LETTER

New Multi-Luminance-Level Subfield Method for Reducing Low Gray-Level Contour in AC Plasma Display Panel

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SUMMARY A new multi-luminance-level subfield method is proposed to reduce the low gray-level contour of an alternate current plasma display panel (AC-PDP). The minimum or maximum luminance level per sustain-cycle can be altered by simultaneously applying the proper auxiliary short pulses. As a result, the multi-luminance levels per one or two sustain pulse pairs can be expressed by properly adjusting the auxiliary short pulses for the one or two sustain-cycle subfields, thereby suppressing a low gray-level contour of AC-PDP.
key words: plasma display, inverse gamma correction, low gray-level contour

1. Introduction

Plasma display panel (PDP) is an emerging consumer electronic appliance as a new large-area full-color wall-mounted digital high definition television (HD-TV). Recently, the realization of the high-class PDP-TV requires a high quality image. However, there still remain serious problems about an image quality, such as dynamic false contour and low gray-level contour [1].

A low gray-level contour problem is unavoidable in a typical ADS (Address Display Separated) driving scheme, because it is basically attributed to the inverse gamma correction which is a requisite procedure for displaying images of PDP-TV. The input and output signals of an inverse gamma correction of PDP are 8 bit digital signal, and have 256 different levels. Because of the inverse gamma correction, several gray levels are merged into a fixed output luminance level, especially for the low input signal level up to 50. This merging effect causes abrupt change in visual gradation patterns leading to the low gray-level contours. The CLEAR (High-Contrast, Low Energy Address and Reduction of False Contour Sequence) driving method has been suggested to improve a gray-level expression in a low luminance image [2]. It is reported that this method contributes to suppressing the low gray-level contour. However, this method is quire different from the typical ADS driving scheme, in that for gray-scale expression the ADS driving scheme uses the combination of sub-

fields, whereas the CLEAR driving method uses the accumulation of subfields. In addition, in a typical ADS driving method, a signal processing method using error diffusion and dithering has been suggested to improve a gray-level expression in a low gray-level region [3]. However, this method may alleviate the low gray-level contour problem more or less, but can not provide the fundamental solution for the low gray-level contour problem. In order to counteract the disappearance of several low gray levels due to the inverse gamma correction in a typical ADS driving scheme, it is the best method to increase the luminance-steps available for the low gray scale. The minimum or maximum luminance level per one sustain-cycle should be altered so as to increase the luminance-steps for the low gray level.

In this letter, a new multi-luminance-level subfield method is proposed to improve the low gray-level color reproducibility. This method can express the various luminance levels in the same one or two sustain-cycle subfield condition by selectively applying the auxiliary address pulses with various amplitudes and delayed times to the address electrodes during a sustain-period.

2. Low Gray-Level Contour Problem in PDP

Since the PDP has a linear electro-optical transfer characteristic, the output luminance level is determined with respect to the input signal level according to the inverse gamma correction curve of $\gamma=2.2$ illustrated in Fig. 1. Because of the inverse gamma correction, several gray levels are merged into a fixed output luminance level. Especially the low input signals up to 20 correspond to the zero output luminance level, thus causing the severe low gray-level contours. To solve this problem, it is necessary to subdivide the low output luminance level below 2 into the fine or multi-luminance levels.

However, it is not possible to produce the multi-luminance levels per sustain-cycle under the conventional PDP driving technology. As shown in the plane view of the conventional AC-PDP of Fig. 2, the sustain pulses are applied commonly to the red, green, and blue cells through the sustain electrodes X and Y during a sustain-period, whereas no signal is applied to the address electrode Z during a sustain-period. Thus, the
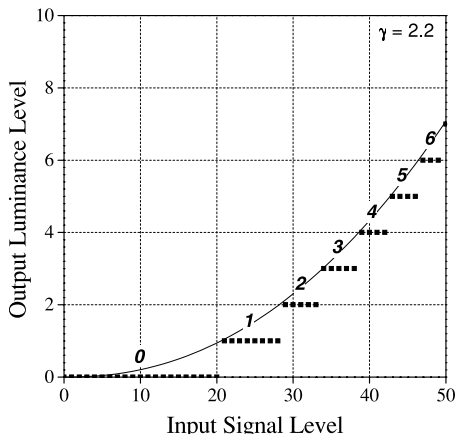
Fig. 1   Relation between output luminance level and input signal level according to inverse gamma correction (γ=2.2) in PDP.
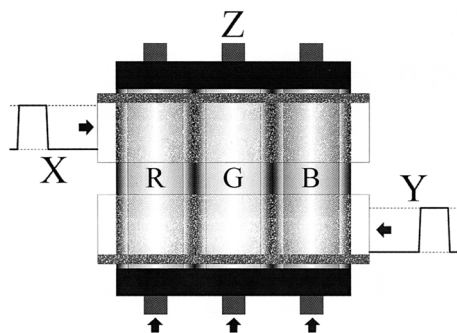

Fig. 2   Plane view of single pixel comprising red, green, and blue cells and three electrodes X, Y, Z of conventional PDP.

luminance levels from the PDP cells are determined by only the number of the sustain-cycles, so that the minimum luminance level depends on the luminance that one sustain-cycle can create. In the conventional driving scheme, the minimum luminance level per one sustain-cycle is relatively high and fixed at a constant value, meaning that one sustain-cycle can also produce the only one luminance level; i.e. one sustain-cycle can not make the multi-luminance levels under the current PDP cell structure and driving scheme.

3.   Multi-Luminance-Level Subfield Method Based on New Driving Scheme Using Short Address Pulses

In the conventional PDP driving scheme, the 256 gray levels are expressed by a combination of 8 subfields in which each subfield consists of the X-Y sustain pulse pairs. The 1-sustain-cycle subfield is composed of the one X-Y sustain pulse pair, whereas the 2-sustain-cycle subfield consists of the two X-Y sustain pulse pairs, as shown in Fig. 3. In this letter, the new driving scheme, which simultaneously applies the auxiliary short pulses
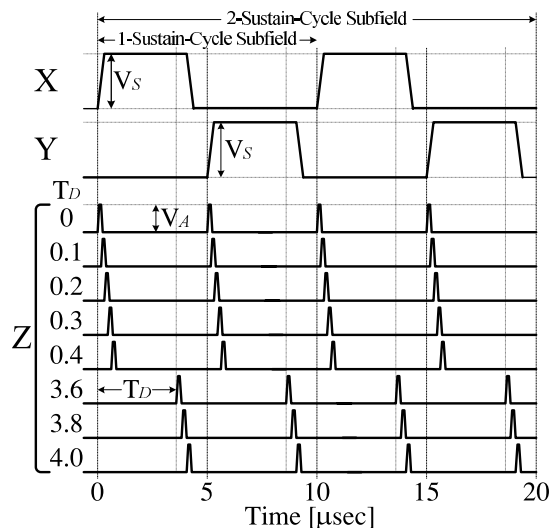

Fig. 3   New driving scheme for the multi-luminance levels in the case of 1-sustain-cycle subfield and 2-sustain-cycle subfield.

Table 1   Measured luminance data with a variation of the T_D and V_A of the auxiliary short address pulses for the 1- and 2-sustain-cycle subfield.

< 1-Sustain-Cycle Subfield >					< 2-Sustain-Cycle Subfield >				
V_A[V]	30	60	90	120	150	V_A[V]	30	60	90	120	150
T_D[μsec] Measured Luminance [cd/m²]					T_D[μsec] Measured Luminance [cd/m²]				
0	1.24	1.25	1.25	1.18	0.88	0	2.81	2.87	2.05	0.84	1.20
0.1	1.28	1.28	1.29	1.15	1.09	0.1	2.92	2.97	2.72	1.83	1.83
0.2	1.31	1.33	1.38	1.32	1.26	0.2	2.88	2.94	3.07	2.82	2.51
0.3	1.29	1.32	1.34	1.35	1.36	0.3	2.90	2.93	2.99	2.95	2.89
0.4	1.25	1.26	1.27	1.29	1.32	0.4	2.80	2.81	2.80	2.78	2.79
3.6	1.32	1.36	1.37	1.37	1.40	3.6	2.72	2.77	2.79	2.75	2.79
3.8	1.33	1.39	1.40	1.38	1.43	3.8	2.65	2.67	2.65	2.66	2.72
4.0	1.31	1.33	1.38	1.38	1.35	4.0	2.58	2.55	2.57	2.51	2.52
No Aux. Pulse	1.25					No Aux. Pulse	2.73				

to the address electrodes in addition to application of the sustain pulses, is proposed to subdivide the luminance levels for the 1- and 2-sustain-cycle subfields, as illustrated in Fig. 3. The use of the auxiliary short pulse can have a significant influence on the sustain discharge characteristics if the amplitudes and the delayed times of the auxiliary short pulse are varied with respect to the sustain pulse. This means that the variation in the amplitude and delayed time of the auxiliary short pulse can increase or decrease the luminance level per sustain pulse.

In this experiment, the sustain pulses with an amplitude of 180 V and a pulse width of 4 μsec are applied to the sustain electrodes X and Y at 100 kHz condition. For the auxiliary short address pulses applied to the address electrode Z, the amplitudes and the delayed times vary from 30 V to 150 V, and from 0 μsec to 4 μsec, respectively, while the width keeps a constant

value of 400 nsec. As shown in Table 1, the various luminance levels are obtained by varying the T_D (delayed time) and V_A (amplitude) of the auxiliary pulses for the 1- and 2-sustain-cycle subfields. The luminance varied from 70% to 114% is obtained for the 1-sustain-cycle subfield, whereas the luminance varied from 31% to 112% is obtained for the 2-sustain-cycle subfield, indicating that the 1- and 2-sustain-cycle subfields can represent the multi-luminance levels. As a result of adopting the new driving scheme, it is observed that the diverse luminance levels can be made even in the one or two sustain pulse pairs.

In this letter, the multi-luminance-level subfield set is selected within the 1- and 2-sustain-cycle subfields according to the following procedure. First, the output luminance level for the conventional 2-sustain-cycle case is assumed to be 2, and this luminance level is chosen as a reference output luminance level. Then, the measured luminance data shown in Table 1 are rescaled into the relative luminance data based on the reference luminance level. However, all the various relative luminance levels can not be used in the multi-luminance-level subfields. Of the relative luminance data, only the luminance levels which can satisfy the following multi-luminance selection criteria are selected as multi-luminance-level subfields:

[1] The minimum luminance level can not be given arbitrarily.

[2] The ith subfield SF_i is not included in the multi-luminance-level subfield set, provided that $L(SF_i) = L(SF_j) + L(SF_k)$ where j, $k < i$ and $j \neq k$. Here, $L(SF_i)$ reperesents the ith output luminance level of the subfield SF_i after the various possible subfields have been sorted and numbered from the minimum luminance level.

[3] The error produced in the low gray level should not be diffused into the higher gray levels. In other words, an element or the sum of some elements in the multi-luminance-level subfield set must be an integer or at least very close to it:

$$\sum_i L(SF_i) = 1.0 \text{ or } 2.0$$

where i is included in the multi-luminance-level subfield set.

[4] The total subfield number including the multi-luminance-level subfield should be within the 12 subfields because the total subfield must be employed within the limited time of a sustain-period.

As a result of adopting the multi-luminance-level subfield selection criteria, five subfields having the relative output luminance levels of {0.8, 1.0, 1.2, 1.4, 1.6} are chosen as the multi-luminance-level subfield set and finally renumbered from SF_1 to SF_5. The selected luminance levels for the 1- and 2-sustain-cycle subfield are illustrated in Fig. 4. For the 1-sustain-cycle sub-
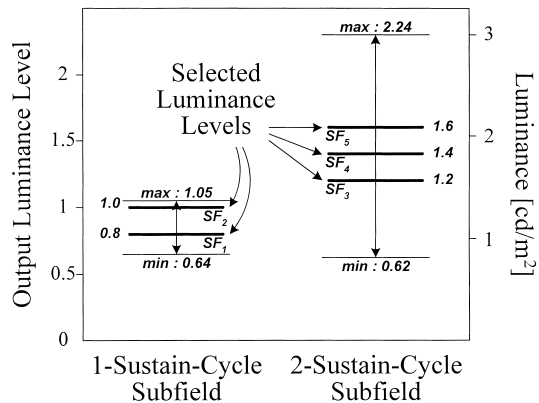

Fig. 4 Selected luminance levels for 1- and 2-sustain-cycle subfield.

field, SF_1 has a relative luminance level of 0.8, and SF_2 has a relative luminance level of 1.0. For the 2-sustain-cycle subfield, SF_3, SF_4, and SF_5 have the relative luminance levels of 1.2, 1.4, and 1.6, respectively. The new method changes the total subfield number from 8 into 11 by selecting the 2 luminance-steps in the 1-sustain-cycle subfield and the 3 luminance-steps in the 2-sustain-cycle subfield, respectively. However, the output luminance levels overlapped by a combination of the multi-luminance-level subfields should be excluded, even though the possible output luminance levels are 32 ($=2^5$) levels by a theoretical combination of the subfields from SF_1 to SF_5. As indicated in Fig. 2, the output luminance levels that matter in this letter are limited up to 6, because a severe degradation of image quality is mainly caused in these levels due to the inverse gamma correction procedure in the conventional subfield method. Consequently, the multi-luminance-level subfield set from SF_1 to SF_5 is used only to express the low gray levels up to 6, and the specific subfields, for example, SF_2 for the output luminance level of 1, and a combination of SF_1 and SF_3 for the output luminance level of 2, are determined in advance to express the output luminance levels 1 and 2 necessary for the higher gray levels. Therefore, for the output luminance levels up to 6, the 28 luminance levels can be expressed in the new multi-luminance-level subfield method, whereas only the 7 luminance levels can be expressed in the conventional subfield method. It is expected that the resultant 28 luminance levels in the 1- and 2-sustain-cycle subfields can improve the expression capability in the low gray level up to 6, thereby resulting in reducing the low gray level contour in AC-PDP.

4. Conclusion

New multi-luminance-level subfield method is proposed to reduce the low gray-level contour of an alternate current plasma display panel (AC-PDP). The luminance

levels in the 1- and 2-sustain-cycle subfields are fine-tuned into 5 luminance-steps by applying various auxiliary short pulses to address electrodes in the same sustain-cycle subfields. As a result, it is confirmed that the 28 luminance levels produced in the low gray level up to 6 by the new multi-luminance-level subfield method can contribute to suppressing a low gray-level contour in AC-PDP. If this method is combined with error diffusion and dithering methods, a low gray-level contour can be suppressed more efficiently.

References

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