41.3: Reduction of Large Area Flicker in Plasma Display Panels

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Abstract

This paper describes the occurrence of large area flicker in PDP's. Flicker is mainly a problem in 50 Hz PDP's, although at high peak brightness 60 Hz PDP's will also display flicker artifacts. The description is based on existing theories on flicker that are applied to the PDP's situation. Using this knowledge a new concept has been developed that provides extra possibilities in PDP design to prevent flicker.

1. Introduction

Flicker is the human perception of rapid changes in light intensity. This phenomenon is known to cause headaches and eye-fatigue. It exists to a certain extend in almost all display types, including CRT's and PDP's. In CRT's the problem of flicker has been tackled by choosing a high frame frequency. In Europe television sets have been developed where the frame frequency is doubled to 100 Hz. Computer monitors usually have a frame frequency that is above 70 Hz. Because television broadcasts are at either 50 or 60 Hz, frame rate conversion is necessary however. This is undesirable in PDP's; at a higher frame rate less time is available per frame for light output, which results in lower peak brightness.

Because flicker is a perception phenomenon, the properties of the human eye are involved. The sensitivity of the human eye for changes in light intensity is extremely frequency dependent – above about 10 Hz the sensitivity falls off steeply. This explains to a certain extend why flicker is a much larger problem in 50 Hz than in 60 Hz PDP's. Nevertheless, because the sensitivity also increases at higher light intensity it still is a problem at 60 Hz in bright images.

An important factor in the occurrence of flicker in PDP's is the driving scheme, called Address Display Separated (ADS) [1], as shown in figure 1. This principle is used in (almost) all current AC PDP's to provide multiple gray levels. Unfortunately it provides 'excellent' conditions for flicker because of the highly peaked light output in certain situations.

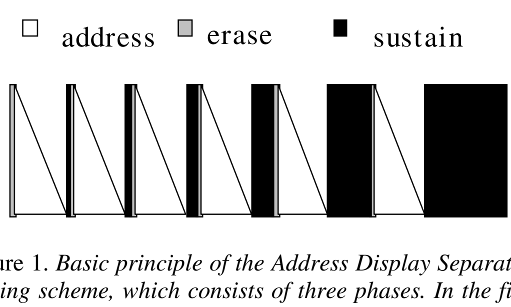

Figure 1. *Basic principle of the Address Display Separated (ADS) driving scheme, which consists of three phases. In the first phase (erase) all pixels are simultaneously reset. In the next phase (address) data is written to all pixels in a line-at-a-time basis. This takes quite some time. In the last phase (sustain) light is emitted in all addressed pixels simultaneously by applying an AC voltage to the panel.*

Methods to reduce flicker have the disadvantage that either the number of gray level or alternatively the peak brightness is reduced. In this paper a solution is shown which provides extra possibilities to reduce flicker while imposing less restrictions on the amount of gray levels and the peak brightness.

2. Flicker theory

Already some 40 years ago H. de Lange performed extensive research on the topic of flicker. [2] A conclusion is that the most important parameters in determining the perception of flicker in periodic light signals are the light waveform and mean intensity. Other parameters are surrounding light intensity, viewing distance and viewing angle. These parameters shift the so-called De Lange curves but do not essentially change them.

The De Lange curves as shown in figure 2 give the relation between de 'ripple ratio' and the Critical Flicker Frequency or 'CFF'. The ripple ratio is the ratio between the average light intensity and the Fourier amplitude of the ground frequency in the signal. This ratio will always vary between the values of zero (for constant signals) and two (for extremely peaked signals). The CFF is the threshold frequency above which no flicker will be perceived. Farell developed a numerical model to calculate the CFF value [3].

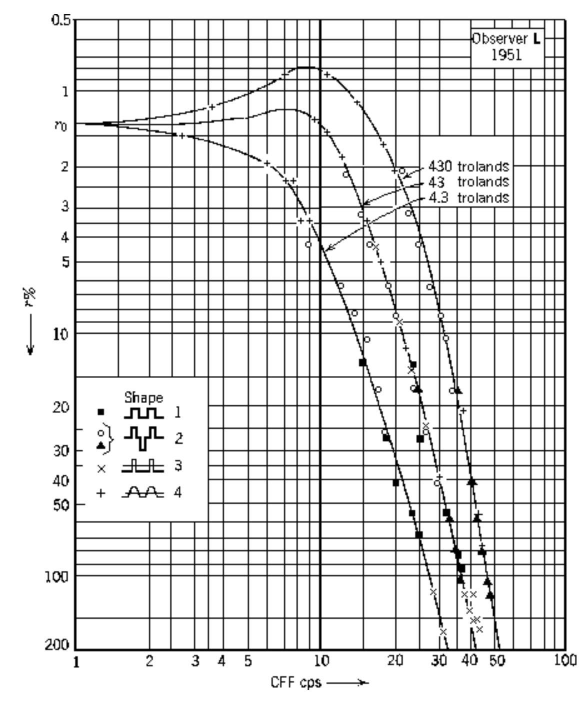

Figure 2. *De Lange curves. On the vertical axis the 'ripple ratio' is depicted. This is the ratio between de DC-component and the Fourier amplitude of the ground frequency of the signal.*

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At lower frequencies flicker will become increasingly visible and thus more annoying. An alternative description is that at the CFF the value of the transfer function has been reduced to zero – no amplitude variation is visible in the signal.

The conclusion can be formulated as follows. Once the exact waveform of a certain light signal is known, its ripple ratio can be determined. If the CFF value is above the operating frequency of the light signal, flicker will be visible. In PDP design the situation is exactly reversed: the frame frequency is fixed at either 50 or 60 Hz. Therefore the light signal must be designed such that its CFF is below this frame frequency.

3. Flicker in Plasma Display Panels

As an example a PDP with eight binary subfields will be regarded. The order of the subfields is assumed to be linear, i.e. 1-2-4-8-16-32-64-128. This situation is already shown in figure 1, though with 6 subfields. Such a setup that displays an entire gray picture with intensity 128 has the light output depicted in figure 3. This is a worst case scenario for PDP's, because the amplitude of the ground frequency is quite high. This implies a high ripple ratio and thus a high CFF. One must realize that the above situation is a theoretical one. In practice this will almost never occur.

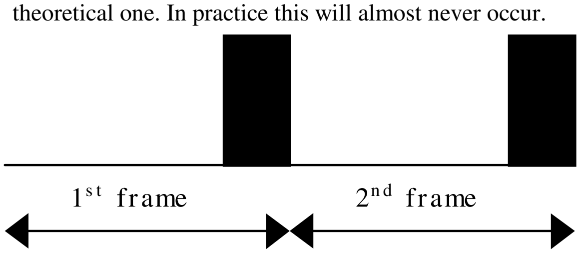

Figure 3. *Light output of two frames with intensity 128. The amplitude of the ground frequency is quite high.*

For a PDP with a peak brightness of about 500 Cd/m^2 the CFF value will be about 70 Hz, meaning that such a pattern must be shown at a frame rate of at least 70 Hz to prevent flicker from occurring. Thus even in a 60 Hz PDP flicker will still be visible! In a 50 Hz PDP the flicker perceptions will be so intense that this situation is unacceptable.

Each gray level consists of a different combination of subfields. The light output thus has a varying pattern, implying different ripple ratios. Using the numerical model by Farell calculations can be made for each gray level. The result is shown in figure 4.

The most obvious solution is to change the order and/or the weight of the individual subfields. In this way the Fourier amplitude of the ground frequency can be influenced, which in turn increases of decreases the large area flicker. However there are certain disadvantages. All non-binary subfield distributions have the disadvantage that fewer gray values can be made.

Another problem is found in motion artifacts [4]. This is the phenomenon that moving pictures in PDP's tend to show artificial contouring lines. Current methods to tackle this problem usually involve changing the subfield order and values. So a lot of problems in PDP's are related via the subfield values and order. Changing this to reduce one problem usually increases the problems in other aspects.

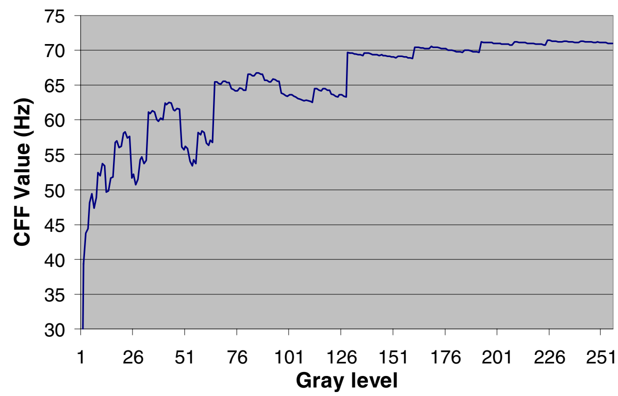

Figure 4. *CFF values for an eight subfield, 500 Cd/m^2 PDP. Viewing conditions such as distance were assumed to be 'normal'. Flicker will be perceived for almost all gray levels in a 50 Hz PDP, and for a lot in a 60 Hz display.*

4. Implementation

The first harmonic of the light output in PDP's is at either 100 or 120 Hz. 100 Hz is already more than sufficient to prevent large area flicker, regardless of the light intensity. This can be achieved by using a subfield distribution that has two subfields with approximately the same weight at a time difference of half the frame rate. For instance 1-2-4-8-16-32-64-128 can be transformed to 1-2-4-64-8-16-32-64-64. Now the '128' intensity level can be made by turning two different '64' subfields on. Because they are approximately half a frame time apart, the amplitude of the ground frequency is almost zero, whilst the amplitude of the first harmonic (at 100 Hz) is high. But this is above the human perception limit, so in this particular situation no flicker will be seen.

There still are some problems however. Firstly an extra subfield is needed to maintain the possibility to make 256 gray level. Due to the required address time the peak intensity will now decrease. The other problem is how to make the '64' intensity. This can only be done by using a single '64' subfield. This gray value will indeed show a lot of flicker. In general one would like to have different choices to make a certain gray level. Thus there is always the possibility to choose the combination with the least amount of flicker. A good example is shown in Figure 5.

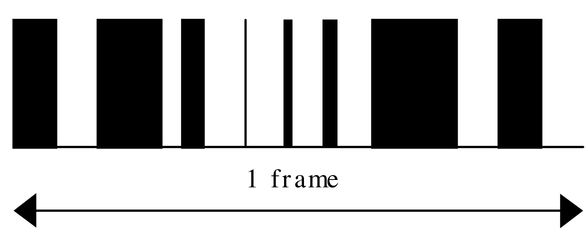

Figure 5. *Eight subfield frame. The values (lengths) of the individual subfields are 22-37-5-1-2-3-44-12. For almost all gray values there are at least two possibilities, e.g. 49 = 44 +5 or 49 = 37 +12*

At the cost of half the total amount of gray values – only 128 different remain- flicker can be reduced considerably. This can be seen in figure 6. About 70% of the gray values has a CFF below

60 Hz. This means that these gray levels are flicker free. At 50 Hz however the situation is still awkward.

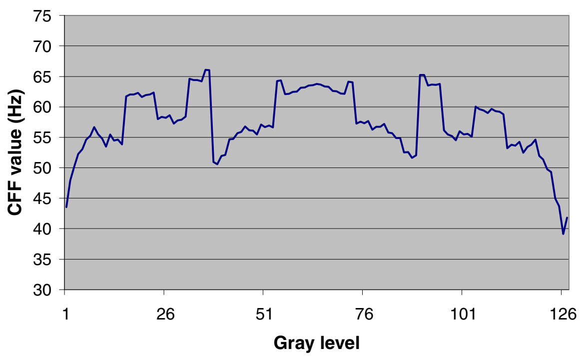

Figure 6. *CFF values for the 22-37-5-1-2-3-44-12 distribution. Especially high gray levels have relative good behavior. This is caused by the approximate half frame time-distance between the high valued subfields (37 and 44) Notice the reduced amount of gray levels.*

Although the concept of providing choices is quite useful, it does not always work as good as in the previous example. Sometimes situations occur where neither choice is acceptable. In this case other options are required.

5. Colored subpixels.

In certain subfield distributions choices do exist for one single gray level, although neither choice has good 'flicker performance.' A good example is the next subfield distribution: 16-2-40-8-20-1-36-4. Most gray levels can be made in a good way with respect to flicker behavior. For instance the gray level of '40' can be made with 20+16+4. Two possibilities exist to make the '20' level: '20' on its own and '16' + '4'. Both have a high ground frequency amplitude.

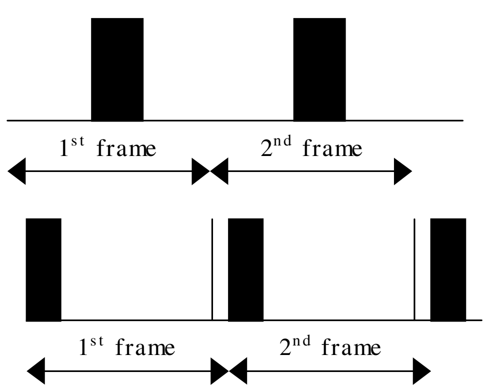

Figure 7. *Two different options to make gray level '20.' Both have a high ground frequency component, and will thus display flicker.*

An elegant solution exists in these situations. Gray pixels are made in PDP's by three individual subpixels in the three primary colors: red, blue and green. By using one of the above mentioned combinations for the green subpixels, and the other combination for the red and blue subpixels a light flash is made every half frame time.

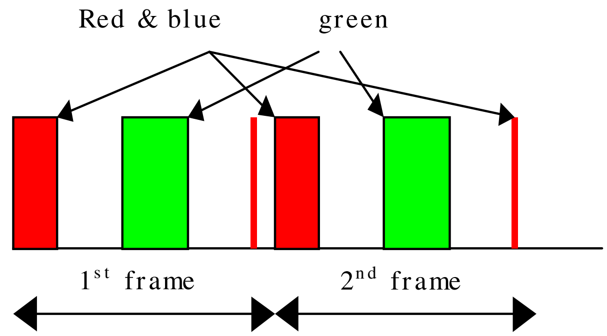

Figure 8. *Using different subfields for different colors results in less flicker.*

Because the luminance of the green subpixel is approximately equal to the summed luminance of the red and blue subpixel, the amplitude of the ground frequency is reduced significantly, hence less flicker. This has indeed been verified in a split-screen experiment. The part of the screen using this option showed less flicker compared to the other half which used only one subfield combination for all subpixels.

In pictures where only one primary color is used, an extra modification is necessary. The 'compensation' cannot be provided by other colors, so the two different choices are both used in a checkerboard pattern. Because two adjacent pixels are close to each other, the human eye will perceive the combined light output as a single light source. Again, the amplitude of the ground frequency of this combined light source is low. The checkerboard pattern on its own is visible in moving pictures [4]. Combining the checkerboard pattern with changing colors also reduces these motion artifacts.

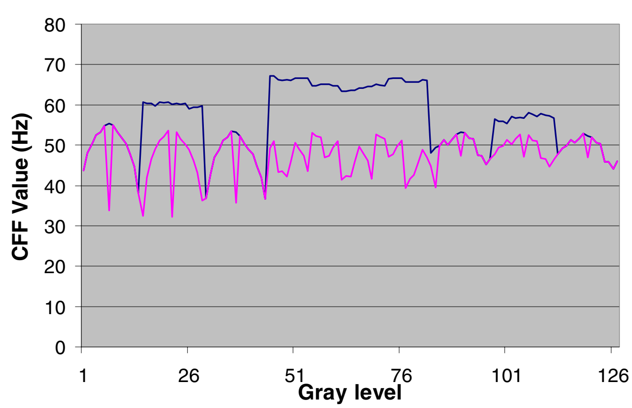

Figure 9. *Improvement when using the 'color-option.' At certain gray levels this option provides useful alternatives to reduce flicker.*

A very nice property of this concept is that it provides extra degrees of freedom for optimization. No limitations are involved whatsoever – one could decide to use this color option only in certain areas of the screen, or only at high intensities. It can also depend on picture properties. The choice which possibility to use for a certain gray level can even be made in real time, depending on picture content.

6. Conclusions.

A general flicker model by H. de Lange is used to predict flicker in PDP's. The most important property for PDP design is that flicker sensibility decreases with higher frequency. However it increases with higher mean light intensity. Given a fixed frame frequency it is possible to reduce flicker by attenuating the ground frequency of the light signal, in favor of the higher harmonics.

Using this concept, subfield distributions in PDP's can be analyzed and suggestions can be made towards better performance. Alternating choices for different color subpixels provide extra flexibility. This can be useful when other optimization aspects impose severe restrictions on subfield order and values. It is also important to realize that threshold values have been investigated in this article. A little flicker can still be acceptable in certain circumstances.

7. References.

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