IPS-Mode Dynamic LCD-TV Realization with Low Black Luminance and High Contrast by Adaptive Dynamic Image Control Technology

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Abstract
In this paper, the active backlight control technology with data processing algorithm was developed in order to improve image quality for IPS-mode LCD-TV applications. The image blinking problem caused by repeatedly abrupt change of the backlight luminance was solved by algorithms-Fba(Flexible Boundary algorithm) and Cfa(Cumulative Feedback algorithm)-and the optimized number and space of backlight dimming steps based on perception. In the IPS-mode 42" TFT-LCD panel, the dynamic contrast ratio can be more than twice the typical level by means of lower black luminance and higher white luminance. Additionally, Power consumption and LCD temperature was decreased.

1. Introduction
The TFT-LCD as a flat type display device has been widespread since the 1990s, owing a lot of advantages-thin and light, low power consumption and relatively high quality. Therefore the TFT-LCD display device became the most popular display device in small and middle sized applications like Monitors and Notebooks. Recently the large sized LCD-TV application market has become bigger and bigger while substituting conventional CRT-TVs for 20"~40" and competing with PDP-TVs for over 40".

Meanwhile, the CRT displays have been the best selling product for over 50 years in the market of TV applications by virtue of many advantages excepting bulky and high power consumption. There is a big difference between CRT displays and LCD displays-emissive and nonemissive type-so that a dynamic image can be easily realized in the CRT display. This is, a peak brightness function in the CRT-TVs that can be useful for realizing the dynamic image quality while almost all LCD-TVs do not have the function[1].

Many researches on picture quality improvement have been done for the LCD-TV applications. Conventionally, there are 5 main factors-luminance, contrast, response time, color and viewing angle-with respect to picture quality for the LCD-TV applications[2]. This paper is focused on the improvement of luminance and contrast. The contrast is typically the ratio of the full-white luminance to the full-black luminance and normally the contrast ratio is approximately 500:1 in IPS-mode LCD-TVs[3]. However it can be obtained more than 1000:1 of contrast ratio by means of the backlight control technology with the data processing algorithm. Futhermore, the power consumption can be improved over 20% and the front temperature of LCD can be decreased over 10% in the normal environment. Therefore, the active backlight control technology can be suggested one of the most efficient solution to obtain the best LCD-TV display in terms of high contrast ratio, lower black luminance level and power consumption[4][5]. This technology in the LCD-TV display has been developed for attaining the CRT-like picture quality so that the LCD-TVs will be main stream in the near future.

2. Technology concept and algorithm
Typically a LCD-TV application is mainly divided into 3 parts-the system part, the LCD controller circuit part and the LCD panel part with backlight. The new type of the schematic diagram is shown in Figure 1. The image processor block is located in the LCD controller circuit part. It is expected that some new algorithms will be introduced in the LCD controller circuit part. Gradually this will give the better image quality and the algorithms would be unique for the IPS-mode TFT-LCDs.

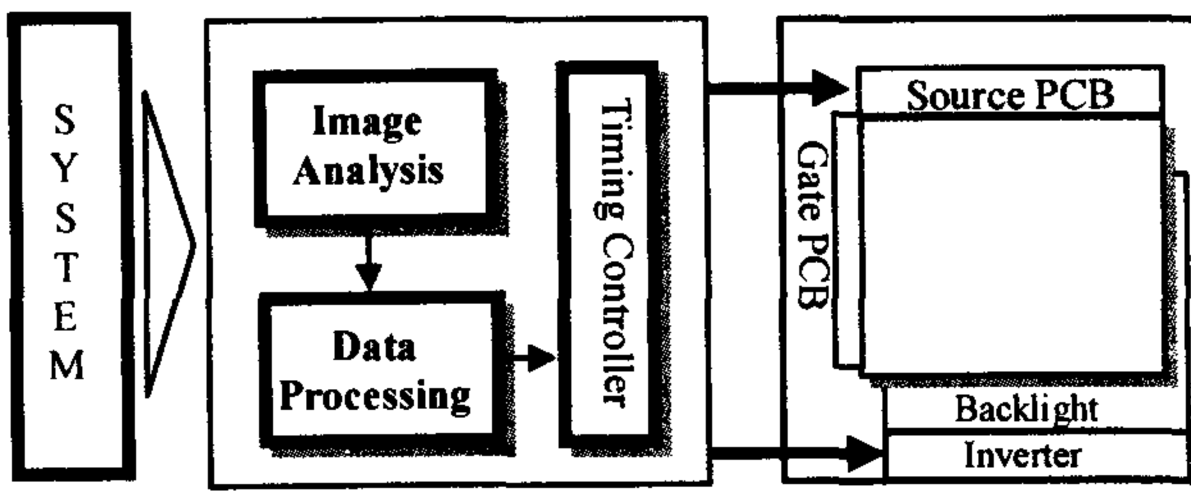


Figure 1. LCD-TV schematic diagram

As shown in Figure 2, this technology consists of 2 steps and two algorithms. After entering an input image data, an image analysis is fulfilled by the histogram method which describes the gray level distribution of the pixels in one frame. According to the histogram, we can confirm whether the image is brighter or darker. In this histogram, three kinds of factor(maximum, average, frequent value) are investigated so that the factors contribute to decide the type of image transmitted to the data processing block.

In this data processing block, firstly the backlight on-duty ratio is decided according to the average of the brightness level of an input image. In case of a brighter image, the backlight is controlled at relatively higher on-duty ratio, in case of a darker image, the on-duty ratio is lowered. Secondly, the data stretch algorithm is applied adaptively according to the conditions so that the output image can be realized more detailed.

As shown in Figure 3, the algorithms can be divided into four typical different groups. The main idea is to emphasize a focusing area inside one frame image. The emphasizing methods are the brightness control by the on-duty of the backlight and the data stretch technique for the detail expression at the focusing area.

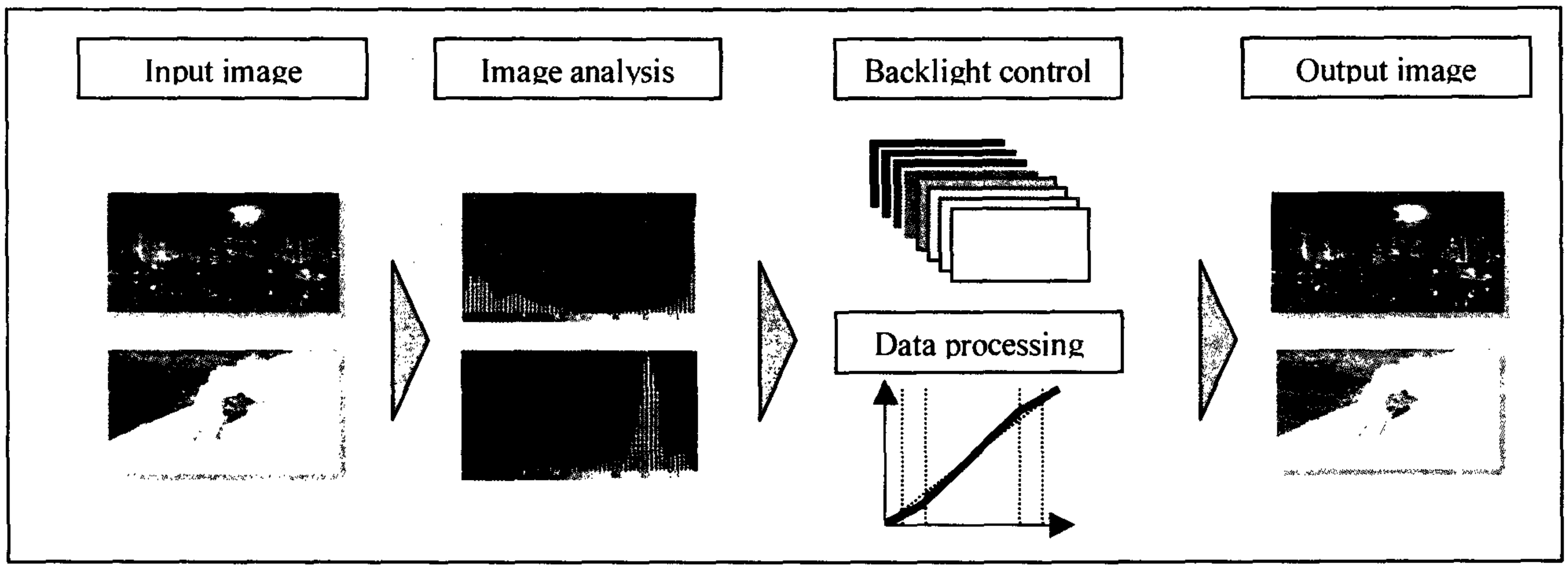


Figure 2. Concept of Adaptive dynamic image control Technology

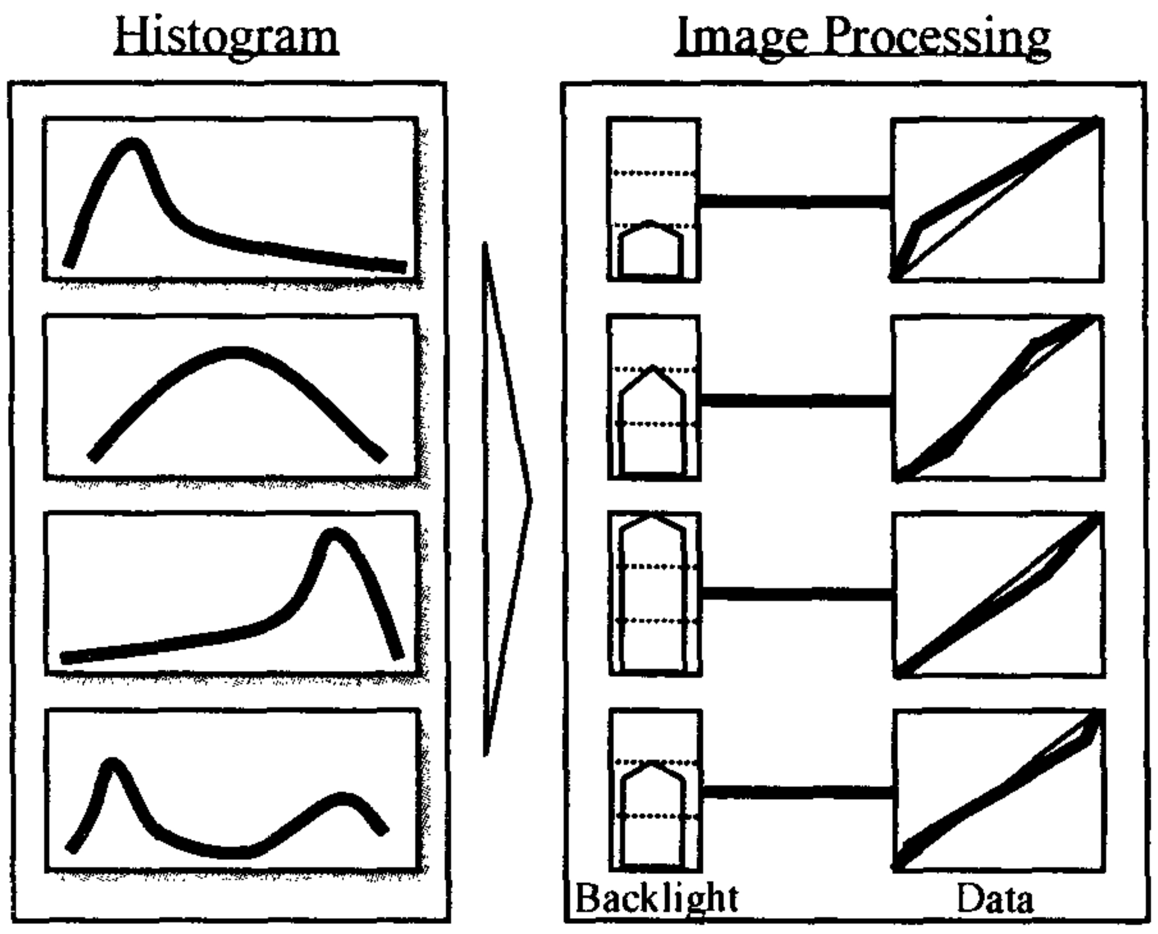


Figure 3. Algorithms for backlight control with data processing

3. Image blinking reduction technology

In case of adapting this dynamic backlight control technology, an image blinking phenomenon would occur in some specific conditions because of repetitive rapid changes of image brightness. In order to solve this problem, two kinds of algorithm-FBa(Flexible Boundary algorithm and CFa(Cumulative Feedback algorithm) were developed. Futhermore, the backlight dimming step was optimized in the viewpoint of the perception.

3.1 Flexible Boundary algorithm

In order to control the backlight luminance, we should make a decision on the number of dimming steps wth regard to the efficient data processing and hardware size. The number of dimming steps is smaller than the gray level number, which is 256 gray levels in the case of 8bit. Therefore, the rapid change of brightness in the boundary of steps occurs. If the change is repeated in a short period, we can recognize the image blinking phenomenon. To reduce this phenomenon, one of the most important solution is disregarding of the repetition so that the Flexible Boundary algorithm was developed as shown in Figure 4. The boundary is not static but changeable under specific situation. If the brightness of some image is going and returning at both sides of the boundary, the position of the boundary is shifted outside the range. Therefore the image blinking phenomenon can be reduced.

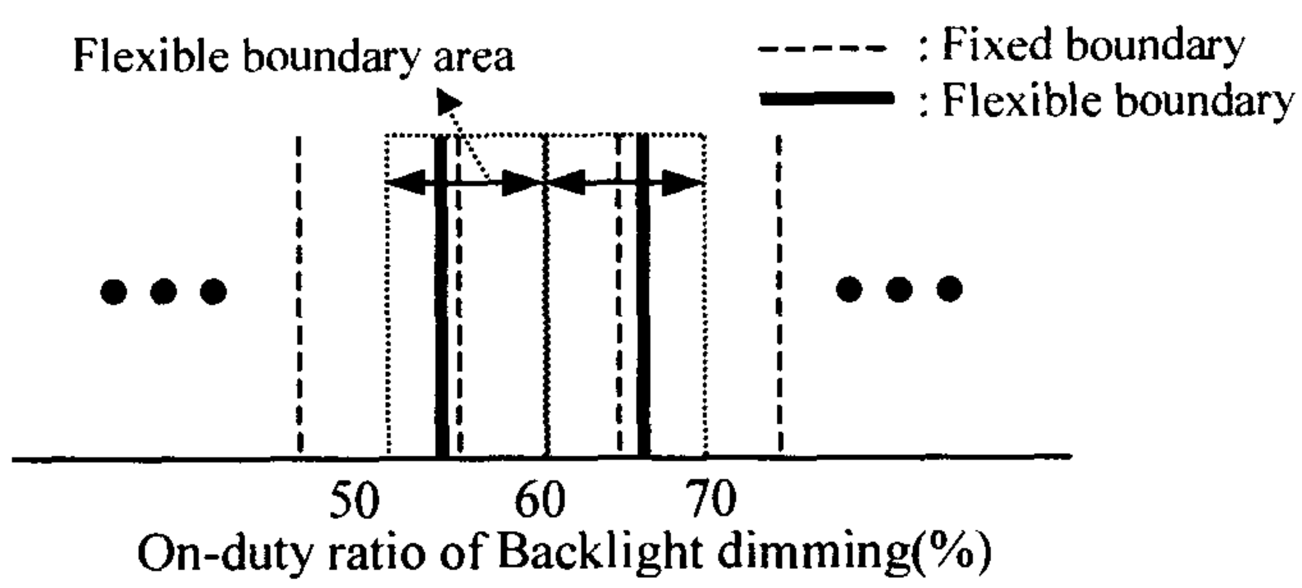


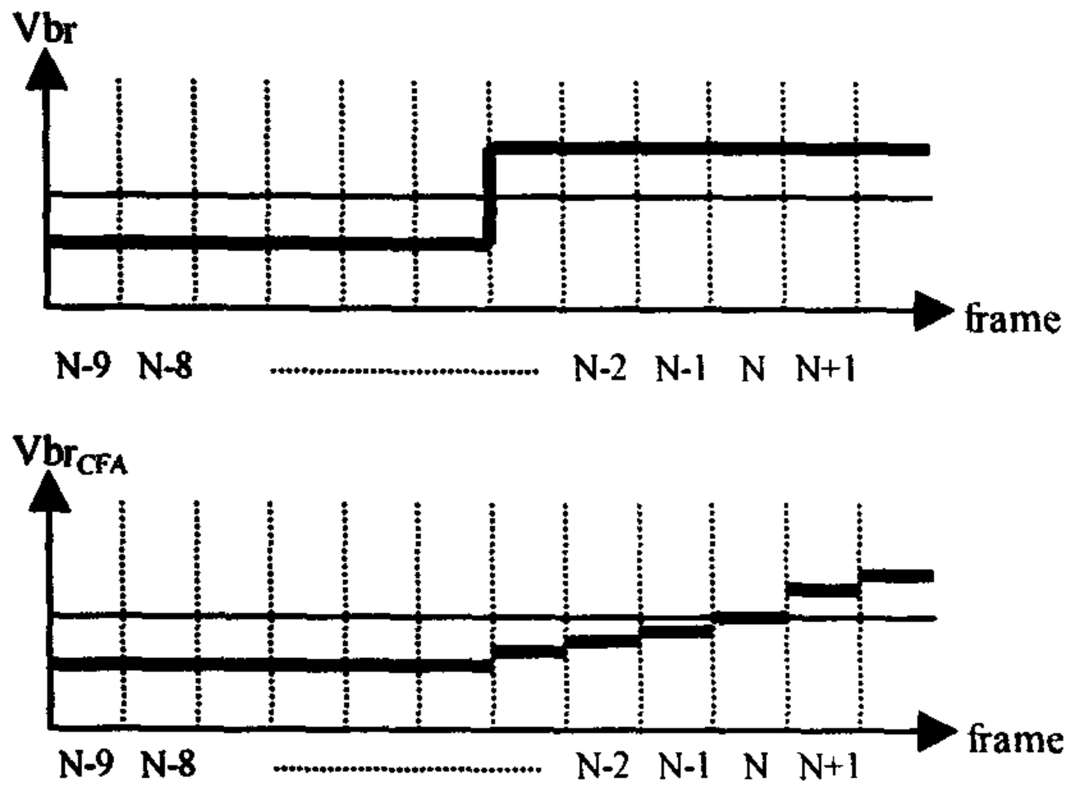
Figure 4. Flexible boundary algorithm

3.2 Cumulative Feedback algorithm

Although the blinking problem can be solved by means of the Fba technology in a narrow dimming range, it still remains in case of drastic change-more than 2 steps-of backlight luminance. As shown in Figure 5, Cumulative Feedback algorithm can be one of the best solution. The backlight dimming ratio is not decided by estimating the current image data but decided by the average luminance from the past data to the current data. Therefore, we can get rid of the situation which leads to an abrupt change of luminance by backlight dimming ratio control. Consequently the image blinking phenomenon can be reduced.

3.3 Optimizing backlight dimming step

The number of the backlight dimming step is generally smaller than the gray level of image. Therefore the big luminance difference between the dimming step leads to the image blinking phenomenon. As shown in Figure 6, the minimum recognition level(JND(Just Noticeable Difference)=△L) on the human eyes is smaller in the dark range, bigger in the bright range. Futhermore, the ratio of △L to image luminance(L) is almost 1.4~1.8%. According to △L and △L/L(Weber ratio) value distribution, the dimming step number and the space between steps should be optimized from the viewpoint of the perception. In this technology, the luminance differene between steps can be controlled under 2△L level.



$$Vbr(N)_{CFA}{}^{\dagger} = \frac{sum[(\alpha_N \times Vbr_N),(\alpha_{N-1} \times Vbr_{N-1}),\ldots,(\alpha_{N-M} \times Vbr_{N-M})]}{M}$$

CFA : Cumulative Feedback Algorithm
Vbr : Inverter dimming voltage
M : Cumulative Index
α : Weighting function

Figure 5. Cumulative feedback algorithm

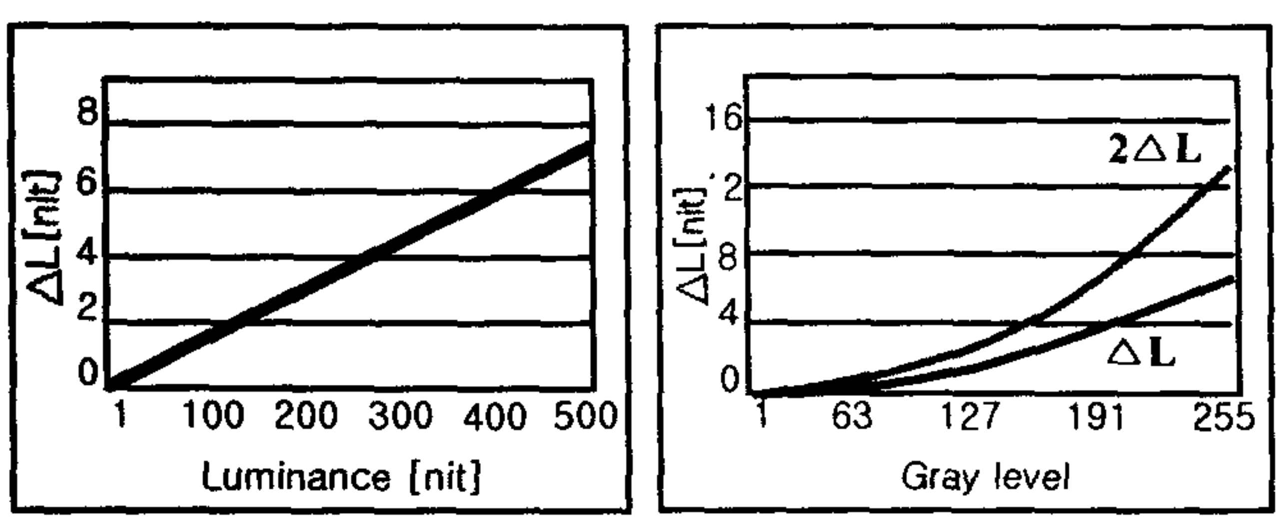


Figure 6. JND(△L) and Weber ratio(△L/L)

4. Performance improvement

In order to realize a dynamic image in LCD-TV displays, the peak brightness realization technology should be necessary like the CRT display. This technology can be attained by the backlight control method with the lower black luminance and higher white luminance. Therefore, the dynamic contrast results in over twice the typical level. In addition, the temperature and the power consumption can be lowered. Consequently the active backlight control technology is one of the most efficient ways in driving the LCD-TVs.

Comparing with the CRT-TV, the conventional LCD displays have had the backlight with static brightness. Therefore, despite displaying a full black image, the backlight is fully on-state. The light leakage is inevitable without any perfect preventing solutions. We evaluated the backlight luminance and the light leakage level on the CCFL(Cold Cathode Fluorescent Lamp) and the EEFL(External Electrode Fluorescent Lamp) according to the on-duty ratio, as shown in Figure 7. The definition of on-duty ratio(%) of the backlight dimming is (t/T) x 100 and related to the PWM(Pulse Width Modulation) frequency and the lamp on time(second). The black level luminance of the IPS-mode dynamic LCD-TV was attained under 1/2 by means of decreasing on-duty ratio.

Meanwhile, the peak white luminance was improved by virtue of decreasing the lamp temperature in case of the dynamic backlight driving. Therefore, there is a 10% to 20% difference between the peak luminance and the saturated luminance. That is also one of the advantages in dynamic backlight control scheme.

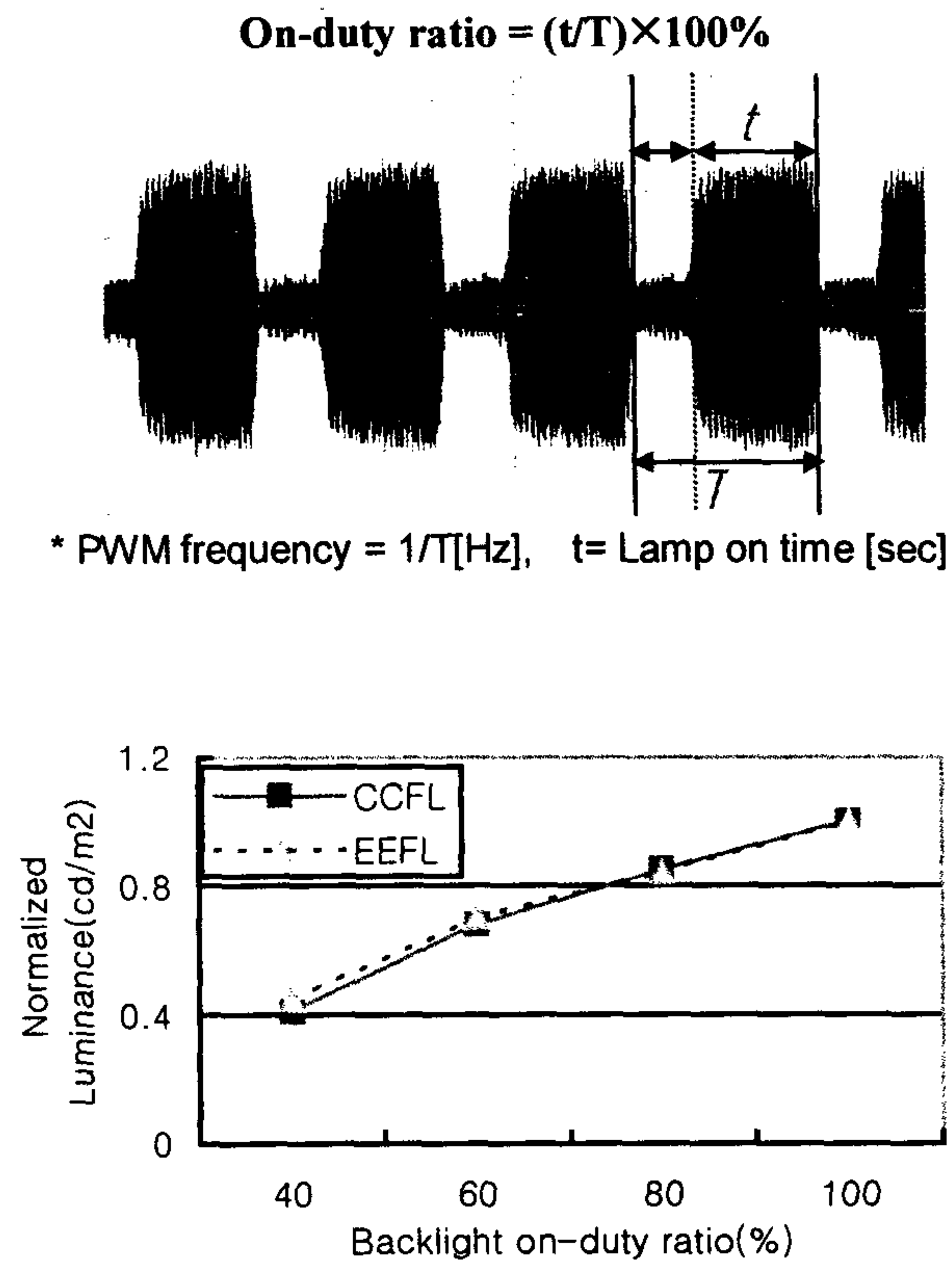


Figure 7. The definition of On-duty ratio and Black luminance versus on-duty

In terms of the luminance efficiency of the backlight, there is a little difference between the dynamic backlight control and the static backlight driving. In the case of the static driving of the backlight, the luminance efficiency was maximized around 6.5mA lamp current, while the luminance efficiency was maximized around 8mA in the dynamic backlight driving. The dynamic backlight driving method can be more efficient than the static one for LCD-TV applications as shown in Figure 8.

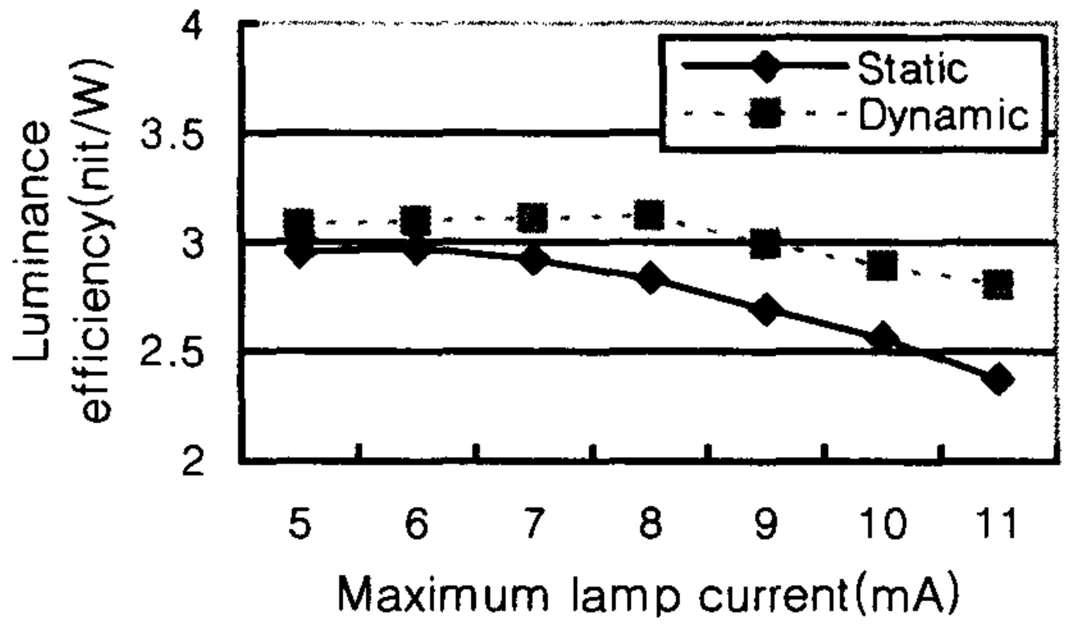


Figure 7. Luminance efficiency of Backlight

5. Conclusion

The active control of the backlight will be popular in the LCD-TV in the near future because of the most efficient method in terms of realizing the best picture quality and the optimized power consumption scheme. We utilized this technology for making our LCD-TV products competitive. As shown in Table 1 and Figure 8, 42" IPS-mode LCD-TV achieved huge improvement in terms of the display specification by means of the active backlight control technology with the data processing.

Table 1. 42" IPS-mode LCD panel specification

		Improved	Normal
Luminance(cd/m2)	Black	0.5	1.0
	White	500	500
	Peak	550	-
Contrast ratio	Static	500 : 1	500 : 1
	Dynamic	1100 : 1	-
Power consumption	cumulation	130W	170W
Temperture	front	40℃	45℃

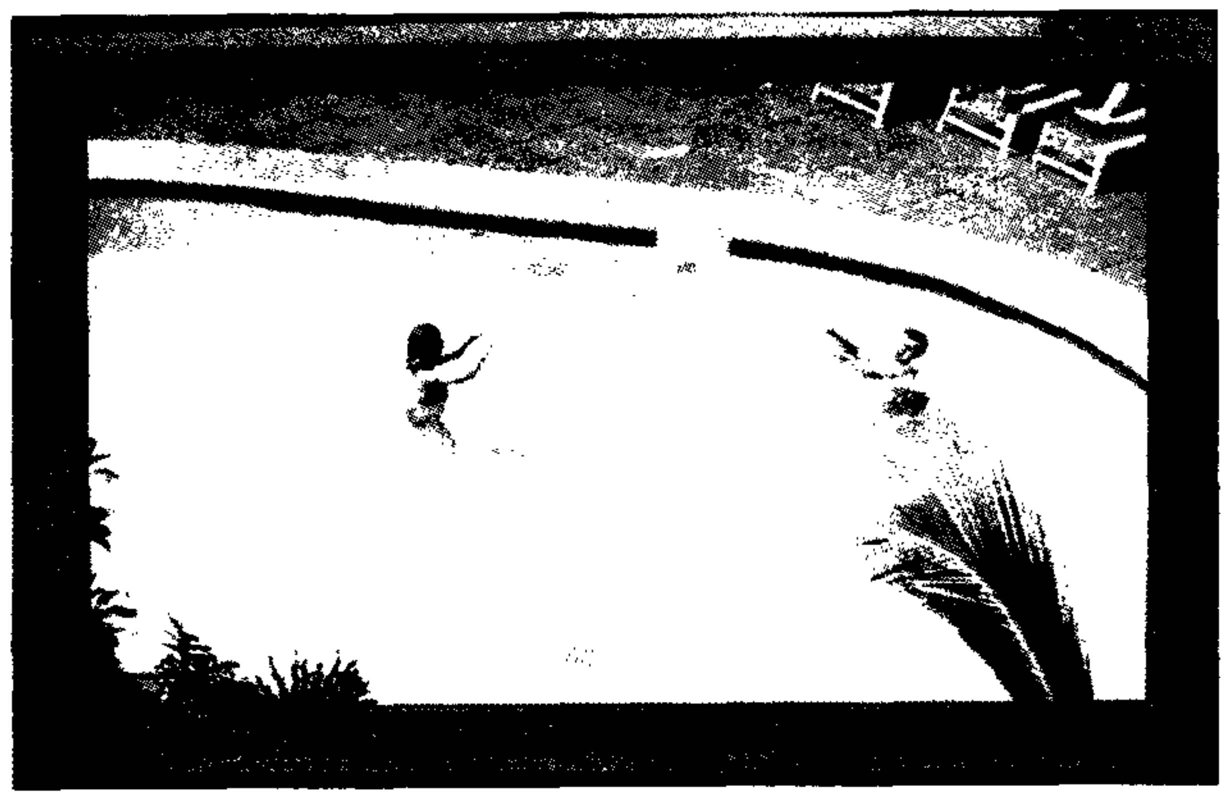


Figure 8. 42" IPS-mode LCD-TV

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