# 8.3: New Bipolar Ramp Waveform for Enhancing Low-Gray-Level Expression in ACPDPs

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## Abstract

*A new bipolar ramp waveform that can reduce the minimum luminance level considerably is proposed to improve the low gray level expression in AC-PDP. In the new bipolar ramp waveform, the conventional first subfield with a sustain-period is replaced by the new first subfield that consists of the first negative square pulse and second positive ramp pulse during a scan-period. The weak discharge produced by the second positive ramp pulse is used to generate and control the low luminance level stably.*

## 1. Introduction

The improvement of an image quality in AC-PDP is a critical issue to preoccupy the market share of a large flat panel display device. The poor low gray level expression in AC-PDP is a serious problem [1, 2, 3], as shown in the two images of Fig. 1 which contain the gray-levels up to 50 and are stretched up to 250 gray levels for the display purpose. In order to improve a low gray level expression, at the viewpoint of the image processing like an error diffusion and a dithering, many studies are being performed. Nonetheless, the image processing methods cannot be fundamental solutions for reducing a low gray level problem. To solve this problem fundamentally, the minimum luminance level should be lowered further compared to the luminance generated by the conventional first subfield. However, in the current PDP technology, the minimum luminance level can not be lowered below a certain level due to the use of the luminance generated only by the strong discharge during a sustain-period. If the weak discharge produced by the ramp pulse is used to generate the luminance, the low luminance can be produced stably to a certain level necessary for the low gray level expression.

In this paper, the new bipolar ramp waveform that can reduce the minimum luminance level considerably is proposed to improve the low gray level expression in AC-PDP. In the new bipolar ramp waveform, the conventional first subfield with a sustain-period is replaced by the new first subfield that consists of the first negative square pulse and second positive ramp pulse during a scan-period. The changes in the luminance generated by the weak discharge are examined depending on the various voltage slopes in the second positive ramp pulse.

## 2. Experiment

Fig. 2 shows the schematic diagram of optical measurement system. The measurement system consisted of the 7-in. test AC-PDP panel, its driving system, a color analyzer (CA-100), and IR detector (Photosensor Amplifier, c6386). The test panel has the

(a) Original image

(b) Displayed image

**Figure 1.** Original image (a) and displayed image (b) on PDP.

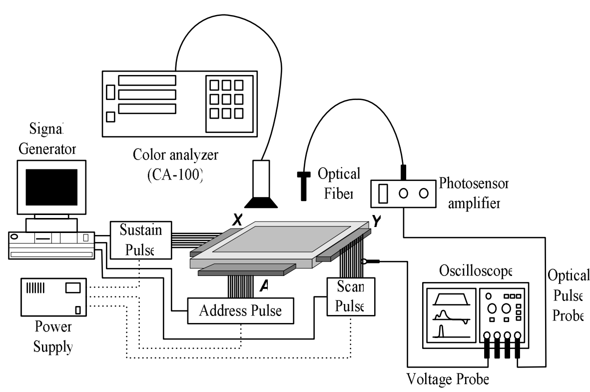


**Figure 2**. Optical measurement system used in this work.

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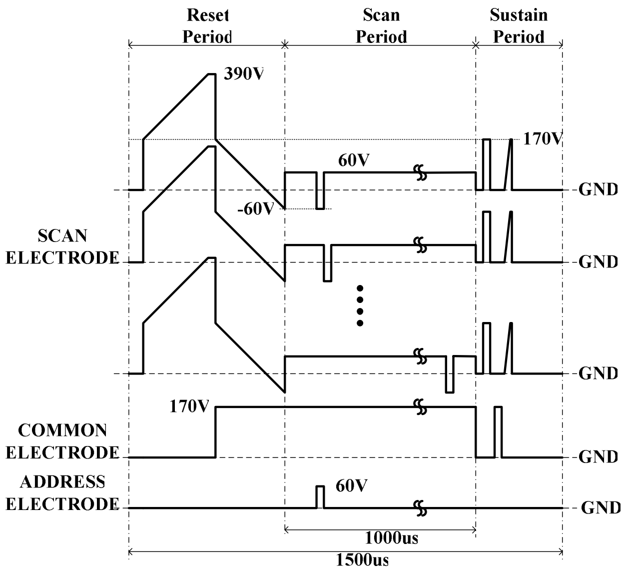
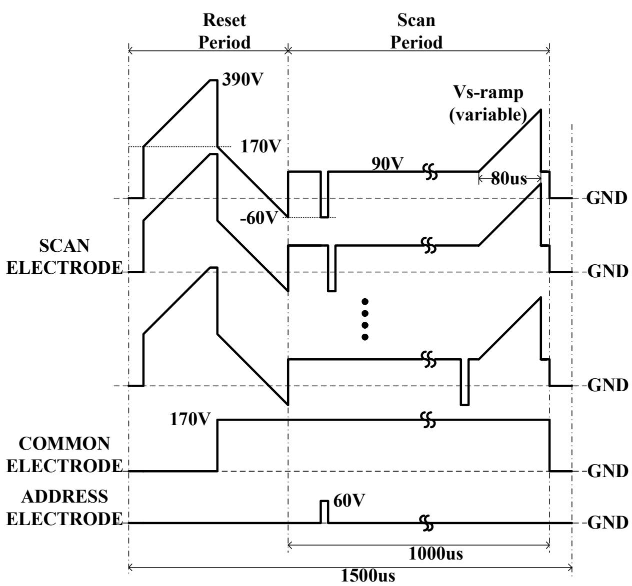
red, green, and blue cells with conventional three electrodes and symmetric barrier structure. Its pixel size is the same with the pixel size of the 42-inch WVGA PDP. The waveform used in the current study was controlled by a signal generator (TIME-98) and several DC power supplies. The luminance from the test panel was measured by the color analyzer, and the IR (Infrared: 828 nm) waveform emitted from the test panel was measured by the IR detector.

Figs. 3 (a) and (b) show the two driving waveforms used in the current study. In the conventional first subfield shown in Fig. 3 (a) that consisted of the reset-, scan-, and sustain-periods, two sustain pulses including an erase pulse were applied to the common and scan electrodes during a sustain-period. The amplitude of the sustain pulse was 170 V. In the proposed first subfield of Fig. 3 (b) that was composed of the reset- and scan-periods without a sustain-period, the negative square pulse was applied for addressing line-by-line and the second positive ramp pulse was applied to the scan electrode for controlling the minimum luminance in the end of a scan-period. The maximum voltage of the second positive ramp pulse was 410 V. Both conventional and proposed driving waveforms have the same ramped reset pulse with a set-up voltage of 390 V and a set-down voltage of -60 V, and negative scan pulse also have -60 V. During the reset- and scan-periods, the DC voltage of 170 V was applied to the common electrode. The same address pulse with an amplitude of 60 V was applied to the address electrode. The widths of the first negative square pulse and address pulse are 2 µs, respectively. For both waveforms, the scan periods were 1000 µs and total periods are 1500 µs, respectively.




(a) Driving waveforms for conventional first subfield




(b) Driving waveforms for proposed first subfield

**Figure 3.** Driving waveforms for conventional first subfield (a) and proposed first subfield (b).

## 3. Results and discussion

Fig. 4 shows the changes in the wall charges for both 'ON cells' and 'OFF cells' in the case of adopting the proposed first subfield. In the case of 'ON cells', the wall charges distributed at the end of the reset-period was shown in ( i ) of Fig. 4 and they did not change before the first negative scan pulse was applied, as shown in ( ii ) of Fig. 4. When the address pulse with an amplitude of 60 V and the negative scan pulse with -60 V were applied simultaneously, a strong address discharge was produced, as shown in (iii) of Fig. 4. Then, the wall charges were redistributed newly, as shown in (iv) of Fig. 4. The redistributed wall charges did not change even though the address and negative pulses changed from 60 V to 0 V and from -60 V to 90 V, respectively, as shown in (v) of Fig. 4. When the second positive ramp pulse applied to the scan electrode Y increased over a certain level, the relatively weak discharge was initiated to be produced, and the corresponding wall charges were also redistributed, as shown in (vi) of Fig. 4. At the falling edge of the second positive ramp pulse with a maximum voltage greater than about 350 V, a self-erasing discharge was produced. In the case of 'OFF cells', the wall charges distributed at the end of the reset-period remained without change until the second positive ramp pulse was applied, as shown in ( i )~ (v) of Fig. 4. When the second positive ramp pulse was applied, the weak discharge intensity was very low due to the absence of the address discharge, as shown in (vi) of Fig. 4. In both 'ON cells' and 'OFF cells', the wall charge distribution after the second positive ramp pulse was not important because the proposed first subfield has no sustain pulse.

Figs. 5 (a) and (b) show the IR (828 nm) waveforms measured form the 'ON cells' and 'OFF cells' of the test panel when the voltage slope of the second positive ramp pulse was varied from 23.6V/µs (Case A) to 3.06V/µs (Case G). In the 'ON cells' of Fig. 5 (a), the IR peak intensities increased in proportion to the voltage slope of the second positive ramp pulse. It was also observed that the IR emission was induced by the self-erasing discharge immediately after the falling of the second positive ramp pulse. The light emitted from the self-erasing discharge can contribute to the enhancement of the luminance. In the case of adopting the second positive ramp pulse with a voltage slope faster than Case A, it was observed that an unstable discharge was produced. This undesirable discharge is due to the strong discharge induced by the second positive ramp pulse with a voltage slope faster than Case A. In the case of adopting the second positive ramp pulse with a voltage slope slower than Case G, even the weak discharge was not observed. In this case, the strong discharge was produced during the subsequent reset period. In the 'OFF cells" of Fig. 5 (b), the IR peak intensities relative to the voltage slope of the second positive ramp pulse showed the tendency similar to that of the 'ON cells' in Fig. 5 (a). However, the IR emission intensity of the 'OFF cells' was very small in comparison with that of the 'ON cells'.

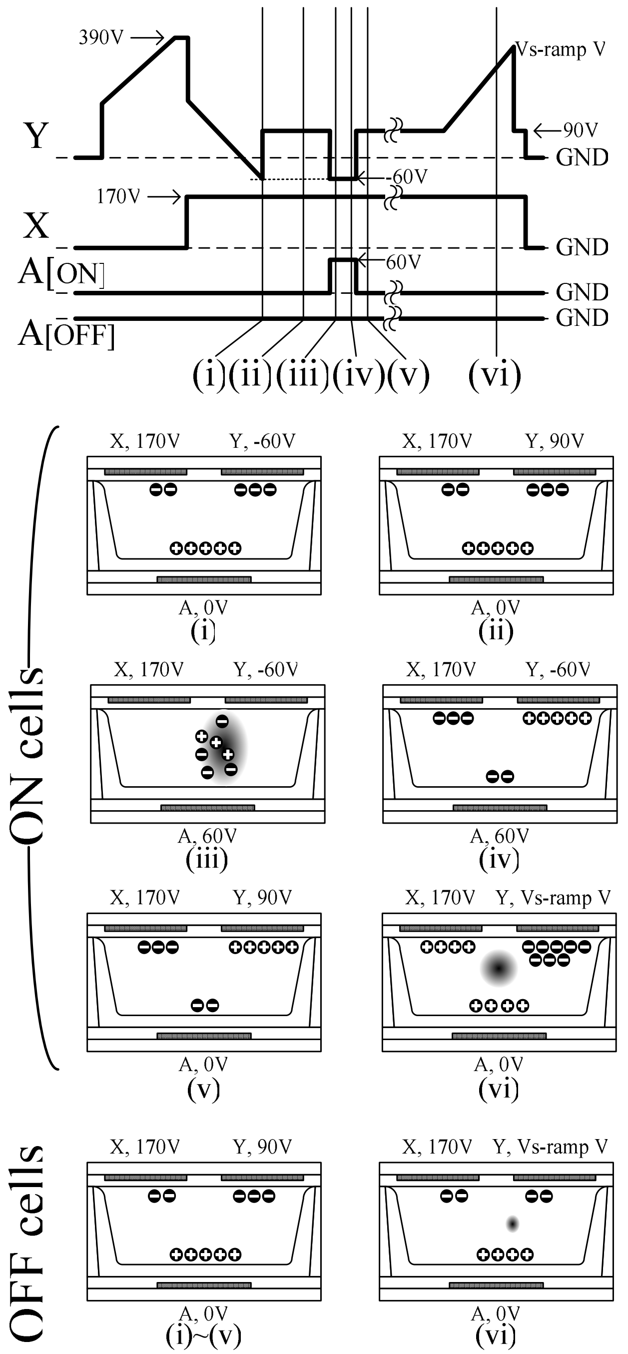



**Figure 4.** Changes of wall charge when new driving scheme was applied.

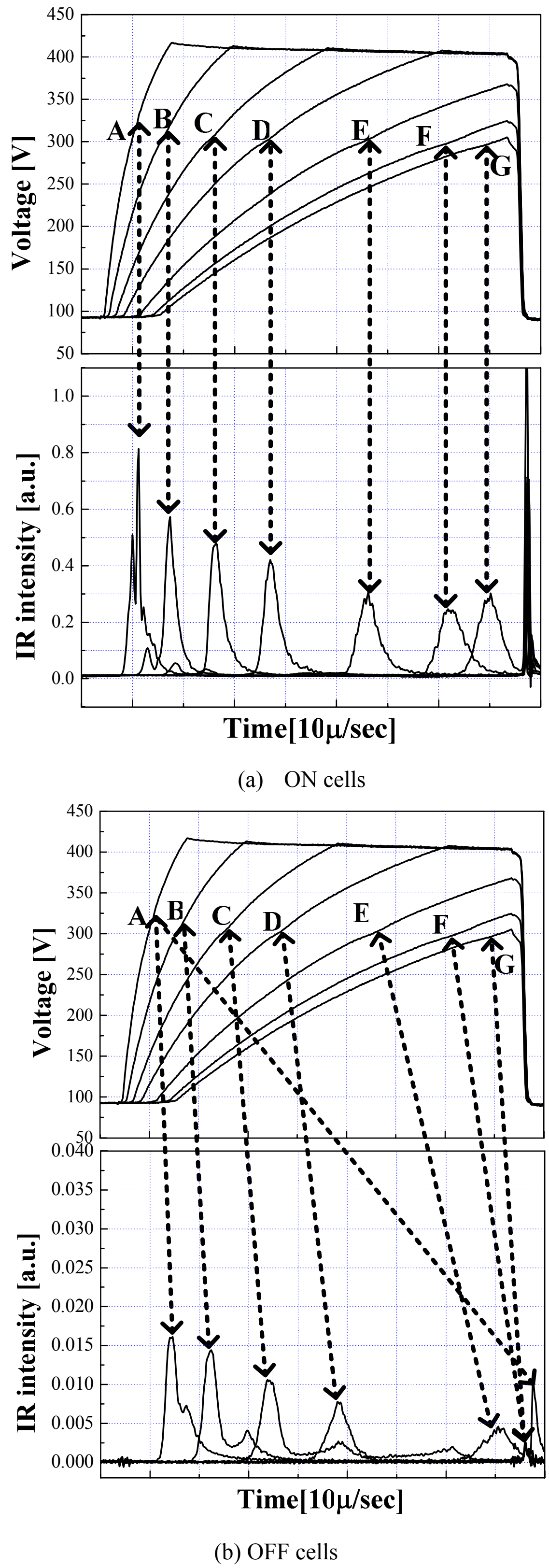



**Figure 5.** Measured second positive ramp pulses and IR waveforms with various voltage slopes in second positive ramp pulses.

**Table 1.** Changes in luminance when driving waveforms for both conventional and proposed first subfields with period of 1500 µs were applied repeatedly.

| | | Luminance | |
|---|---|---|---|
| | | ON cells | OFF cells |
| Conv. First Subfield | | 25.6 cd/m² | 1.68 cd/m² |
| Proposed First Subfield | Case A (23.6V/µs) | 15.8 cd/m² | 2.42 cd/m² |
| | Case B (13.1V/µs) | 15.3 cd/m² | 2.21 cd/m² |
| | Case C (7.49V/µs) | 14.8 cd/m² | 2.03 cd/m² |
| | Case D (4.63V/µs) | 14.4 cd/m² | 1.94 cd/m² |
| | Case E (3.52V/µs) | 14.0 cd/m² | 1.75cd/m² |
| | Case F (3.30V/µs) | 13.5 cd/m² | 1.68 cd/m² |
| | Case G (3.06V/µs) | 12.9 cd/m² | 1.68 cd/m² |

Table 1 lists the luminance values measured from the test panel when the driving waveforms for both conventional and proposed first subfields with a period of 1500 µs were applied repeatedly. In Table 1, the 'ON cells' means that the address pulse was applied, whereas the 'OFF cells' means that the address pulse was not applied. By utilizing the second positive ramp pulses with various voltage slopes, diverse luminance ranging from 15.8 cd/m$^2$ to 12.9 cd/m$^2$ was obtained. The luminance of 'OFF cells' of Table 1 means the background luminance. If the background luminance was increased by the second positive ramp pulse, the contrast ratio could go bad. But in Cases F and G with a minimum luminance level, the luminance of 'OFF cell' is the same as that of the conventional case. Therefore, the proposed first subfield with the voltage slope of 3.06 V/µs (Case G) could generate about half luminance compared with the minimum luminance generated by conventional first subfield without an increase in the background luminance.

## 4. Conclusion

This paper proposes a new discharge mode driven by the bipolar ramp waveform for enhancing the low gray level expression. This discharge mode is to use the weak discharge produced by the second positive ramp pulse plus the first negative square pulse during a scan-period, thereby resulting in generating and controlling the low luminance level stably. It is expected that the replacement or addition of the new first subfield driven by the proposed discharge mode can lead to more powerful low gray level expression.

## 5. References

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