Improved PDP Driving Methods Based on Three Wall Charge States

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ABSTRACT

We present gray scale implementation method based on QMA driving technique. We clarified the mechanism of wall charge quantization through discharge current measurement. We used three wall charge states to implement gray scale. The cells would be one of fully-ON, half-On, and OFF states. We built a five sub-fields 243 level gray scale with sustain pulse count of 2, 6, 18, 54, and 162.

Introduction

Recent efforts to develop HDTV class PDP (Plasma Display Panel) face difficulties in improving the luminous efficiency, resolution, contrast ratio and so forth[1-3]. Since these difficulties originated from both material characteristics and PDP driving techniques, development of better PDP driving method is crucial.

In this work, we investigated a new gray scale implementation technique with three wall charge states. This method adopts the principle of the quantized memory addressing but is a much simpler version applicable to the current panel manufacturing technology.

Veryfication of Quantized Wall Charges

AC PDP driving methods utilizing the wall charges have been developed since 1970's[5]. The popular ADS type AC PDP driving methods use two wall charge states and eight weighted sub-fields to implement 256 gray scale. The wall charge states are initial conditions to the sustain periods during which graphic information is displayed. If a discharge cell contains enough wall charges at the beginning of the sustain period, glow discharges occur in response to the sustain pulses. On the other hand, no glow discharge occurs during the sustain period when there is no wall charge. In one picture frame, there are eight sub-fields in Fig. 1 and each sub-field consists of an address period and a sustain period. All of the address periods have same length in time while the sustain periods have different lengths. *N*th sub-field has a sustain period whose length is 2^N times longer than that of the shortest sub-field, SF1. In some sub-fields, the address period is longer than the sustain periods. For higher resolution displays, this problem becomes more serious since there will be more electrodes to scan.

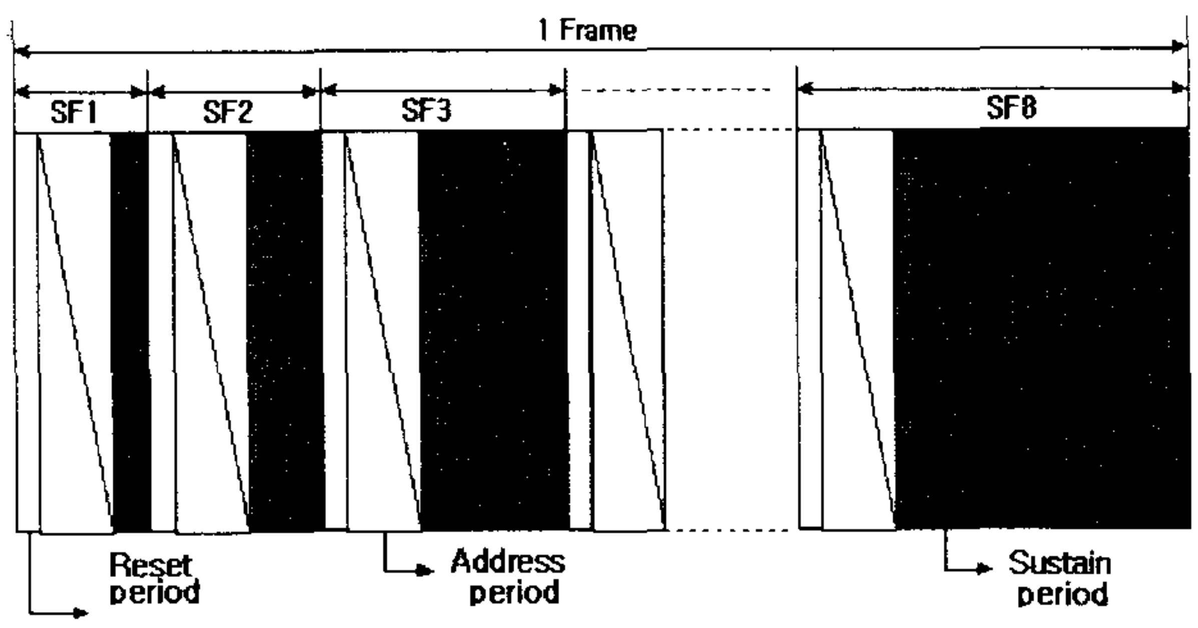

Fig. 1 Constituents of one picture frame of the ADS driving scheme

A new gray scale implementation method, the quantized memory addressing(QMA)[7], is proposed to overcome the above mentioned problems. The most prominent characteristic of the QMA driving method is multiple wall charge states set during the address period. When the same number of sustain pulses are applied to the cells with different wall charges, a cell with more wall charges becomes brighter than a cell with less wall charges.

Nolan[6] used diminishing discharges and tried to control the discharge lifetime to realize gray scale. However, the time varying discharge intensity is difficult to use as a control variable for gray scale. Furthermore, since the discharge lifetime is controlled by the pulse amplitude modulation, higher luminance needs higher voltage and results excessively strong discharge.

In our case, the variable intensity discharges, whose intensities were set by pulse width modulation of the address pulses, were maintained throughout the sustain period. Therefore, we can use two control variables, the number of sustain pulses and the wall charge quantity, to implement the gray scale.

In Fig. 2, address pulse waveforms (top) and corresponding discharge currents (bottom) are shown. For 2.5 usec wide address pulse, discharge occurs fully while discharge terminates prematurely when shorter address pulses are applied. Since the area of the discharge current is proportional to the accumulated wall charges, one can see that the pulse width modulation of address pulse controls resulting wall charge quantities.

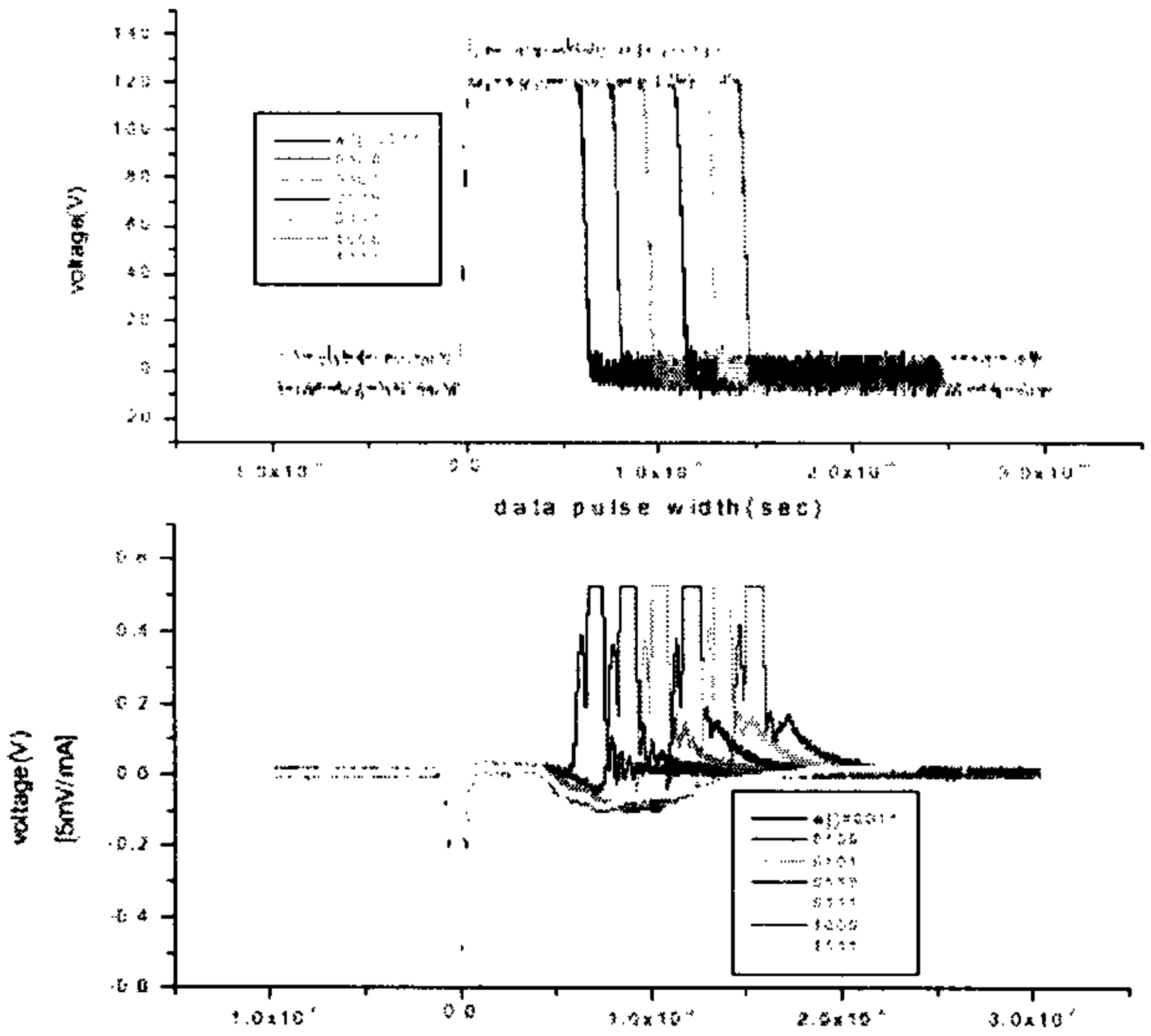

Fig. 2 Address pulse (top) and corresponding discharge currents (bottom).

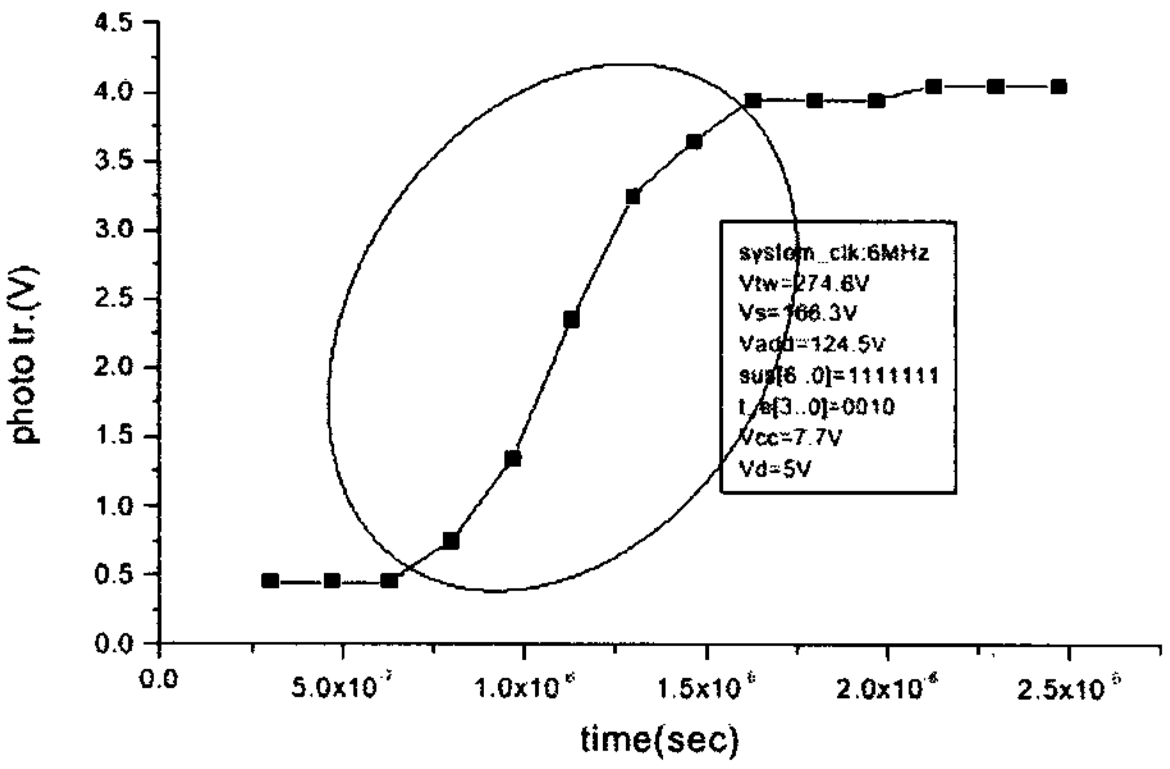

Fig. 3 Luminance obtained by applying 255 sustain pulses for different address pulse widths.

Fig. 3 shows the luminance obtained when applying 255 sustain pulses for different address pulse widths. As expected from Fig. 2, the luminance is proportional to the address pulse widths between 0.6 usec and 1.6 usec. Outside of the range, the test panel is either OFF or fully on.

To test further, we applied different subfield combinations and measured the luminance for different address pulse widths. In Fig. 4, the square symbol represents 255^{th} gray level while the circle symbol represents 127^{th} gray level and so on. For 2.5 usec wide address pulse 127^{th} gray level exhibits the luminance which is about 50% of 255^{th} gray level. This luminance difference is maintained for shorter address pulse widths. From this result, one can implement the gray scale with QMA driving method.

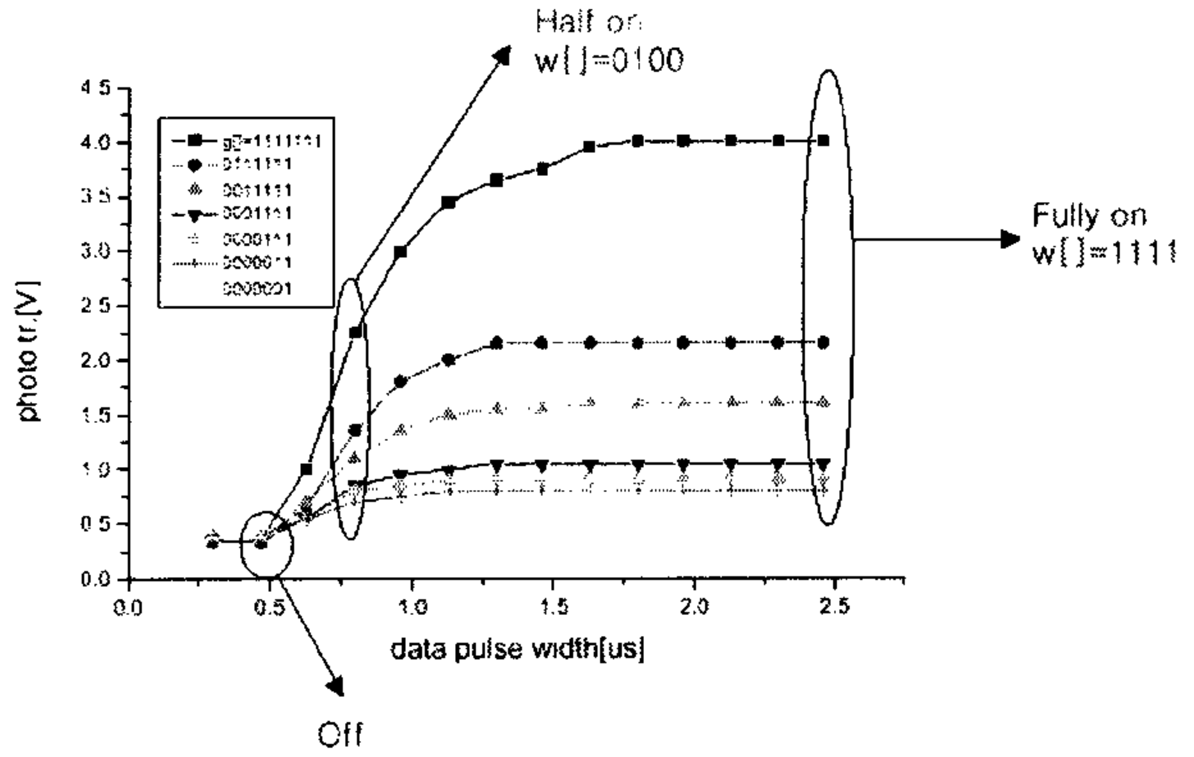

Fig. 4 Luminance measured for various subfield combinations with different address pulse widths.

Gray Scale Implementation with Three Wall Charge States

Ideally, the QMA method can eliminate the use of sub-field only if one can define 256 different wall charge states. In that case, one picture frame may consists of one address period and one sustain period to implement 256 gray scale. Regarding current technology, we decided to define three wall charge states. For fully-on state we applied 2.0 usec wide address pulse while we applied 0.8 usec pulse for half-on state. The driving waveforms for three electrodes are shown in Fig. 5.

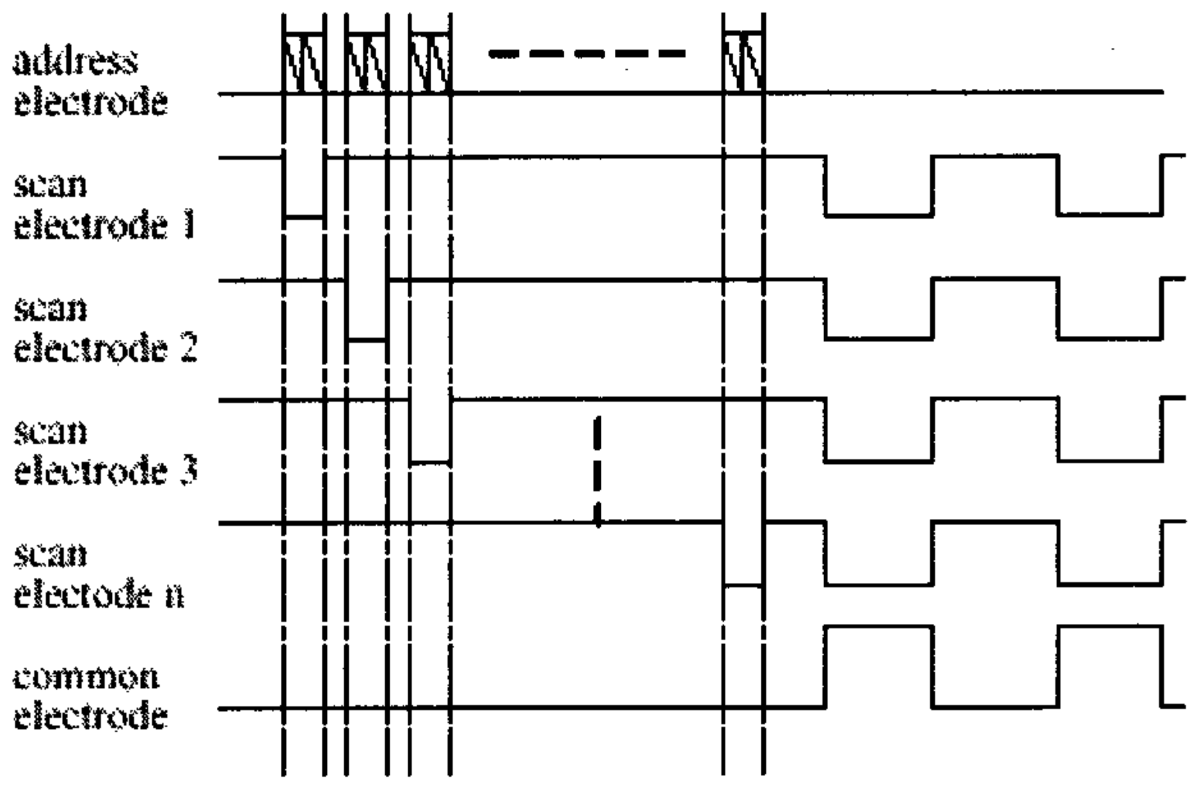

Fig. 5 Driving waveforms for three wall charge states

As can be seen from the Fig. 5, the address pulse for one line is consisted of two pulses. When one wants to setup fully-on state, two pulses are applied to the address electrodes. When one wants to achieve medium wall charge quantity, only one address pulse is applied.

After applying address pulses to setup wall charge quantity, sustain pulses are applied between scan and common electrodes. During this sustain period, the same number of sustain pulses are applied to all the discharge cells in the PDP. If the sustain period contains N pulses, cells with maximum wall charges emits photons that corresponds to Nth gray level. For cells in the "half-on" state, emitted light corresponds to

(N/2)th gray level as shown in Table 1.

Table 1 Gray scale for different wall charge state

Number of sustain pulses	Gray level of fully ON	Grey level of Half-ON
2	2	1
6	6	3
18	18	9
54	54	27
162	162	81

The five numbers (2, 6, 18, 54, 162) in Table 1 represent the number of sustain pulses in sub-fields which we used in our experiment. And since sum of the five numbers are 242, we can implement 243 level gray scale with only 5 sub-fields as shown in Fig. 6.

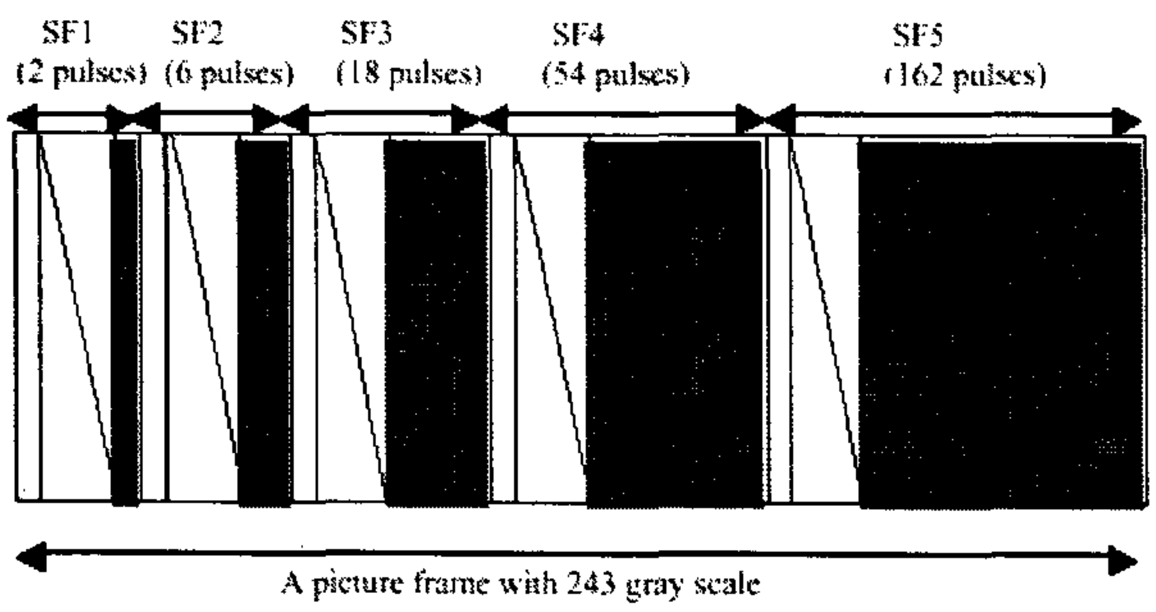

Fig. 6 Composition of one picture frame with the new five subfield 243 level gray scale system.

Table 2 shows how we combine the five sub-fields to obtain gray scale. The symbol "$1^{1/2}$" represents the half-ON state where 50% of the wall charges were setup by the address pulses. With this scheme, the gray levels 1, 2, 3 can be written as $0000 1^{1/2}$, 00001, $0001^{1/2}0$, respectively.

Implementation of 243 level gray scale with only five sub-fields is advantageous since we can have more time to scan electrodes and more time to display graphic information. Therefore, better PDP characteristics than those obtained with ADS method can be achieved.

We have used three electrodes, planar discharge type, 2-inch test panel with gas mixture of Ne-4%Xe 300 Torr and RGB phosphors. The spacing between x-y electrodes was 90 um. The firing and sustain voltage, at which all cells in the panel begin to exhibit stable discharge, was 210 and 150 volts, respectively. We measured luminance and discharge currents of the test panel to check the validity of the QMA driving method. The sustain pulses were 50 KHz, 150 volts.

We designed a new controller which controls the number of the sustain pulses with multiplier as schematics shown in Fig. 7. This controller was programmed to Altera MAX7128 FPGA chips.

We used three photo-transistors connected in parallel to collect photo current from the glow discharges. We used an array of 45x8 discharge cells throughout our experiments. The photo current was converted to photo voltage by a collector resistor. To measure the discharge current directly, we used Tektronix CT-1 current probe. The photo voltage from the photo transistor represents time averaged luminance of the panel since we read the voltage on a digital multi-meter. On the other hand, the discharge current measured by CT-1 current probe showed detailed discharge current behavior since it is monitored through Tektronix TDS3054 four channel digital oscilloscope. In addition, the digital oscilloscope monitors voltage waveforms applied to the three electrodes types.

Table 2 Five sub-fields combination for gray scale

Gray level (sus. Pulse)	SF5 (162)	SF4 (54)	SF3 (18)	SF2 (6)	SF1 (2)
0	0	0	0	0	0
1	0	0	0	0	$1^{1/2}$(1)
2	0	0	0	0	1(2)
3	0	0	0	$1^{1/2}$(3)	0
4	0	0	0	$1^{1/2}$(3)	$1^{1/2}$(1)
5	0	0	0	$1^{1/2}$(3)	1(2)
6	0	0	0	1(6)	0
7	0	0	0	1(6)	$1^{1/2}$(1)
8	0	0	0	1(6)	1(2)
9	0	0	$1^{1/2}$(9)	0	0
10	0	0	$1^{1/2}$(9)	0	$1^{1/2}$(1)
11	0	0	$1^{1/2}$(9)	0	1(2)
....	....	....	....	....	....
237	1 (162)	1(54)	1(18)	$1^{1/2}$(3)	0
238	1 (162)	1(54)	1(18)	$1^{1/2}$(3)	$1^{1/2}$(1)
239	1 (162)	1(54)	1(18)	$1^{1/2}$(3)	1(2)
240	1 (162)	1(54)	1(18)	1(6)	0
241	1 (162)	1(54)	1(18)	1(6)	$1^{1/2}$(1)
242	1 (162)	1(54)	1(18)	1(6)	1(2)

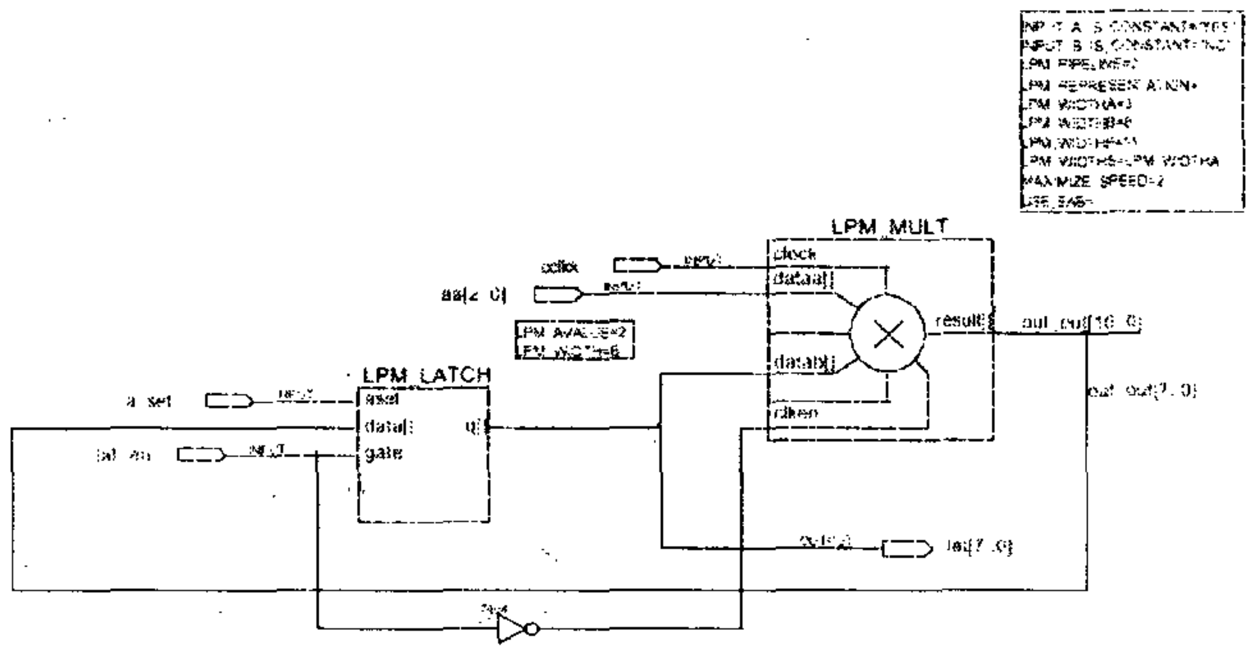

Fig. 7 A new controller circuit for generating the new sub-field pulse pattern

Conclusion

We investigated how wall charges can be quantized by modulating address pulse widths. We adopted a new QMA[7] driving method and compromised to today's panel technology by utilizing three wall charge states, ON, OFF, and half-ON. We demonstrated a new gray scale implementation technique which combines conventional pulse count modulation and PWM of address pulses. We showed that 243 level gray scale is achievable with only five sub-fields with pulse count of 2, 6, 18, 54, and 162. With the new technique, it is possible to improve the PDP driving characteristics since we can reserve more time for line scanning and/or sustain discharge.

Acknowledgement

Financial support from the Ministry of Information and Communicationof Korea through IMT-2000 Research Fund is gracefully acknowledged.

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