Large Area Flicker Metric for Display System

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Abstract
Large area flicker is one of the most annoying image defects, and it is an inherent characteristic of impulsively driven displays such as CRTs. Recently, LCDs have also adopted impulsive driving methods for improved motion picture quality, therefore LCDs can also show large area flicker. Existing metrics do not account for the non-linearity of human brightness perception. This paper presents an improved large area flicker metric to more accurately quantify large area display flicker performance.

1. Introduction

Large area flicker is an inherent defect in display systems using impulsive driving schemes, for example, in CRT and PDP displays. LCDs have been considered to be flicker-free because the normal addressing schemes use hold-type driving. Flicker in LCDs arises from a different source, specifically, unequal luminance between positive and negative data polarities. It is only visible in patterned images depending on the polarity sequence. However, recently developed LCDs employ impulsive driving schemes to improve motion picture quality, hence can also show large area flicker. Large area flicker is very subjective because it depends on the viewer's visual sensitivity. This paper proposes a new large area flicker metric for display systems by combining the conventional JEITA method with a factor that accounts for the human visual system's luminance sensitivity.

2. Experimental

Large area flicker arises mainly from two sources, 1) frame repetition rate and 2) illumination of the retina by an image and ambient brightness [1]. According to the human visual system (HVS) sensitivity function, 60Hz flicker is less perceivable compared to 50Hz driving, for which large area flicker is noticeable even to untrained eyes. Illumination of the retina depends on brightness of the image. The conventional JEITA flicker measurement method calculates the flicker value by using the amplitude of frequency components in a fluctuating luminance function and by weighting each component differently according to frequency [1].

$$\mathrm{Flicker} = 20 \times \log\left[\frac{\sqrt{2} \times weight(freq) \times FFT(freq)}{weight(DC) \times FFT(DC)}\right] \quad \text{(Eq.1)}$$

Equation Eq. 1 shows that the flicker value can be calculated using the amplitude of frequency components and a weighting function which is set according to the HVS frequency response function. It is a useful method to measure flicker of display systems. However, this approach does not adequately represent display performance in terms of large area flicker because different impulsive driving schemes are applied to LCDs, and flicker values will vary according to measurement conditions such as absolute luminance and maximum brightness. Fundamental impulsive driving schemes insert black data between frames. In addition, some newer impulsive driving schemes not only insert black data, but may also insert a non-zero gray level which may vary depending upon the image's gray level [2]. The JEITA prediction accounts for peak to peak luminance variation as a function of temporal frequency and a DC component on the mean luminance level that has a linear relation with the flicker value. The weighting used in Eq. 1 represents only the human eyes' sensitivity to temporal frequency. However the amount of perceived large area flicker does not have a linear relation with mean luminance because human brightness perception has a non-linear characteristic whose model has been defined by Barten [3]. According to Barten`s model, human brightness perception is approximately an inverse of the nonlinear gamma-characteristic of CRT displays. Hence, this factor should be considered for measurement of large area flicker on display systems. Our proposed metric calculates large area flicker using the following steps:

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(a) Measure JEITA flicker values for all image gray levels in 8 gray level increments

(b) Apply a weighting value corresponding to the absolute luminance of each gray level

(c) Calculate large area flicker level by averaging the values from (b)

$$\text{Flicker Level} = \frac{1}{\mathrm{N}}\sum_{i=1}^{N} CSLF(Gi) \times \text{Flicker}(Gi) \quad \text{(Eq. 2)}$$

where N is the total number gray levels at which the flicker value is measured (for a 256 gray level system, N = 256/8 = 32), G_i is each of the 8 gray level increments, and CSLF is a function that is called the contrast sensitivity of luminance field [3]. For the purposes of this metric, spatial frequency is fixed, however, the HVS luminance sensitivity is extracted from the CSLF equation in Barten`s model. CSLF is reproduced in Eq. 3.

$$CSLF(f) = afe^{-bf}(1+ce^{bf})^{0.5} \qquad \text{(Eq.3)}$$

where

$$a = \left[540(1+0.7/L)^{-0.2}\right] \Big/ \left[1+12(1+f/3)^{-2}/w\right]$$

$$b = 0.3(1+100/L)^{0.15}$$

$$c = 0.06$$

and f is the spatial frequency of the stimulus, w is the stimulus size in degrees of visual angle, and L is the mean luminance of the stimulus in cd/m^2. To extract $CSLF(G_i)$ from Eq.3, the absolute luminance that matches G_i to L in a and b is applied. Other factors, such as spatial frequency and stimulus size, are considered to be fixed values for this calculation.

3. Results and discussion

The proposed large area flicker metric was applied to many display devices. According to the new metric, the amount of perceived large area flicker varies according to the type of impulsive driving scheme used even when evaluating the same display. Also, LCDs showed better large area flicker performance compared to CRTs or PDPs. Figure 1 shows the measured JEITA flicker value of each gray level. Figure 2 shows calculated large area flicker level according to the new metric, which includes effects of the human visual system. The results show that the CRT display has a relatively high flicker level and that the CRT display's large area flicker is the most visible among the test vehicles. Also it shows that different impulsive driving schemes generate different levels of large area.

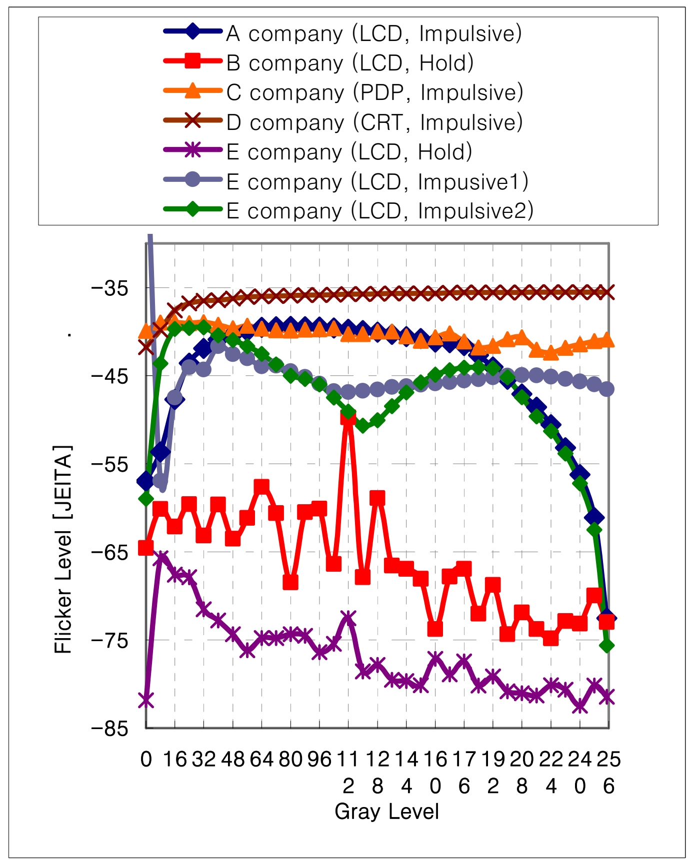

Fig. 1. JEITA flicker level versus gray level for various displays

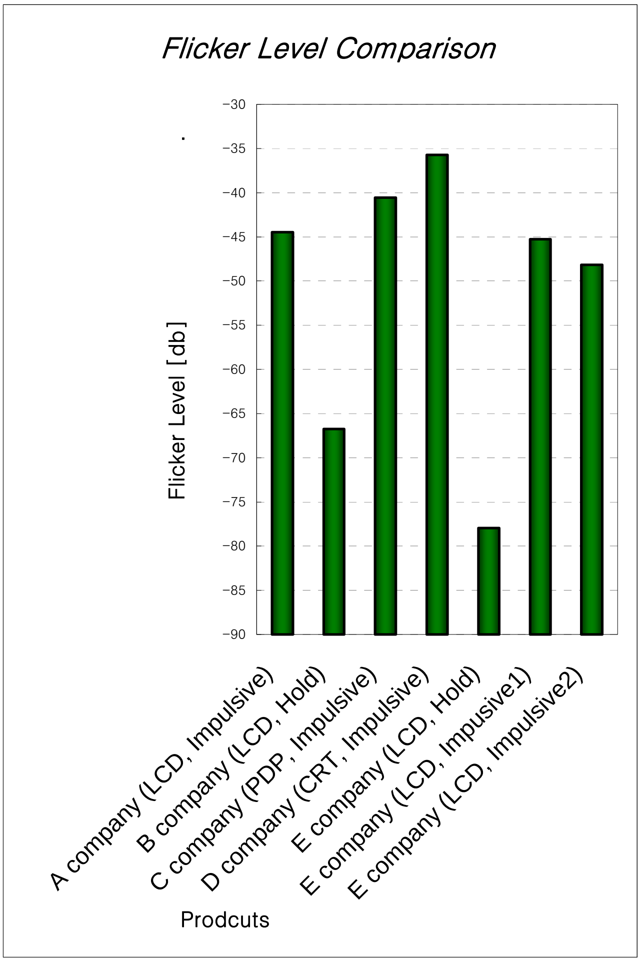

Fig. 2. Large area flicker comparison of various displays using new metric

4. Summary

The conventional large area flicker metric focuses on luminance fluctuation, but it does not account for the non-linearity of human brightness perception. As new displays are developed, such as impulsively driven LCD-TVs with gray (non-black) insertion, the current metric does not adequately predict perception of flicker. Our new metric provides a method for evaluating flicker variation taking both peak to peak luminance fluctuation and human brightness perception into account. To obtain a value that matches the HVS, the new metric combines the JEITA method with weighted HVS luminance sensitivity as extracted from the CSLF function defined by Barten. Considering all gray level flicker values, the new metric provides a value that more accurately represents human perception of flicker from large area display systems.

5. References

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