The acceptable limit of the contrast ratio of LCD TV based on human visual system

Kwang Hoon Shin, Jong Won Moon, Sun Ah Park, Ji Young Ahn, Dong Woo Kang, and Hyun Ho Shin
LCD R&D center, LG.Philips LCD Co., Ltd.,
Hogae-dong, Dongan-gu, Anyang-shi, Gyongki-do, Korea
TEL:+82-31-450-7479, E-mail: khshin@lgphilips-lcd.com

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Abstract

Visual perception experiments were conducted to determine the acceptable limit of the contrast ratio of LCD TV under the watching condition. The results showed that the corresponding contrast ratio should be below 10,000:1 at the 3H(height of screen) distance in the living room environment.

1. Introduction

Since 2000, several flat panel displays such as LCD, PDP, SED and OLED have been released and replaced CRT at the display market. Especially, due to the improvement of mass production techniques in LCD, LCD has been dominant and LCD users continue to demand the higher quality of LCD, which elicits the improvement of the image quality in LCD. [1,2] However, there have been not many studies on suggesting the numerical specification for the perceivable limit of image quality factors such as the luminance level, response time, contrast ratio, etc. In case of contrast ratio, some of the contrast ratio enhancement techniques have trade-offs with characteristics. Therefore, a search and awareness of optimal and allowance levels to the contrast ratio and their factors are very important to set target for a development of high quality display.

We already proposed the acceptable limit of the luminance level and the response time of the human visual system. [3,4] In this paper, we also proposed the acceptable contrast ratio. The contrast ratio is the ratio of the brightest luminance value to the darkest one. Since the contrast ratio is different among kinds of displays, and some display makers present their contrast ratio to be over 10,000:1 or even over 100,000:1, we might ask: what is the acceptable range of the contrast ratio based on the human visual system? Thus, this paper suggests the perceivable limit of the contrast ratio and the target value in improving the contrast ratio of TV.

Visual perception experiments were executed to determine the acceptable contrast ratio of LCD TV under the watching condition. Because the contrast ratio is the ratio of the brighter luminance level and the darker one in the display screen, we conducted visual perception tests of the black (experiment 1) and white (experiment 2) luminance level respectively.

In lighting engineering, a variety of methods to determine if given light sources will produce discomfort glare has been developed empirically [5,6, 7]. In North America, the visual comfort probability (VCP) system, which is a method used to predict a lighting system's potential for direct glare problems, has been developed. The VCP is an estimate of the percentage of people that would consider a given lighting arrangement visually comfortable. The VCP of 70 percent is considered acceptable by IES Standards. [8] On the contrary, the visual discomfort probability (VDP) is defined as (1-VCP).

$$VDP = 1 - \frac{100}{\sqrt{2\pi}} \int_{-\infty}^{6.3741-3227\ln DGR} e^{-t^2/2}\, dt \qquad (1)$$

The DGR shown in equation (1) represents discomfort glare rating and the formula is

$$DGR = \left\{ \sum_{i=1}^{n} \left(\frac{0.50 L_S Q}{P F_V^{0.44}} \right)_i \right\}^{n^{-0.0914}} \qquad (2)$$

, where
n = Number of sources in the field of view,
L_s = Average luminance of the source in cd/m2,
Q = Function of the solid angle, ω_s
P = Position index of a source,
F_V = Average luminance for the entire field of view.

The DGR is a metric of discomfort that increases as discomfort increases and related to luminance of light sources, luminance of entire field of view, sizes of sources, positions of sources, the number of sources, and configuration of sources. Supposed a LCD TV is one of light sources, we can say that DGR is affected by three dominant factors such as average luminance level of LCD TV, a size of it, and ambient illuminance.

2. Experimental 1

2.1 Method

Observers.

Fifteen observers between ages of 26 and 39 participated in the study. All observers had normal, or corrected to normal, visual acuity. Five of the authors served as observers. Those fifteen observers included engineers working in LCD field and nonengineers.

Stimuli and Apparatus.

The ambient lighting levels were adjusted to 4 and 200 lx each, measured at the center of a TV perpendicularly to the direction of an observer.

In order to quantify the black level that humans perceive on LCD, we carried out subjective evaluation experiment. Several observers using the following evaluation scale evaluated the quality of the test picture relative to that of the reference picture. [1] Five-grade impairment scale for deterioration of quality of the test picture is:
5: imperceptible, 4: perceptible, but not annoying,
3: slightly annoying, 2: annoying, 1: very annoying.
Grade 4.5 is sometimes called “threshold of perception (for deterioration)” and grade 3.5 is sometimes called “limit of acceptance” in the result.

Our subjective evaluation is operated in a test room, which is modeled on a movie theater and a living room to emulate the LCD-TV consumer environment. And we carried out the visual perception experiment with commercial IPS HD LCD at 3H distance, where H is Height of display. Two patch were used in this experiment, one was reference, another was stimulus; two of them were of one size, 2degrees of visual angle, each of them displayed at 10degrees distance diagonally. [9] Black level of reference was low enough, so that was no doubt of result of experiment. For the experiment, there were 11 images and 3 times repeat, 5times pseudo-test, resulting in 38 trials (11*3+5) at different ambient lighting level. Background was chosen the luminance that was average of low gray level of movie histogram analysis. To set the background level, we analyzed the gray histogram of movies to get the average of low gray levels. And we chosen the luminance level that was converted to sRGB (3). [8]

$$R_{sRGB} = \left[(R'_{sRGB}+0.055)/1.055\right]^{2.4}$$
$$G_{sRGB} = \left[(G'_{sRGB}+0.055)/1.055\right]^{2.4} \quad (3)$$
$$B_{sRGB} = \left[(B'_{sRGB}+0.055)/1.055\right]^{2.4}$$

2.2 Results.

Visual perception experiments of the acceptable black level showed that the threshold of the perception level were 0.02 and 0.13 cd/cm^2 and on the average, the limit of acceptance level were 0.07 and 0.42 cd/cm^2 at the movie theater and the living room environment respectively.

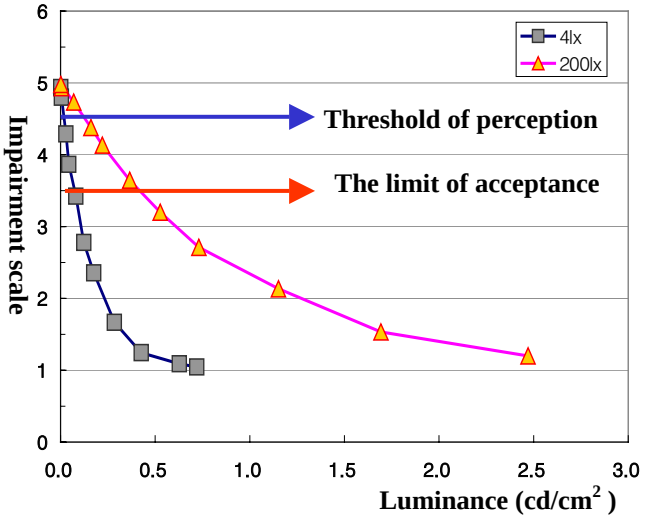

Figure 1. Perception of black level

Table 1. Perception limit of black level

	Movie theater (4lx)	Living room (200lx)
Threshold of perception	0.02	0.13
The limit of acceptance	0.07	0.42

3. Experimental 2

3.1 Method

Observers.

Fifteen observers participated in Experimental 2. Five of authors again served as observers. All observers had normal, or corrected to normal, visual acuity.

Stimuli and Apparatus.
We also executed visual perception test for simple window patterns to determine maximum luminance levels of a LCD TV under a couple of ambient conditions and the same size of stimuli in experiment 1. [3] This pattern had various luminance levels from 170 to 800 cd/cm^2 at 30 cd/cm^2 intervals as stimuli and the same illuminance of experiment 1 as background of stimuli. For the experiment, there were 21 images and 3 times repeat, 5times pseudo-test, resulting in 68 trials (21*3+5) at different ambient lighting level.

3.2 Results.

The results of experiments revealed that the visual discomfort level chosen by 50% of observers was 420 and 570 cd/cm^2, and the visual discomfort level from 30% of observers was 360 and 490 cd/cm^2 at the movie theater and the living room environment respectively.

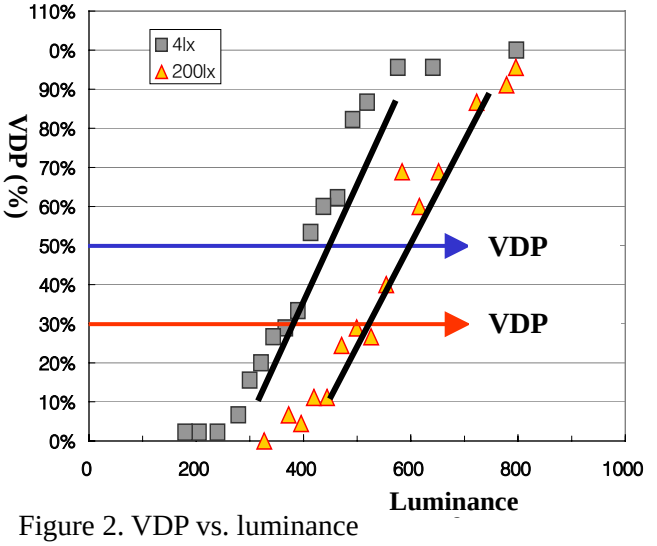

Figure 2. VDP vs. luminance

Table 2. Perception limit of luminance

	Movie theater (4lx)	Living room (200lx)
50% VDP	420	570
30% VDP	360	490

4. Results and discussion

Visual perception experiments were executed to determine the acceptable contrast ratio of LCD TV under the watching condition. Because the contrast ratio is the ratio of the brighter luminance level and the darker one in the display screen, we conducted visual perception tests of the white and black luminance level respectively. The visual perception test of the white level was executed by testing the visual discomfort level of the white luminance from observers. We found that the visual discomfort level chosen by 50% of observers was 420 and 570 cd/cm^2, and the visual discomfort level from 30% of observers was 360 and 490 cd/cm^2 at the movie theater and the living room environment respectively.

Furthermore, visual perception experiments of the acceptable black level showed that the threshold of the perception level were 0.02 and 0.13 cd/cm^2 and on the average, the limit of acceptance level were 0.07 and 0.42 cd/cm^2 at the movie theater and the living room environment respectively.

Accordingly, the acceptable contrast ratio is from the limit of acceptance black level and the visual discomfort of the white level by 30% of observers. The acceptable contrast ratio is 5100:1 and 1200:1 respectively at the movie theater and living room environment, which means the acceptable contrast ratio is below 10,000:1.

5. References

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