Method for Improving Burn-in for RGBW OLED Displays

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Abstract

We proposed new methods that can improve burn-in in RGBW OLED displays. While there is only one combination of grey levels of R, G, B which realize a color in an RGB-pixel, there are numerous possible combinations of grey levels of R, G, B and W which can realize a color in an RGBW-pixel. Among the numerous possible combinations, we selected specific combinations that suppress the peak of sub-pixels' total accumulated amounts of illuminance so that burn-in can be slowed down. And we selected specific combinations that make the pattern of burn-in less artificial so that the burn-in can still occur but it can be felt less severe or less recognizable from a human perceptual view.

Author Keywords

Burn-in; OLED; RGBW; lifetime; image sticking

1. Introduction and Background

OLED Displays have lots of superior advantages than other types of displaying methods [1]. They have been popularly adopted by various types of products and widely and rapidly spread to markets. But it has suffered from burn-in [2]. While lots of research have been tried to improve this problem, compensating video digital data according to the illuminating history of each sub-pixel is one of the representative methods [3-5]. We found out that the RGBW pixel type enables us to try more various types of video data compensating methods than the RGB pixel type. While an RGB pixel consists of R, G, B sub-pixels, an RGBW pixel consists of R, G, B, W sub-pixels. Because current display system infra can deliver only R, G, B video data to display panels, the W video data should be generated by display panels using the information of R, G, B video data and the R, G, B video data should also be modified based on the generated W video data by display panels. The prototype formula to calculate W from R, G, B video data is like equation-1.

$$W_{Generated\ Data} = Min(R_{Input\ Data}, G_{Input\ Data}, B_{Input\ Data}) \qquad (1)$$

We can select any values between 0 and $W_{\text{Generated Data}}$, because they do not distort original image. But, because the brighter the white is, the more beneficiation of RGBW we can enjoy, prototype displays of RGBW have conventionally adopted this $W_{\text{Generated Data}}$ as their W video data. But, if we have some flexibility so that we allow selections of less bright grey levels of W than the $W_{\text{Generated Data}}$, we get to be able to select numerous values from 0 to $W_{\text{Generated Data}}$ as W video data. This means that while there is only one combination of grey levels of R, G, B, which realizes a color in RGB-pixel, there are numerous possible combinations of grey levels of R, G, B and W which can realize a color in RGBW-pixel like Figure 1. We found out that this characteristic is useful and can be exploited for improving burn-in. Among the numerous possible combinations, if we select specific things, the burn-in can be slowed down or felt less severe. We will introduce the 2 new methods and explain how to join them together and how to apply them on conventional video data counting methods [3-5]

2. Proposed method-1

OLED displays' burn-in is caused by the differences of illuminating capacities among sub-pixels and these differences are caused by the differences of total accumulated amounts of illuminance among sub-pixels [2]. In the case of RGB pixels, because sub-pixels had no choice but to illuminate what external video sources order, the total accumulated amounts of illuminance of sub-pixels were solely decided by external video sources and these differences are inevitable. But, in the case of RGBW pixels, the previously mentioned RGBW's characteristic enables us to have numerous possible choices about how to combine grey levels of sub-pixels without violating what external video source orders. So, we proposed the following method. Among these numerous possible choices, we choose some specific things which make sub-pixels whose total accumulated amounts of illuminance are more illuminate less and sub-pixels whose total accumulated amounts of illuminance are less illuminate more. For example, in Figure 1, if the max of R, G, B sub-pixels' total accumulated amounts of illuminance is larger than that of W, we select the case-1 so that R, G, B sub-pixels illuminate less and W sub-pixel illuminate more, whereas in the opposite case, we select the case-4. So, this suppresses the peak of sub-pixels' total accumulated amounts of illuminance. Considering that as sub-pixels' total accumulated amounts of illuminance increase, sub-pixels become exhausted, the OLED sub-pixels' illuminating capabilities decrease [6], this method makes more exhausted sub-pixels illuminate less and less exhausted sub-pixels illuminate more. This prevents already exhausted sub-pixels from being exhausted more. So, it slows down further exhaustion of the already exhausted sub-pixels so that burn-in can be suppressed.

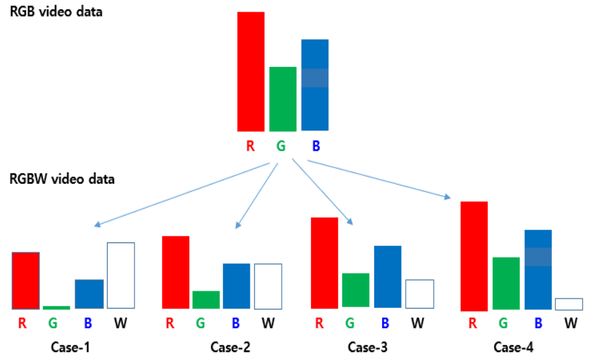

Figure 1. Example of numerous possible combinations of grey levels of R, G, B, W sub-pixels which realize a color

Figure 2 shows the video processing electronic circuit which implements method-1. In Figure 2, the logic "Scaling W" is the only newly added part of conventional video digital data compensating methods. It scales the W^1 video data, which comes from conventional RGB to RGBW converting logic, by S time based on which is larger between the max of the total accumulated amounts of illuminance of R, G, B sub-pixels and that of W sub-pixel. If the total accumulated amount of illuminance of W is larger than that of R, G, B, the W needs to illuminate less and the W is scaled down to 'S x W^1', where the 'S' is a value between 0 and 1.

So, the W sub-pixel can illuminate less. Because the W is modified to S x W^1 from W^1, the grey levels of R, G, B become modified based on the new W. This modification makes R, G, B sub-pixels illuminate more. A balancing operation of total accumulated amounts of illuminance between more illuminated W and less illuminated R, G, B is established.

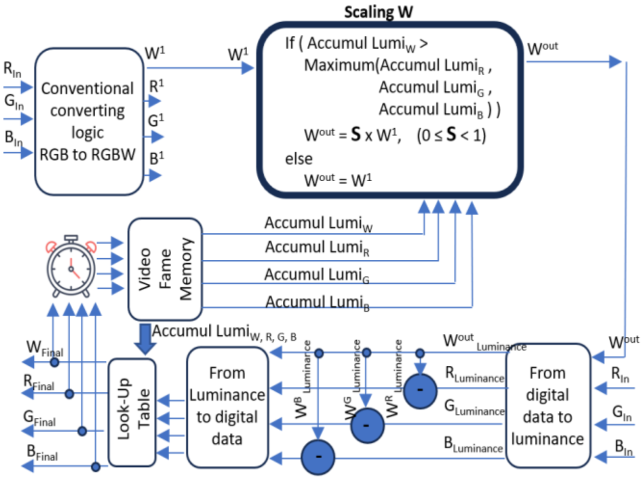

Figure 2. Video signal processing circuit for method-1

3. Proposed method-2

People tend to feel burn-in that has artificial patterns more severe than burn-in that has less artificial patterns. Figure 3 shows a comparison of perceptual severity between burn-in which has artificial patterns and burn-in which has less artificial patterns. The former looks more severe than the latter. So, we need to make the burn-in pattern as less artificial as we can. How can we do this?

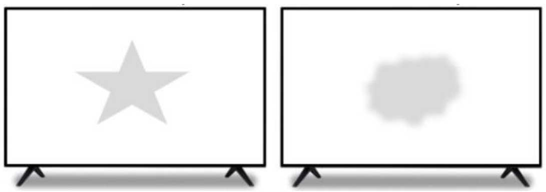

Figure 3. The comparison of perceptual severity between burn-in which has artificial patterns and burn-in which has less aritificial patterns

We found out that among the previously mentioned RGBW pixel's numerous possible combinations of R, G, B and W which realize a color, if we can select some specific combinations, the spatial variations of R, G, B and W can be changed to less artificial patterns without distorting the original image. Figure 4 shows one example of this case. In figure 4, we assume that a greenish box pattern is displayed on white background. Case-1 shows the horizontal spatial distributions of grey levels of R, G, B and W by conventional methods. They are also box patterns. Case-2 shows the horizontal spatial distributions of grey levels of R, G, B and W by the proposed method. They are less like the box pattern. While a color is not distorted, the relationship between R, G, B and W is inversely proportional so that as W increases from 0 to W in equation 1, the R, G, B decrease and vice versa. For this reason, as long as W is not 0, we can make the spatial variation of R, G, B and W have some patterns as we wish without distorting original images. If the pattern can be less artificial, the burn-in pattern will also be less artificial so that it can be felt less severe or less recognizable.

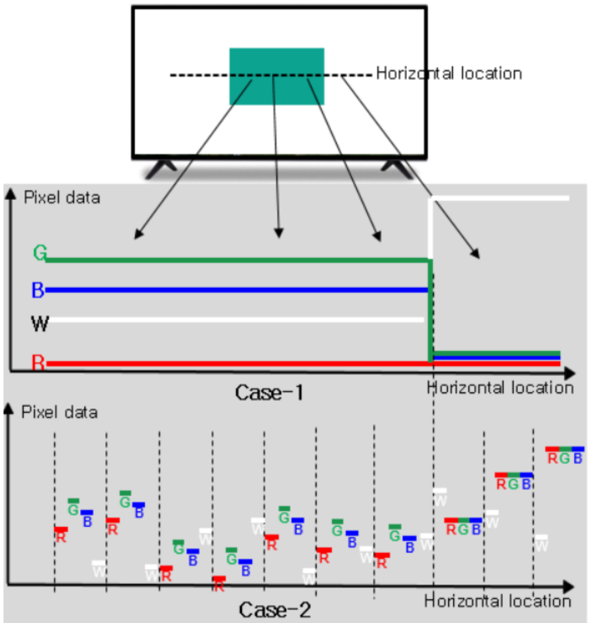

Figure 4. Different spatial variations of luminance of R, G, B, W which realize a same image

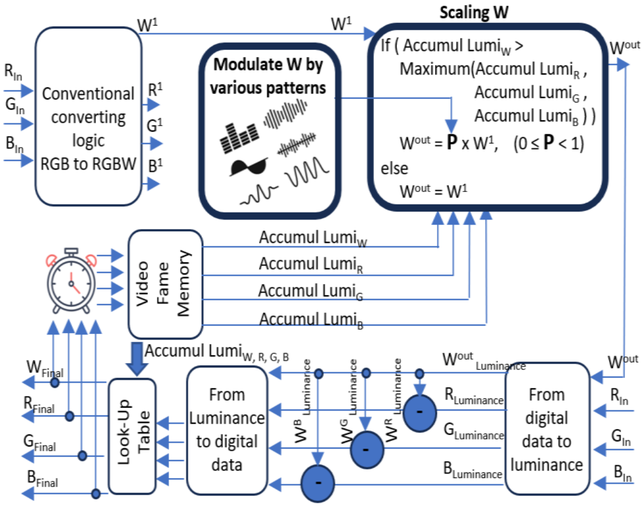

Figure 5. Video signal processing circuit for method-1 and 2

Figure 5 shows the video signal processing circuit that implements method-1 and method-2. The logic of "Modulate W by various patterns" is newly added on the logic in Figure-2. The 'Modulate W by various patterns' generates some patterns which are changed spatially and temporally, and the P is a value between 0 and 1. The W^1, which is the grey level of white calculated by conventional RGB to RGBW converting logic, is patterned by the P. In the logic of "Scaling W", if the total accumulated amounts of illuminance of W is less than the max of the total accumulated amounts of illuminance of R, G, B, we should make the W sub-pixel illuminate more but we cannot do this, because original image's color is distorted. So, the W^1 is selected. Neither method-1 nor method-2 is selected, but the conventional method is selected. If the total accumulated amounts of illuminance of W is larger than that of R, G, B, the W sub-pixel needs to illuminate less and the R, G, B sub-pixels can illuminate more, the P x W^1 is selected; Both of method-1 and method-2 are selected. Because the grey level of W is changed, the grey levels of R, G, B also become changed based on the new W. Because the W^1 is newly patterned, the correspondingly modified R, G, B are also newly patterned. This patterning action makes the spatial variation of the R, G, B, and W less like the original image. The burn-in will be less like the original image. The burn-in will be less like artificial patterns. The burn-in will look less severe. In other words, the patterns P play a role in modulating the W, R, G, B. For making current image not affect future images, we need to change the modulating pattern P in Figure 5 more often than every scene change. However, the modulating pattern should not be changed too frequently. This is because too frequent change of modulating patterns can average out the different modulating patterns so that the useful effects of different modulating pattern can be weakened and the pattern of the total accumulated amounts of illuminance of R, G, B and W can begin to follow the original image pattern again.

4. Simulating method

There have been no RGBW-based picture file standard formats, no RGBW-based video data delivering standard format from PC to monitor, no HDMI EDID for RGBW. The RGBW have been generated and processed only in specific RGBW display panels by specific HWs. So, even if we simulated proposed methods and made RGBW-based picture files using software programs, there are no ways to display the picture files on our conventional monitors. But we found a workaround method that can display RGBW processed picture files on the RGB display system infra like the following. Figure 6 shows the method. We assume an initial picture which consists of RGB pixels like ‘A’. We enlarge the size of the initial picture 4 times by just repeating the video data of the original picture 2 times horizontally and vertically like ‘B’. We give the full black grey levels to the right-bottom pixel like ‘C’. We find the grey level of the primary color which has the minimum grey level among R, G, B sub-pixels in a pixel except the right-bottom pixel. And we divide the luminance of the primary color which has the minimum grey level by 3 like ‘D’. We imaginarily move one-third of the luminance of the primary color which has the minimum grey level from the upper two pixels and the left-bottom one pixel to the right-bottom pixel like ‘E’. Considering that the combination of R, G, B of the same grey levels can be considered as white, we can consider that ‘E’ is the same with ‘F’. If we imaginarily move the 3 white segments of ‘F’ to other 3 pixels, we can get ‘G’. The ‘G’ can be considered as 4 RGBW pixels whose right-bottom pixel is black. There are two different things between the ‘G’ and real 4 RGBW pixels. The first is that the ‘G’ is darker than the real RGBW pixel. The action ‘C’ of giving black data to 1/4 of whole pixels directly reduces its luminance to 3/4 of the original image. But it does not affect the hue and saturation. So, if we can consider the loss of luminance as a known issue, it will be enough to verify any video signal processing algorithms that deal with hue and saturation. The second is that we can exploit only one-third of ‘M’ in ‘C’, whereas we can exploit the whole ‘M’ in a real RGBW pixel. We already mentioned that the ‘M’ is the minimum grey level of R, G, B in a pixel, whose luminance can move to the W sub-pixel during the conversion of RGB to RGBW. This partial usage of ‘M’ will make the beneficiation of RGBW not optimal. Considering that the previously proposed methods are based on the control of the ‘M’, the key purpose of this simulation is whether the partial control of ‘M’ distorts the original video image or not. So, this non-optimal beneficiation of RGBW does not matter.

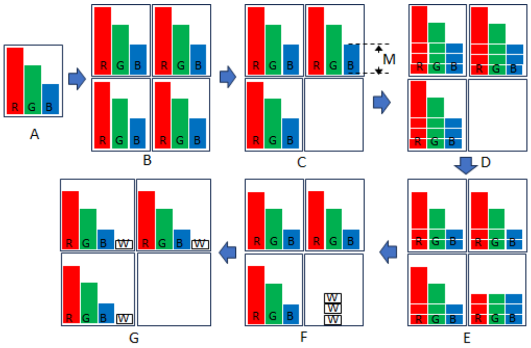

Fig. 6. How to model RGBW pixels’ operation on non-RGBW pixels.

5. Simulated results

We simulated the proposed method-2 using open CV software program. We took a grey box pattern and a cartoon character as the original picture images, like Figure 7. In Figure 7, you can see an arrow on which a white horizontal line is drawn. We checked what spatial variations of grey levels of R, G, B, and W on the white horizontal line look like under the various W-modulating patterns. Figure 7 also shows 5 W-modulating patterns that are used for this test. The simulated result shows that the spatial variations of grey levels of R, G, B and W become less like the original picture image like Figure 8. Figure 10 shows the images by various W-modulating patterns. They are the same as each other, the original image can be kept intact while the spatial variations of grey levels of R, G, B and W are changed.

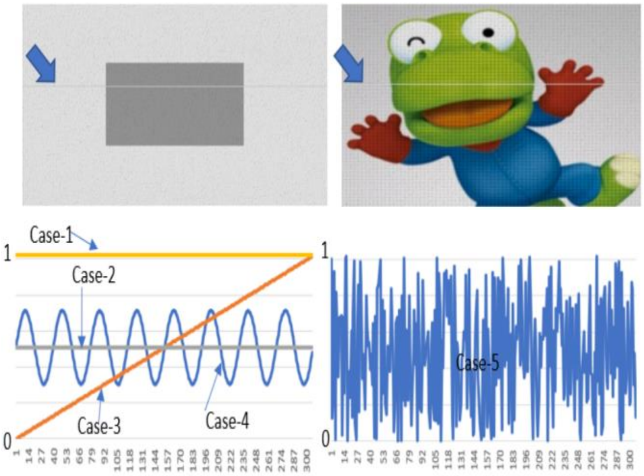

Fig. 7. Patterns which are used for modulating W.

People tend to feel that a blur-edged burn-in pattern is less severe than a sharp-edged burn-in pattern. Method-2 also provides a mean by which the sharpness of burn-in pattern of R, G, B and W can be controlled. According to W generating algorithm (Equation 1), the sharpness of R, G, B and the sharpness of W is the trade-off relation so that if we make R, G, B pattern more blur, W pattern will become sharper and if we make R, G, B pattern sharper, W pattern will be more blur. The optimal balancing between the sharpness of R, G, B burn-in patterns and that of W burn-in pattern will make burn-in less severe. Figure 9 shows the "Modulate W by various pattern" block in Figure 5, which implements this method. The W^1 is low pass filtered or high pass filtered and W^1_{Filter} is created. Considering that a low pass filter or a high pass filter can reduce or increase the original data, the W^1_{Filter} can be larger than

W^1. If W^1_{Filter} is larger than W^1, the color is distorted, and we cannot select it. We can only select W^1_{Filter}, which is smaller than W^1. We can see this selecting logic in Figure 9.

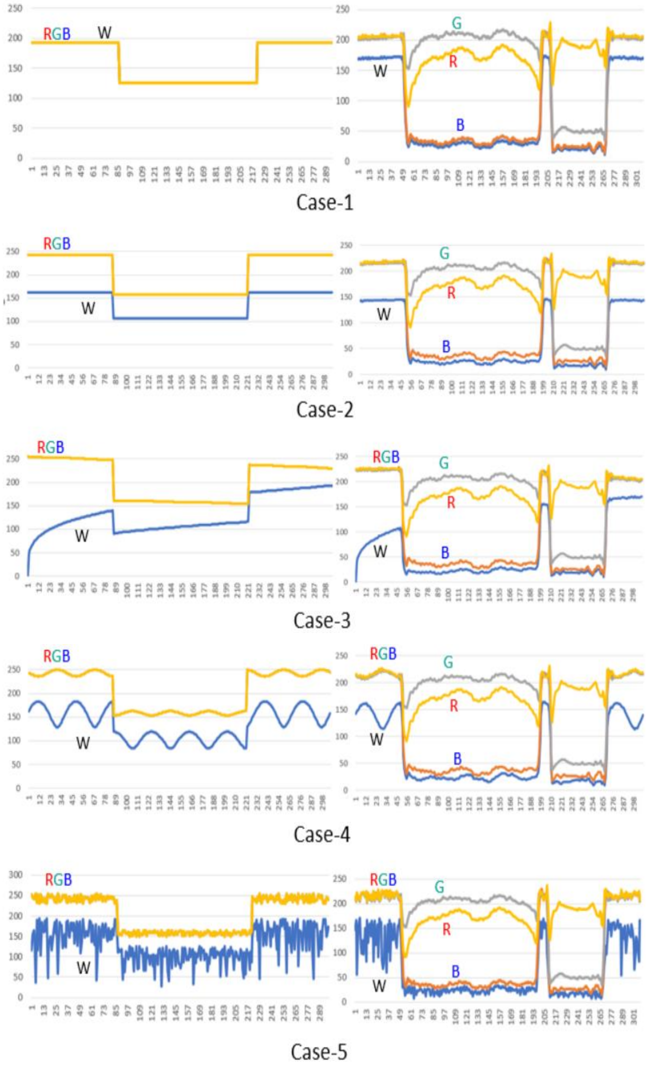

Fig. 8. Different spatial variations of luminance of R, G, B, W which realize the same image.

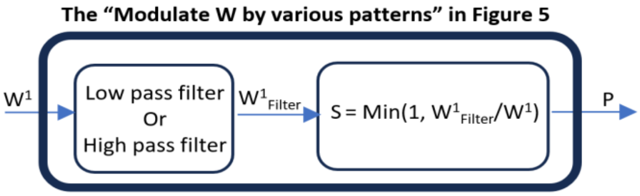

Fig. 9. Modulating W by Low or High pass filter

6. Conclusion

By optimally balancing grey levels of R, G, B sub-pixels and W sub-pixel, we can slow down the exhaustion of OLED pixels' luminating capacity. By optimally patterning the balancing ratio of grey levels of R, G, B sub-pixels and W sub-pixel, we can make the burn-in less severe in human perceptual view. These methods work without distorting the original image. The first method is a time domain approach and the second method is a spatial domain approach. These 2 new methods can easily be joined together and they can harmoniously be applied to conventional video data counting methods [3-5] like Figure 2 and Figure 5. These characteristics and these multi and complementary domain approaches will make these methods more applicable to more various conditions.

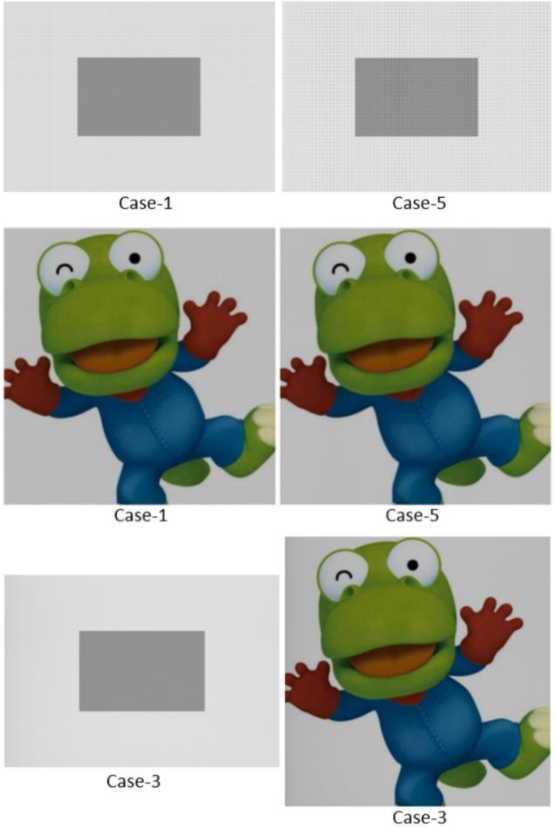

Fig. 10. Comparison among image by various types of W modulated patterns

7. References

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