Temperature Compensation Method of Local Dimming LED Backlight System

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Abstract

Temperature Compensation Method of Local Dimming LED Backlight System is proposed. The luminance levels of the LED backlight are not stable over temperature and time due to the inherent characteristics of the LED. The characteristics of LED backlight are investigated and a temperature compensation method is presented. The image distortion caused by temperature variation of LED block can be effectively compensated by the proposed temperature compensation method.

1. Introduction

The luminance levels of the LED backlight are not stable over temperature and time due to the inherent characteristics of the LED [1]. In order to minimize luminance variation over temperature and time, optical feedback system is a good solution [1], [2]. However, it is difficult to compensate the luminance difference between each LED modules. The luminance variation rate between upper and lower part of LED backlight is different because the temperature of upper part of LED backlight is normally higher than that of lower's. Especially, in case of the local dimming LED backlight [3], the luminance variation rate of each LED blocks is different due to the different temperature variation of each LED block. Therefore, temperature compensation is needed to prevent the image from being distorted.

To solve these problems, a new temperature compensation method of LED backlight for LCD TVs is proposed. As shown in Fig. 1, the proposed LED backlight utilizes channel switches to control the luminance of individual division screen and a resistor to sense the current of each LED blocks. By using the proposed technique, low power consumption as well as high contrast ratio is successfully obtained with less number of drivers than that of conventional local dimming method. Moreover, the luminance variation of each LED blocks caused by temperature variation is effectively compensated. In this paper, the characteristics of LED backlight are investigated and a new adaptive dimming algorithm as well as the temperature compensation methods is proposed for the X-Y channel LED backlight [3].

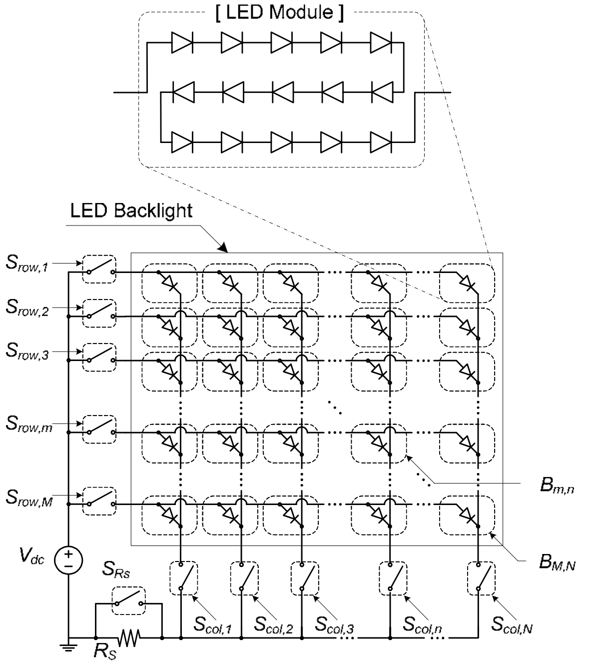


Fig. 1. Configuration of the Proposed LED backlight.

2. Operational Principle

The proposed LED backlight system as shown in Fig. 1 consists of LED modules which have series connected LEDs. These LED modules are connected to each other in a matrix structure with row channels

(X channels) and column channels (Y channels). To control each channel, row and column switches are connected at the end of each channel and to an external power source. Therefore, the brightness of each division block can be controlled by a certain combination of row and column switches. The resistor, RS, and switch, S_{Rs}, are for sensing current of each LED module. The current values sensed by sensing resistor, R_S, are used to compensate luminance variation caused by temperature of each LED blocks.

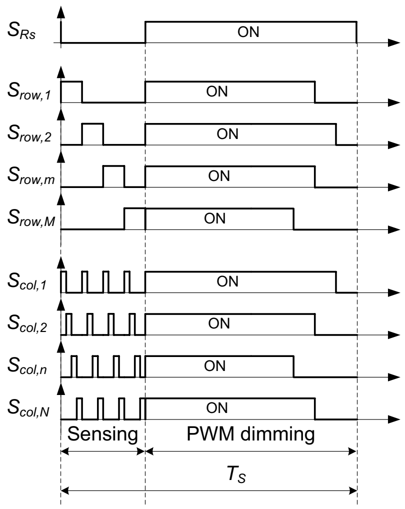


Fig. 2. Timing diagram of switches.

The operation period is composed of sensing and pulse width modulation (PWM) dimming parts as shown in Fig. 2. The current of each LED module can be sensed during the sensing period, and the luminance of each block can be decided during the PWM dimming period. Since the sensing period is much smaller than the PWM dimming period, the luminance of each block affected by the sensing period can be neglected. During the sensing period, the switch, S_{Rs}, is turned off, and row switches are turn on and off sequentially as shown in Fig. 4. During one of row switches, $S_{row,m}$, is turned on, the column switches are turned on and off one after the other. Therefore, only one LED block is turned on for an instant and its current can be sensed by a resistor, R_S.

A new adaptive dimming algorithm is needed to decide the luminance of each division block for the proposed LED backlight system. The proposed dimming algorithm is composed of three major procedures; finding the maximum level data (MLD) from source image corresponding to each division block of LED backlight, selecting the brightness level of each division backlight, and modifying the image information to preserve the source image.

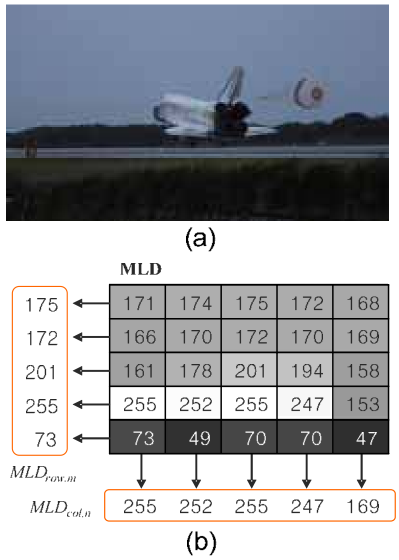


Fig. 3. Information of source image.

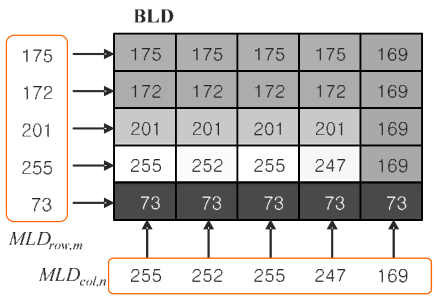


Fig. 4. Gray level data of backlight luminance.

Fig. 3 shows the source image and its maximum level data (MLD) of each block, **MLD**, which is a M by N vector-matrix. From **MLD**, its maximum row and column MLDs, $MLD_{row,m}$ and $MLD_{col,n}$, can be decided as shown in Fig. 3 (b) and expressed as

$$MLD_{row,m} = \max(MLD_{m,1}, MLD_{m,2}, \cdots, MLD_{m,N}) \text{ , (1)}$$

$$MLD_{col,n} = \max(MLD_{1,n}, MLD_{2,n}, \cdots, MLD_{M,n}) \text{ . (2)}$$

From gamma curve and $MLD_{row,m}$ and $MLD_{col,n}$, the duty ratio of each row and column switches can be determined and expressed as equations (3) and (4), as follows

$$D_{row,m} = [MLD_{row,m} / 255]^{\gamma} \text{ , (3)}$$

$$D_{col,n} = [MLD_{col,n} / 255]^{\gamma} \text{ . (4)}$$

Then, the dimming factor of each block, $k_{m,n}$, can be decided by the minimum value of $D_{row,m}$, and $D_{col,n}$, and can be expressed as in equation (5).

$$k_{m,n} = \min(D_{row,m}, D_{col,n}) \quad (5)$$

Fig. 4 shows the gray level data of backlight luminance, **BLD**, which is a M by N matrix after adaptive dimming. Here, the gray level data of each block luminance, BLDm,n, can be expressed as

$$BLD_{m,n} = 255 \times k_{m,n}{}^{1/\gamma} \text{. (6)}$$

For the perceived image after backlight dimming to be identical to that of the original image without backlight dimming, the code value of the source image, $cv_{m,n}$, corresponding to each division block, $B_{m,n}$, of the backlight should be enhanced as

$$cv'_{m,n} = cv_{m,n} / k_{m,n}{}^{1/\gamma} \text{. (7)}$$

3. Temperature compensation method

The proposed adaptive dimming method is adapted for a 32-inch LCD TV. The RGB-LEDs are used as the backlight source and the backlight is divided into 5 by 5 blocks as shown in Fig. 5 (a). Each LED block has 20 RGB-LED clusters which comprises 1 red, 2 greens and 1 blue small size LEDs. To drive the LEDs, 30 drivers as shown in fig. 5 (b) are used. The three power sources for red, green and blue LED strings are used.

The luminance of LED is dependent on temperature and operating current (or voltage). To compensate the luminance variation due to the change of temperature, the luminance-current characteristic with a constant voltage of each red, green and blue LEDs is investigated as shown in Fig. 6. In this figure, point A refers to normal temperature, T_L and point B refers to saturated temperature, T_H. As can be seen in this figure, the LED luminance can be a linear function of LED current when a constant voltage is supplied. Therefore, the luminance of each block can be expected by measuring the current of each LED block and expressed as

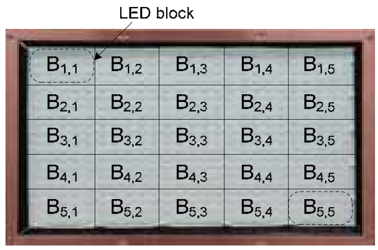
$$L_{m,n} = \alpha \cdot i_{m,n} + \beta \text{, (8)}$$

where, $\alpha = M \times N \cdot \dfrac{L_1 - L_2}{i_1 - i_2}$ and $\beta = \dfrac{i_1 \cdot L_2 - i_2 \cdot L_1}{i_1 - i_2}$.

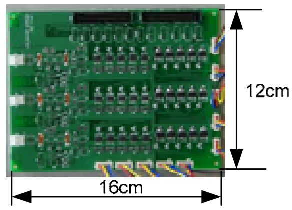
Therefore, the luminance variation ratio between normal and high temperature, $kt_{m,n}$, can be expressed as

$$kt_{m,n} = \frac{L_1}{L_1 + \Delta L} = \frac{\alpha \cdot i_1 + \beta}{\alpha \cdot (i_1 + \Delta i) + \beta} \text{. (9)}$$

Here, i_1 can be decided by a reference value, and Δi can be measured by sensing resistor, R_S, in Fig 1. and 2. From the temperature compensation factor, $kt_{m,n}$, it is expected that the luminance of $B_{m,n}$ is enhanced by a factor, $1/kt_{m,n}$.

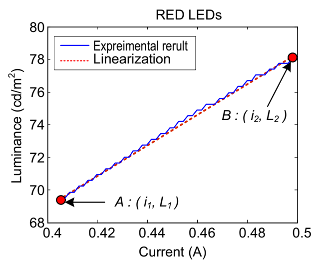


(a) RGB LED backlight

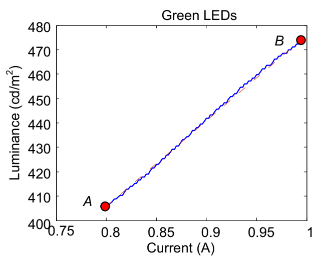


(b) LED driver

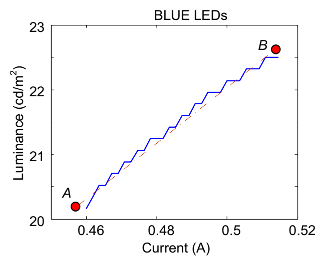
Fig. 5. Implemented LED backlight and its driver.



(a)



(b)



(c)

Fig. 6. Luminance and current characteristics of LEDs with the constant voltage source.

From equation (6), the total luminance distribution of backlight resulting from temperature variation can be expressed as

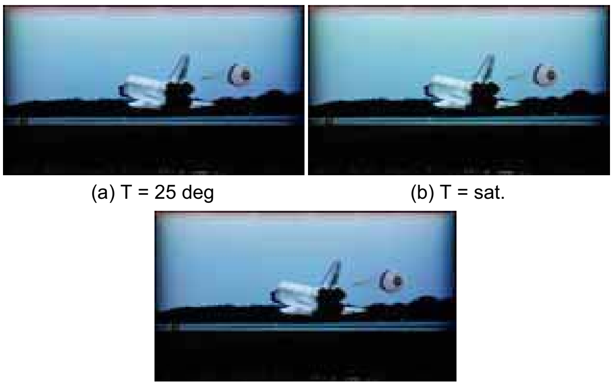
$$BL\_kt = \sum_{m=1}^{M}\sum_{n=1}^{N} kt_{m,n} \times BL_{m,n} \ . \ (10)$$

Therefore, from equation (10), equation (7) can be corrected to

$$cv\_kt = cv / BL\_kt^{1/r} \ . \ (11)$$

4. Experimental results

Proposed temperature compensation method is adopted into X-Y channel dimming LED backlight [3] which is driven by the constant voltage source. To measure currents of all LED blocks, X-Y channel dimming LED backlight and dimming algorithm are modified resulting easily being measured by a resistor and scanning method. Fig. 7 (a) and (b) shows experimental result of the adaptive dimmed panel images at 25℃ and saturated temperature before temperature compensation. It is noted that the panel image is brighter as the temperature is higher when the LED backlight is driven by constant voltage source. Fig. 7 (c) is temperature compensated images using image processing. Fig. 8 shows the gray levels at x = 680 pixels in Fig. 7. From Fig. 7 and Fig. 8, the proposed temperature compensation method can compensate the luminance variation due to change in temperature.



(a) T = 25 deg (b) T = sat.

(c) Image compensation

Fig. 7. Experimental results of dimming images.

5. Summary

In order to minimize luminance variation over temperature and time, optical feedback system is a good solution. However, it is difficult to compensate the luminance difference between each local block in case of local dimming backlight. Temperature measuring is good try to expect the luminance variation. However, it is difficult to measure LED chip. Temperature sensor can only measure temperature around LEDs. The proposed dimming method can expect the luminance variation by measuring current of LED block and effectively compensate the luminance distortion of local dimming backlight due to temperature change with low cost. Therefore, the proposed temperature compensation method can help optical feedback system in local dimming backlight. The validity of the proposed compensation method is verified by simulation and experimental results based on a RGB-LED backlight of a 32-inch LCD TV.

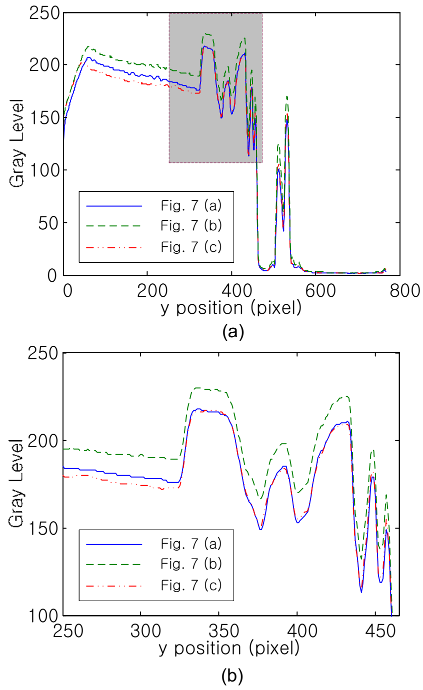


Fig. 8. Gray levels of experimental results in Fig. 7.

Acknowledgment

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6. References

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