Using Net Power Control for AMOLED TV

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Abstract

The maximum current level in organic light emitting diodes (OLED) panel influences the maximum pixel luminance, the width of V_{DD} *lines, the maximum power consumption and the lifetime. We propose an algorithm that limits the overall current without any palpable image artifacts, and therefore, improve panel parameters by program.*

1. Introduction

The life time of OLED is improving rapidly. However, it is still not long enough to be used as TVs. It is known that the life time of OLED is inversely proportional to the current density with the exponential quotient in the range of 1.3 ~ 2.0. Larger aperture ratio yields less current density and thus will produce longer life time for the panel.

One of the elements in the pixel matrix circuitry is the power line (called the "V_{DD} line") which supplies current through the driving TFT to OLED. The width of the V_{DD} line should be sufficient enough to maintain the power voltage. Larger current requires wider line, thus reducing the aperture ratio.

Limiting the maximum panel current allows decreasing the width of the power line and, as a consequence, increasing the area of the light emitting region. Furthermore, it allows increasing the maximum brightness at the same current consumption.

We analyzed various video materials and calculated the power consumption of each frame for an RGBW AMOLED [1]. We have concluded that these video materials mostly consist of video frames with total current well below than 25% of the maximum panel current required. Therefore, limiting the total panel current at 25% does not affect most of the video frames. It only affects the brightest frames [2]. To realize this concept, we propose Net Power Control (NPC) algorithm and FNPC (Fast NPC) algorithm.

With NPC limiting the total current, for example, at 25% of the maximum current, the width of the V_{DD} line can be reduced to one fourth. In our test device, the aperture ratio increased from 40% to 63%, increasing the life time by 100% [3].

2. NPC algorithm

NPC controls the incoming RGB video signal so that the total current for a given frame does not exceed a preset value. We call the preset "NPC limit" and it is expressed in percentage of the maximum of the demanded current for the panel.

Imagine an RGBW AMOLED panel designed to produce maximum luminance of 500 nits. When every pixel draws the maximum current, the panel consumes, for example, 12 A. Setting the NPC limit at 25% means that the maximum allowed current is limited to 3 A.

The main idea of the NPC algorithm is to decrease brightness of every pixel universally (if the overall current for the frame is expected to exceed the threshold value) by multiplying a scale factor S (equal to or less than 1.0), so that the current level should fall below the NPC limit.

The scale factor S is calculated in the previous frame (high correlation of the neighboring frames in the real video materials permits to do this), so that need for frame memory is eliminated. After multiplying, the results are normalized, sorted and undergo gamma transformation. Then, each pixel is converted from RGB to RGBW, and the overall frame current is calculated as follows:

$$I_S = \Sigma\Sigma\,(max^{\gamma}+mid^{\gamma}-min^{\gamma}), \quad (1)$$

$$S_{i+1} = \begin{cases} S_i - 1/N, \text{ if } I_S < I_{th}; \\ S_i + 1/N, \text{ if } I_S > I_{th}, \end{cases} \quad (2)$$

where max^{γ} , mid^{γ}, min^{γ} – maximum, middle and minimum value after gamma (γ) transformation, $\Sigma\Sigma$ – sum of each pixel current in the full frame. Overall current (I_S) is compared with threshold current (I_{th}) and if it is larger, the scale factor (S) is decreased by 1/N, and if it is smaller – increased by 1/N, with N typically being 256 steps.

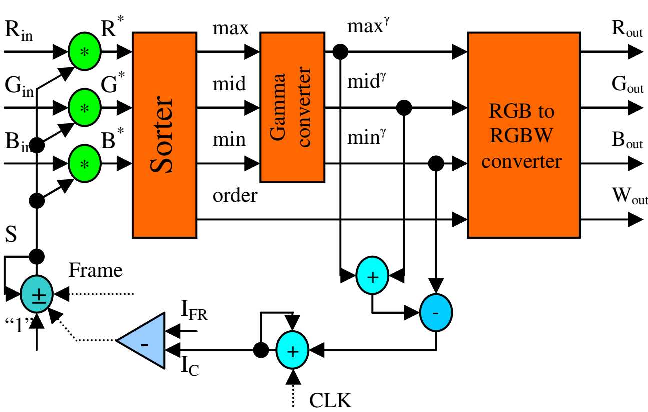

Fig. 1. The structure realized NPC algorithm.

Fig. 1 shows the structure that permits to perform these operations. Sorter performs a sorting of multiplication results (R*, G*, B*), and in output has four variables: maximum, medium, minimum and order of colors. Dealing with max, mid, and min makes calculation simpler than with R, G, and B. The values in grayscale are changed to actual luminance, thus current values by gamma transformation. The RGB-to-RGBW converter calculates the scaled red, green and blue colors and also additional white color based on the Sorter and Gamma converter data [4]. Resulting pixel current is calculated with one adder and a subtracter. One additional adder calculates overall frame current, which compares with threshold current by comparator. The result of the comparison influences the scale factor S according to Eq. 2.

3. Simulation

For the test of the proposed algorithm, fifteen different video materials were processed. Video data were processed by a custom board based on FPGA in which the present algorithm was realized. In the experiment the number of the frames subjected to NPC (S < 1.0) for the different threshold NPC limit was counted. Results are represented in percents in Fig. 2.

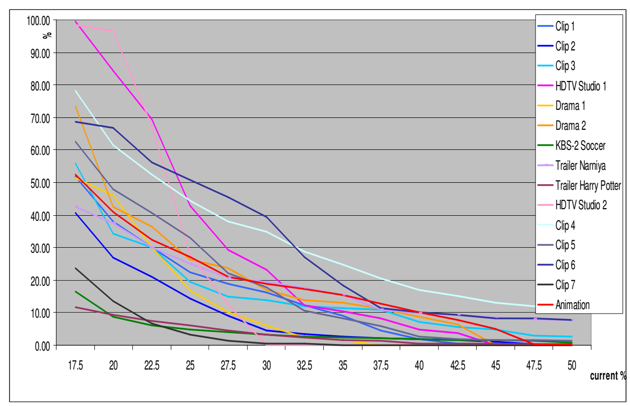

Fig. 2. Percentage of frames that were affected by NPC as a function of NPC limit.

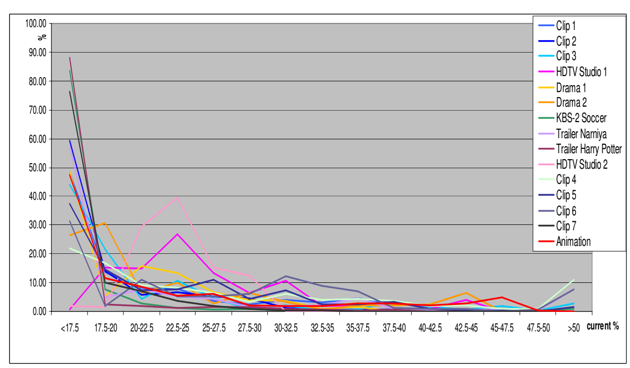

Fig. 3. Percentage of frames as a function of power.

Based on experiment results we came to a conclusion that in analog video materials the number of the frames subjected to NPC was less than 10% at NPC limit = 25% (clip 2, drama 1, soccer, movies). In high-definition digital video materials, the number of the frames subjected to NPC was less than 10% at NPC limit = 35%. It is because they are brighter and more colorful. However, from Fig. 3, we can conclude that the most of frames consume less than 20% of the maximum possible power. Only exception was the "HDTV Studio" in which a substantial number of frames consume power in the range of 20-30%.

The Fig. 4 presents the average number of the frames that was affected modification according to different NPC limit. According this data the average number of the frames that was affected modification is less than 20% at NPC limit = 27.5% and less than 10% at NPC limit = 35%.

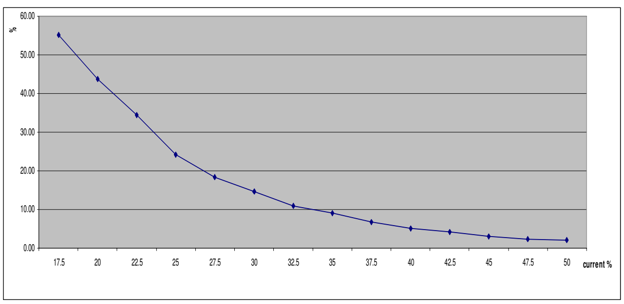

Fig. 4. Average number of frames that were affected according to different NPC limit.

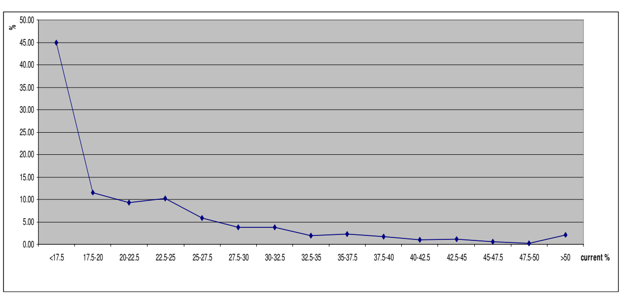

Fig. 5. Average frames distribution according to different NPC limit.

The Fig. 5 presents average frames distribution according to different NPC limit.

At this figure we find that number of frames with current 27.5-30% and 30-32.5% is less than 5%. Also number of frames in each current region from 32.5% less than 2.5%.

4. FNPC Algorithm

The NPC algorithm changes overall current by 1/N at each frame, in order to prevent flicker. Sometimes it is not enough, especially when dark frame is changing bright (for example, night subject is changing by bright sky). In such situations current change takes about 2 sec. Proposed below algorithm allow to fix this problem. Structure is different with previous only what S is changing not by a fixed value, 1/N, but by value that proportionate to difference between overall frame current and threshold current. It's allowed to speed up S change especially in case, when neighboring frames have large difference in brightness.

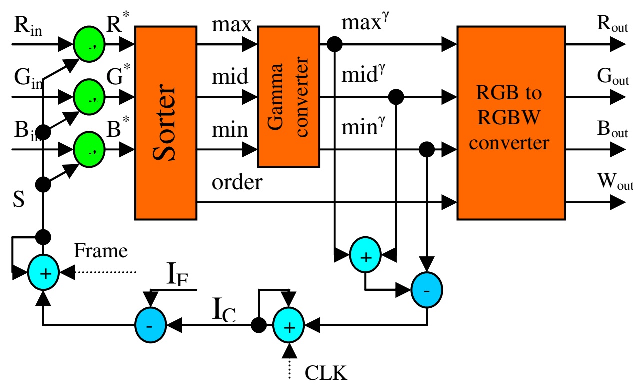

Fig. 6. The FNPC algorithm realization structure.

As in the previous scheme, the each input color (RGB) is multiplied by S and then sorted. After, results of the previous operation subjected gamma transformation. With this data overall frame current and difference between them and threshold current is calculated. This difference is added to S at each end of the frame.

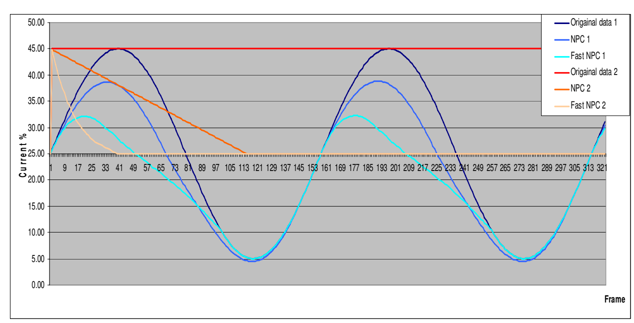

Fig. 7. NPC and FNPC algorithms reaction for the different input data influence.

In Fig. 7, two examples of NPC and FNPC algorithm performance are present. In the both examples, the NPC limit was set at 25%. At the first one, the input current (Original data1) is changed according to sine function. Resulting output data of NPC algorithm (NPC 1) amount to the maximum at

39% (less then 45% only for 6%) and reduced to level 25% in 68 frames. In case of FNPC algorithm maximum amount 32% (less than 45% for 13%) and reduced to level 25% in 50 frames, i.e. by 26% faster. When input current less than threshold current, output current of FNPS algorithm has been equalizing to the input current faster than in case with NPC. When difference between input current and threshold current is not very big, the results of NPC and FNPC algorithm are same.

At the second example input current is changed from 25% to 45% in one frame. NPC took 114 frames (~ 2 sec). FNPC algorithm is changed this current back to 25% in 40 frames, i.e. by 65% faster.

5. Simulation

For the test of FNPC algorithm, different video materials that have neighboring frames with different difference in overall frame current were processed. In Fig. 8, three examples of the NPC and FNPC execution are presented.

Difference in number of frames that was affected NPC and FNPC algorithms for Trailer Narnia is about 5%. This trailer contains neighboring frames where difference in overall current is very big. On the other hand, difference in number of frames that was affected by NPC and FNPC algorithms for clip 6 and clip 3 are present, but they are very little. These clips contain video frames consecution where current changes from frame to frame very gradually.

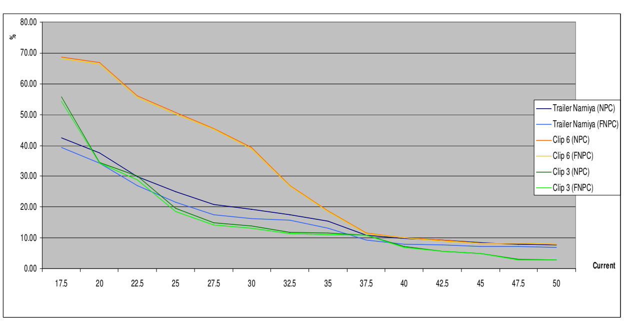

Fig. 8. Number of frames that was affected by FNPC according to different NPC limit.

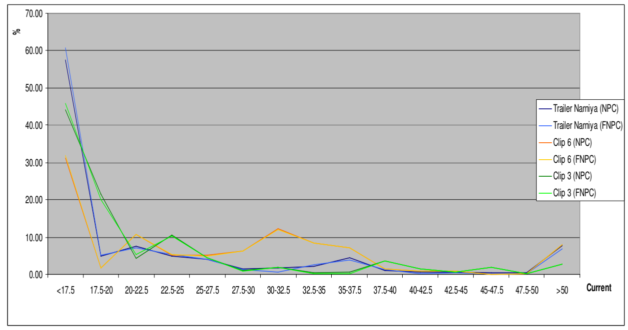

Fig. 9. Affected FNPC modification frames distribution for different current consumption.

6. Conclusion

Two methods (NPC and FNPC) of image processing were proposed. The statistical analysis showed that in real video materials number of frames where overall frame current larger than 40% of maximum current is very rare and applying FNPC algorithm hardly change real video images. Using of FNPC allows confining OLED panel consumption current without changing schematics of the panel and as result – increasing OLED panel lifetime. FNPC method is simple in realization, easily implemented by small-size ASIC.

7. References

1. Baek-woon Lee, Kyongtae Park, Alexander Arkhipov, Sungtae Shin, and Kyuha Chung, “The RGBW Advantage for AMOLED,” *SID 07 Digest*, 1386 (2007).
2. Actually, for a RGBW OLED, the most current-demanding colors are cyan, magenta, and yellow for which two subpixels should be fully turned-on.
3. We assumed the acceleration factor to be 1.5.
4. Baek-woon Lee, Cheolwoo Park, Sangil Kim, Taehwan Kim, Youngchol Yang, Joonhak Oh, Jeongye Choi, Munpyo Hong, Dongsik Sakong, Kyuha Chung, Seongdeok Lee, and Changyong Kim, “TFT-LCD with RGBW Color System”, *SID’03 Digest*, p.1212 (2003).