Optimization of Color and Gray Scale using Brightness Control in CRT Color Monitor

Kim Hong-suk, Park Seung-ok, and Baek Jung-ki
Dept. of Physics, Daejin University, Kyunggi-Do, Korea

Abstract

Tone reproduction characteristics of color and gray have a great influence on the picture quality in visual display. In this study, we optimized tone reproduction characteristics of color and gray of CRT monitor by setting brightness to the optimum level, in which offsets for RGB channels can be assumed to zero. The optimum brightness level could be found by measuring a few tones of neutral for the combination of 2 levels of brightness and 2 levels of contrast. As the result, the relationship between normalized DAC count and normalized luminance of primary color or gray has been simply presented by gamma and result in good phosphor constancy.

1. Introduction

CRT color monitor produces image with the lights emitted by red, green, and blue phosphor. The quality of image depends on the non-linear relationship between the amounts of emitted light and the DAC counts applied to RGB channels. The traditional CRT techniques have been described as the gain-offset-gamma(GOG) model to characterize this non-linear relationship[1].

In most monitors, brightness and contrast vary the offsets and gains of all three channels simultaneously. Many researchers have studied about the effects of brightness and contrast on the reproduced image[2-3]. Brightness affects mainly the luminance of the black and contrast affects the luminance of the white. It is known that tone reproduction characteristics of color and gray can be optimized when brightness is adjusted to a particular setup, in which offsets for all channels can be assumed to zero. However, this optimum setup occurs infrequently in practice. The objectives of this study were to achieve that particular setup by adjusting brightness and contrast levels.

In this paper, we proposed a technique to set the optimum brightness level and showed the improvement of tone reproduction characteristics of color and gray.

2. Theoretical basis

The relationship between luminance and normalized DAC count in CRT monitor, known as the tone reproduction characteristics has been modeled as follows[1]

$$L = [b + a(\frac{d}{2^N - 1})]^{\gamma} \qquad (1)$$

where d is the DAC count, b is the amplifier offset, a is the amplifier gain, and γ is the gamma coefficient for each channel. As the amplifier gain and offset vary, the tone reproduction characteristics of the monitor change.

The normalized luminance dividing by its maximum can be expressed as follows

$$\frac{L}{L_{\max}} = \frac{(b + a\frac{d}{2^N - 1})^{\gamma}}{(b+a)^{\gamma}} \qquad (2)$$

For any luminance ratio of C, DAC counts satisfied the Eq. (2) could be solved like as

$$d = \frac{(2^N - 1)}{a}[C^{\frac{1}{\gamma}}(a+b) - b] \qquad (3)$$

$$= \frac{b}{a}(2^N - 1)(C^{\frac{1}{\gamma}} - 1) + d_0$$

where, $d_0 = (2^N - 1)C^{\frac{1}{\gamma}}$ represents DAC count of $b = 0$. This equation means the relationship between DAC count and offset is linear. For a given gain, the DAC count is increased proportional to offset. However, the ratio of proportion is decreased as the gain is increased. The plot of DAC counts against offset for a constant gain will show the straight line having an intercept of (0, d_0). In addition, the lines obtained from different gains will be crossed at their common intercept.

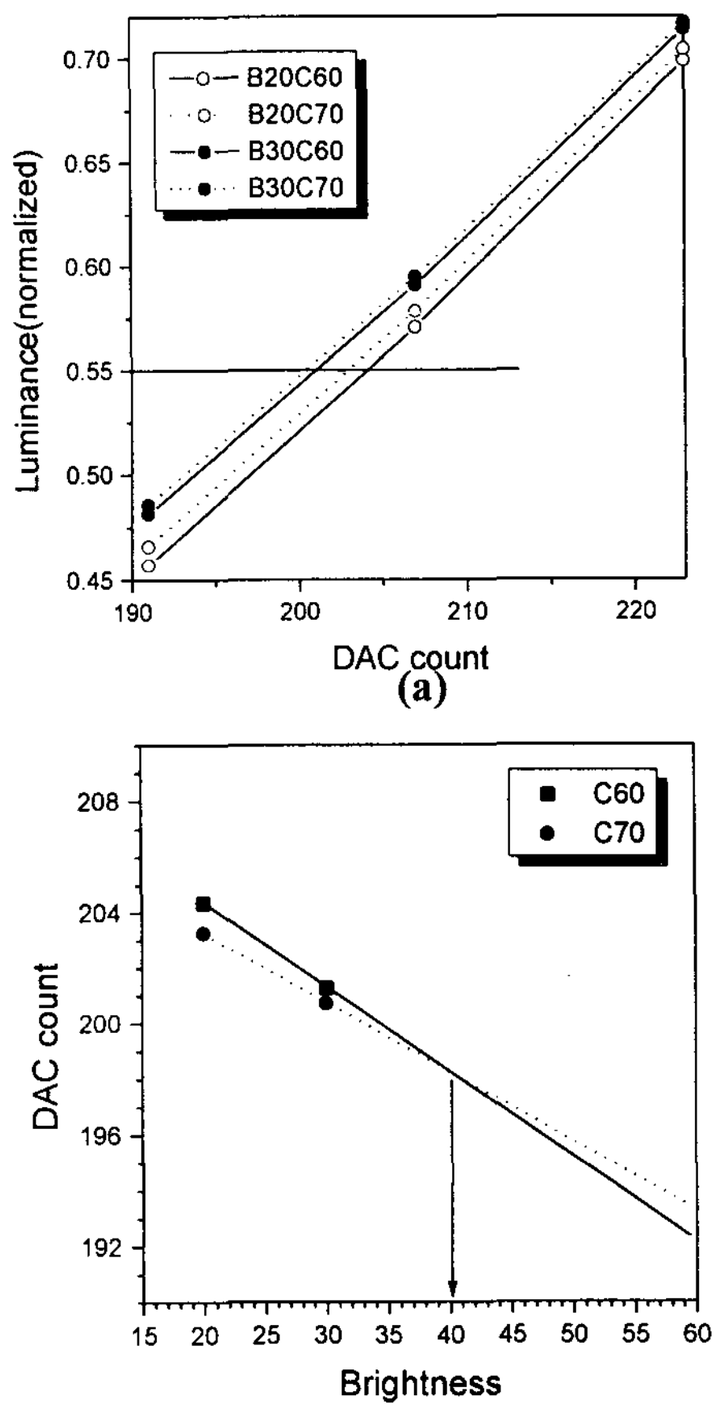


Fig. 1. Measured dater for Samsung. (a) normalized luminance vs. DAC count, (b) plots of DAC count with luminance ratio of 0.55 against brightness level for two different contrasts

Instead of adjusting individual offset of RGB channels, optimum brightness setting can make the offsets of all channels to their minimum. Following the above principle, the optimum

brightness level can be found by measuring a few tones of neutral for the combination of 2 levels of brightness and 2 levels of contrast. However, in practical monitor, the levels of brightness or contrast are not linear to offset or gain. It is advantageous to choose two levels of brightness or contrast whose interval is small.

3. Results and discussion

Samsung SyncMaster 700P has been tested. The levels of brightness and contrast could be varied between 0 and 100 using the monitor's digital control system. In this test, brightness and contrast levels are selected as 20, 30, and 60, 70, respectively. Luminance ratio C in Eq. (3) was determined to 0.55 to be able to measure high DAC counts. Then, for the four combinations of setting, the luminance for 4 tones of neutral: (191,191,191), (207,207,207), (223,223,223), (255,255,255) were measured using a spectroradiometer CS-1000 of Minolta in a dark room. The normalized luminance vs. normalized DAC count shown in Fig. 1(a). In addition, the DAC count corresponding to the luminance ratio of 0.55 can be obtained by 2nd order polynomial fitting for each curve. The plots of DAC count against brightness level for two contrast levels are shown in Fig. 1(b). First, by extrapolating the two data for each line, we could determine the optimum level of brightness as 40. Next, the level of contrast was adjusted to 85, in which the luminance of maximum white is just below saturation.

This optimized adjustment was examined by measuring RGB and gray ramps displayed on the monitor in which each of the three primaries was stepped from 31 to 255 in increments of 16. Figs. 2(a) and (b) show luminance curves illustrated in log scale and chromaticity coordinates for an arbitrary combination of brightness and contrast B65C70, and Figs. 3(a) and (b) is for an optimum setting B40C85. The interpolated data in Fig. 3(a) form straight lines compared with Fig. 2(a), and the chromaticity coordinates of RGB in Fig. 3(b) are almost constant from 255 to 31 compared with Fig. 2(b). These lead to high contrast of color and gray in displayed image. However, the chromaticity coordinates of gray in Fig. 3(b) are more shifted due to the difference of γ in RGB.

4. Conclusion

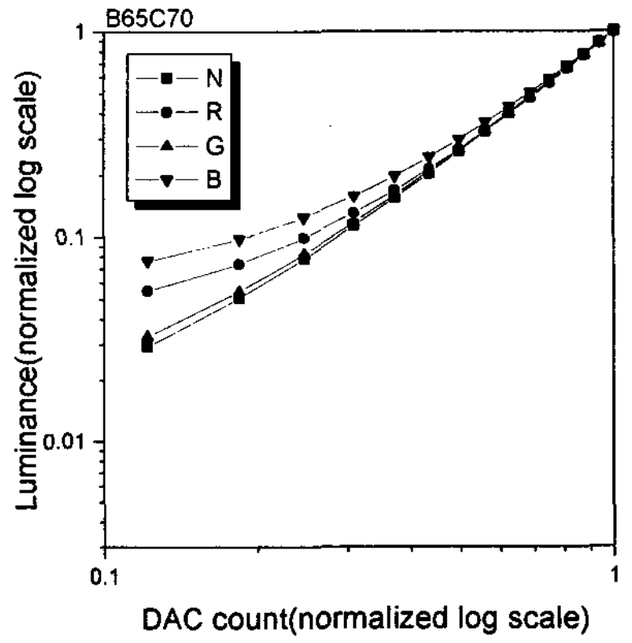
Tone reproduction characteristics of color and gray were optimized using brightness control. The technique to set the optimum brightness level, in which offsets for RGB channels are approximately zero, is very practical. It does not require measurements for low DAC count, including 0. The plots of log-normalized luminance against log-normalized DAC count show straight lines and the chromaticity coordinates for each channel are constant from 255 to 31, while the chromaticity coordinates of gray vary. These lead to high contrast of color and gray in displayed image.

Reference

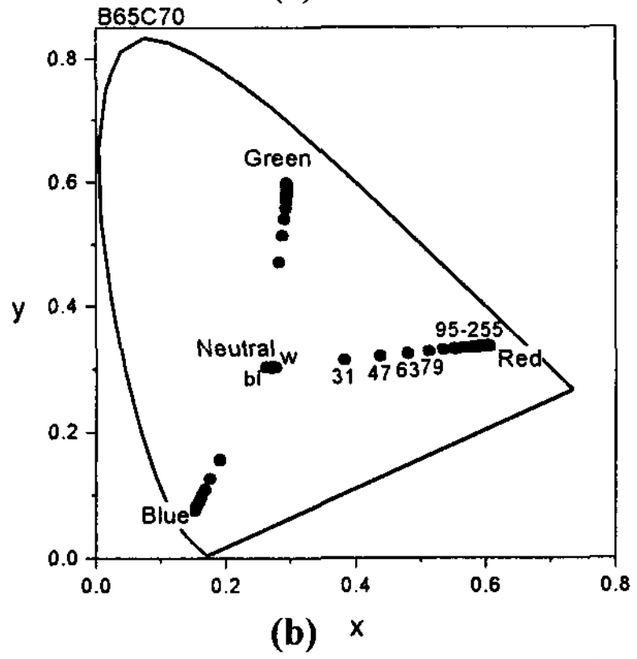
(1) Roy S. Berns, Ricardo J. Motta, and Mark E. Gorzynski, Color Res. Appl. **18**, 299-314(1999)

(2) Charles Poynton, Black level and Picture, Http://www.Inforamp.net/~poynton/notes/black_and_picture/index.html

(3) J. R. Jimenez, J. F. Reche, J. A. Diaz, L. Jimenez del Barco, and E. Hita, Color Res. Appl. **24**, 207-213(1999)

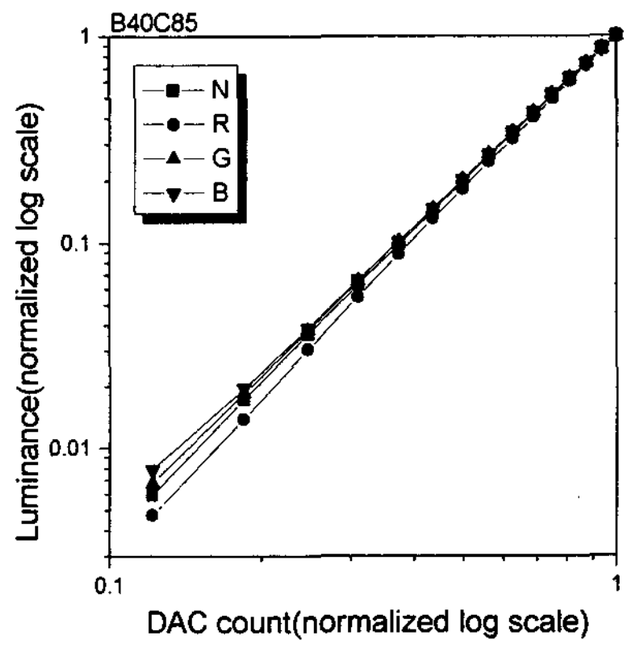


(a)

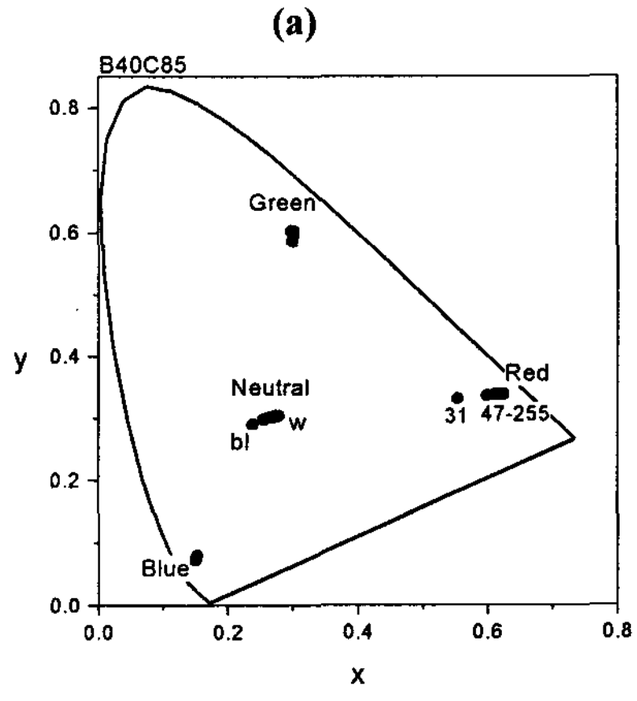


(b)

Fig. 2. Tone reproduction characteristics for B65C70 (a) luminance, (b) chromaticity



(a)



(b)

Fig. 3. Tone reproduction characteristics for B40C85 (a) luminance, (b) chromaticity