i} = \frac{\pi BS}{V(I_{on} - I_{off})} \qquad (1)$$

where B is luminance, S is display area, P_i is input power, V is input voltage, I_{on} is average current when the load is on and I_{off} is average current when the input voltage is right below the turn-on voltage. If we use the input power into the panel for P_i in Eq.(1), Eq.(1) represents the luminous efficiency of the panel. If we use the input power into the system that includes the driving circuit and the panel for P_i in Eq.(1), Eq.(1) represents the luminous efficiency of the system.

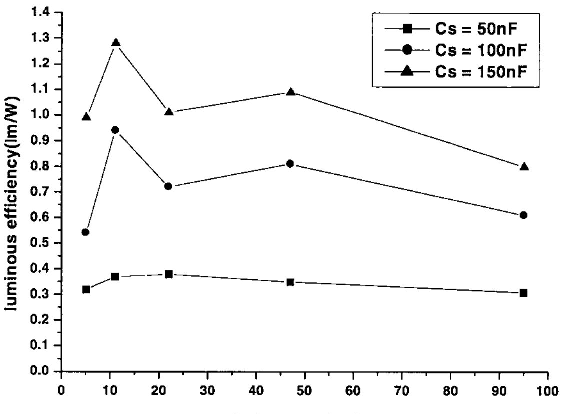


Fig. 7 The Luminous efficiency as a function of Inductance

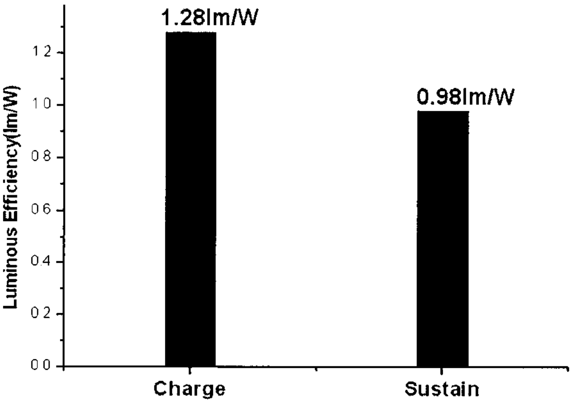


Fig. 8 The luminous efficiency of the Charge-Controlled Driving Method and the conventional sustain driving method

Fig.7 shows the measured luminous efficiency of the system consisting of the charge controlled driving circuit and the panel. Fig.8 compares the luminous efficiency of the charge controlled driving circuit with that of the conventional sustain driving circuit.

When the charge-controlled driving method was used with C_{ss} of 47uF, C_s of 150nF and L of 11uH, the luminous efficiency of 1.28 lm/W was measured. The luminous efficiency of the conventional sustain driving circuit was measured to be 0.98 lm/W. Thus, the charge-controlled driving method improved the luminous efficiency by 30.6%.

4. Conclusion

A new sustain driving method for the AC PDP was introduced. The experimental characterization results of the charge-controlled driving method were presented. This driving method supplies the discharge current of the panel from the intermediate storage capacitor, the limited source of charge. This limits the input power to the panel, while the output luminance is not reduced as much. Thus, the luminous efficiency can be improved in this method. In the charge-controlled driving method, first, the storage capacitor is charged from the power supply, and then the intermediate storage capacitor is charged from the storage capacitor through a L-C resonance circuit. By the LC resonance, the intermediate capacitor is charged up to about twice the voltage of the storage capacitor. Thus, the method can drive the AC PDP with a low voltage. Furthermore, the ramping rate of the voltage applied to the panel can be controlled independently of the LC resonance circuit. When the conventional energy recovery circuits are used, the independent control of the ramping rate is difficult.

The experimental results showed that the charge-controlled driving method could drive an AC PDP with a voltage as low as 107V and luminous efficiency of 1.28 lm/W.

The experimental test results suggest that the charge-controlled driving method is a low voltage and high luminous efficiency sustaining driving method for the AC PDP. The charge-controlled driving method should serve as a solution to the low efficiency problem of the AC PDP and thus provide the PDP with a better capability to compete with other displays.

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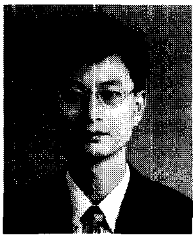

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