(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 337 014 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.06.2011 Bulletin 2011/25

(51) Int Cl.:
G09G 3/36 *(2006.01)* ***G09G 3/34*** *(2006.01)*

(21) Application number: **09179604.5**

(22) Date of filing: **17.12.2009**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR
Designated Extension States:
AL BA RS

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(54) **Color display devices with backlights**

(57) A color display comprises a backlight (152) and a display panel (150) for modulating the backlight output. The backlight comprises portions of four different colors, wherein the intensity of each color is independently controllable.

The use of four colors enables more efficient color backlight device to be used in preference to less efficient color devices. For example, the backlight portions can comprise three non-white colors (84,86,82) and white (80). White light generation (with current technology) is more efficient than the generation of other colors.

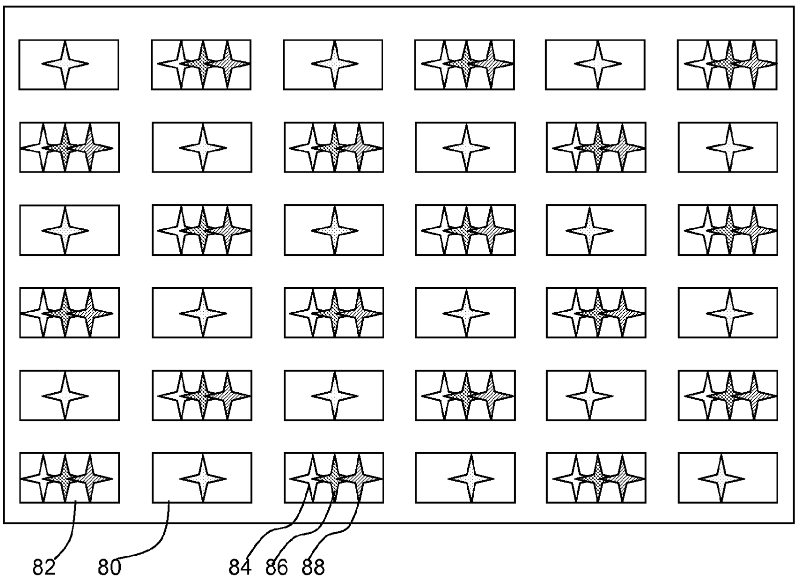

FIG. 8

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Description

[0001] This invention relates to color displays with backlights, for example LCD displays.

[0002] There is a desire to improve picture quality, reduce cost and reduce power consumption of LCD-TV systems. Advanced LED backlights and 2D-(Color)-dimming technology already provide proposed solutions.

[0003] RGBW display panels using white LED backlights provide one way to reduce the inefficiency associated with in-pixel color filters, by having transparent subpixels in addition to the RGB sub-pixels. These transparent sub-pixels enable bright unsaturated colors to be produced, but the color reproduction of bright, saturated colors can be a problem.

[0004] When two colors are scaled differently in brightness and placed next to each other, they will look different. This phenomenon is called "simultaneous contrast". In most RGB-to-RGBW conversion algorithms, colors such as pure yellow with maximum luminance, (r, g, b) = (1, 1, 0), are not scaled because any addition of white would change the saturation. On the other hand, colors with low saturation can be scaled by adding a suitable amount of white. For example, the full white (r, g, b) = (1, 1, 1) is scaled by a factor of two with the addition of the white sub-pixel (r, g, b, w) = (1, 1, 1, 1), thus becoming twice as bright.

[0005] This means that a sharp boundary between white and yellow within an image can appear very unnatural. These kinds of boundaries are relatively rare in moving, natural pictures. However, when they do appear, colors look extremely unattractive. Among all pure colors, yellow on white is most severe. That is because yellow has the highest luminance, very close to full white, combined with the 50% luminance deficit compared to white on the RGBW display.

[0006] Another alternative to the use of a RGB backlight and transparent display panel is the use of color field sequential display technology. These build up a color image in a sequence color-by-color. In-pixel color filtering can be avoided. However, these are not widely used in display applications, as color break-up can be a problem, and fast LCD panels are required to address the multiple sub-frames.

[0007] Color Field Sequential displays using RGB LED backlights have been proposed, as a way to avoid the need for in-pixel color filtering altogether, by providing colored backlight outputs. This can improve the efficiency of the display device.

[0008] For the basic color field sequential displays, light with fixed primary colors such as pure red, green and blue are used to expose the LCD panel at different moments in time, synchronous to the addressing of the color fields by the LCD panel. As there are no color filters applied in the display panel, the power efficiency is significantly increased (factor 3 power savings). Specifically for saturated colors the aperture of the panel is increased a lot, as the RGB sub-pixels are now joined into a single transparent pixel, having factor 3 more aperture (area) for transmitting the primary colors (factor 3 extra brightness), yet this benefit does not apply for unsaturated colors such as the display's white-point.

[0009] With color field sequential displays, the individual color fields can be locally dimmed for video-data comprising areas without bright/unsaturated content (this can give an average factor 2.5 extra power savings). For video-data comprising areas with bright/saturated content, the saturated colors, e.g. yellow with maximum luminance, the backlight and video-data are locally driven (r, g, b) = (1, 1, 0) providing a factor (or area) 1.5 more brightness than the brightness of the white-point color.

[0010] Thus, when color sequential dimming technology is used to drive the color field sequential display, each of the color-fields can be driven with an adaptively determined gamut on a local image-content basis. For example, all fields can be driven locally with the yellow color to reduce color breakup. This implies that the maximum luminance for the yellow color can be much higher than with a normal color field sequential display. As the red and green colors are driven simultaneously, the backlight can be exposed with almost the same yellow color for each of the color fields (giving up to a factor of 3 extra brightness).

[0011] Color field sequential technology is not yet widely used in display applications as a result of the extra complexity and cost involved (for example the need for fast LCD panels to address the multiple sub-frames), as well as problems of color break-up,. However, these issues are being resolved so that color sequential technology is of increasing interest.

[0012] There are thus various different ways to arrange display panels and backlights, but different solutions suffer different problems. This invention aims to provide improved backlight brightness for proper color reproduction of regions with bright, saturated pixels, as well as regions with bright unsaturated pixels. In addition, the invention aims to provide this improvement of overall picture quality, but also reduce the power consumption and reduce the cost of the system.

[0013] A further consideration is that the visual output of the display in response to driving to different colors should be predictable and consistent with relevant standards. For example, the sRGB standard indicates the desired relative brightness of different colors, and a display should provide these outputs in response to driving to the different colors.

[0014] According to the invention, there is provided a color display, comprising:

> a backlight; and
> a display panel for modulating the backlight output, wherein the backlight comprises portions of four different colors, wherein the intensity of each color is independently controllable.

[0015] The use of four colors enables a more efficient color backlight device to be used in preference to less efficient color devices. For example, the backlight portions can comprise three non-white colors and white. White light generation (with current technology) is more efficient than the generation of other colors.

[0016] The contribution to the maximum output intensity of the backlight from the white portions can be approximately 50%. The backlight portions can be red, green, blue and white. The backlight portions can comprise LEDs, and the display panel can comprise an LCD panel. By combining an LCD panel with an RGBW LED backlight instead of an RGB LED backlight, the efficiency of the display system is improved, as the power efficiency is increased. At the same time the cost of these systems can reduce.

[0017] In one example, the display panel comprises RGBW pixels. The extra white pixel enables efficient generation of white output based on the white component of the backlight. For example, with the white pixel occupying 1/4 of the pixel area, and the white backlight portion having the same intensity as the RGB (combined) output, the output white intensity can be increased by 50%.

[0018] In another example, the display can comprise a color field sequential display. When the backlight of the invention is combined with a color field sequential LCD panel, the power efficiency and cost improves significantly, when matching the color reproduction aspect of the panel and RGBW backlight system to the sRGB standard format.

[0019] Preferably, the backlight comprises segments, wherein the intensity of the four colors within each segment can be controlled independently of the other segments. This provides local dimming capability, so that the efficiency of the display can be improved, and the control of the backlight can be made dependent on the image content. 2D dimming is made possible by providing segments which divide the backlight area into rows and columns, so that the backlight has the form of a grid (of coarser resolution that the grid of pixels of the display panel).

[0020] The local dimming can be used to improve black-level and increase the temporal and spatial contrast, the higher contrast ratio increases the perceived brightness (Bartleson-Breneman effect).

[0021] The backlight can have local dimming and local boosting capability, wherein all RGB gamut colors can be mapped into the display output gamut.

[0022] Local dimming and boosting can be used for image-content adaptive backlight and video brightness modulation. More local backlight brightness is provided for the required proper color reproduction of pixels and less local backlight brightness is used for the reduction of power consumption.

[0023] Preferably, the output gamut of the display matches the sRGB standard. Thus, the invention enables matching of the properties of LED backlights and LCD display panels with properties of the standard sRGB format. An input according the sRGB standard is thus converted into an output gamut of the display such that it matches the sRGB standard. On standard LCD display panels, the color spectrum of power efficient white LEDs and color filter materials are designed to match with the sRGB color space of the input video data, so compatibility with the standard simplifies the use of existing display technology.

[0024] This can be achieved by the invention with optimal picture quality, using minimum system resources and consuming minimum power.

[0025] The invention also provides a method of controlling a display device, comprising:

providing a backlight output as portions of four different colors, and independently controlling the intensity of each color; and
modulating the backlight output using a display panel.

[0026] Preferably, the backlight portions comprise three non-white colors and white, wherein the method further comprises selecting the desired white component based on the lowest intensity required by the three colors depending on an image or image portion to be displayed, and deriving the required non-white components therefrom, such that the maximum white component is used.

[0027] This method balances the local luminance ratio of RGB and White LEDs for optimal color rendering, as well as optimal power efficiency.

[0028] As clipping sub-pixels are prevented, the image-content is not de-saturated and does not reduce the perceived brightness (Helmholtz-Kohlrausch effect).

[0029] The invention also provides a computer program comprising computer program code means adapted to control a display panel and backlight using the method of the invention.

[0030] It can be seen that invention can be used to provide a competitive solution for realistic color reproduction on power efficient RGBW LCD display panels, as well as color field sequential LCD displays.

[0031] Examples of the invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 shows a cross section of the color space for an RGB LCD display panel;
Figure 2 shows a cross section of the color space for an RGBW display panel with white backlight and four sub-pixels per pixel;
Figure 3 shows a cross section of the color space for an RGBW panel with RGBW backlight of the invention;
Figure 4 shows a cross section of the color space for a known color sequential panel;
Figure 5 shows a cross section of the color space for a color sequential panel using an RGBW backlight of the invention;
Figure 6 shows in schematic form an RGB LED back-

light;

Figure 7 shows in schematic form a white LED backlight;

Figure 8 shows in schematic form an RGBW backlight of the invention;

Figure 9 shows the so-called L6W pixel layout;

Figure 10 shows an RGB stripe configuration;

Figure 11 shows an alternative representation of color space;

Figure 12 shows one possible mapping of RGB space into RGBW space;

Figure 13 shows an RGB to RGBW mapping which can be used in the system of the invention, and which makes use of backlight dimming and backlight boosting to save power and backlight boosting to bring points into range;

Figure 14 shows the effect of this backlight dimming and boosting on the color space; and

Figure 15 shows schematically the display device of the invention.

[0032] The color reproduction capabilities of known systems will first be described before the approach of the invention is explained in detail.

[0033] Figure 1 shows a cross section of the color space for an RGB LCD display panel. This shows the luminance (Y axis) for three colors (blue, white, yellow) and the evolution of this luminance when moving linearly between blue and yellow (via white) in the 2D color space (x,y axis).

[0034] The RGB color primaries determine the (nominal) limitations of the color gamut. The RGB primaries and luminance ratio preferably match sRGB standard. Very approximately, the blue component contributes 10% to the white luminance, the green 70% and the red 20%. This ratio is reflected in the low luminance of blue and the high luminance of yellow (red + green).

[0035] Figure 2 shows a similar cross section of the color space for an RGBW display panel (i.e. a system with white backlight and four sub-pixels per pixel).

[0036] There is more brightness for unsaturated colors (colors near the white output) but less brightness for saturated colors. This can be seen in Figure 2, in which the blue and yellow luminance has dropped to 75%. An advanced RGBW rendering algorithm is required to convert the output to match the sRGB standard (for example).

[0037] The invention provides a backlight having individually addressable portions of four different colors (e.g. three primary colors and white), for example RGBW portions. This will be termed an RGBW backlight in the following.

[0038] Figure 3 shows a cross section of the color space for an RGBW panel with RGBW backlight of the invention.

[0039] When compared to a normal LCD system, a system using an RGBW display panel (with white subpixel having 1/4 of the total pixel area) has the capability to create a factor 2 more brightness for pixels showing unsaturated colors than the brightness for pixels showing very saturated colors.

[0040] Figure 3 shows the contribution 30 of the white LEDs, the overall output 32 and the RGBW output 34 of Figure 2 for comparison.

[0041] By using the RGB LEDs locally instead of the more efficient white LEDs, the color-point can be adaptively controlled towards the colors which locally need to be rendered. For example, if in a region a lot of saturated blue pixels need to be rendered, then locally the blue LEDs can create more light, yet at the same time the white LEDs, or more importantly the green and red LEDs, can be dimmed.

[0042] When in a region a lot of un-saturated pixels need to be rendered, then locally the white LEDs can create more light as this is the most efficient light source, yet at the same time the contribution of the blue, green and red LEDs, can be dimmed as these light sources are less efficient in making white light.

[0043] The use of the RGBW backlight with local backlight dimming control therefore enables efficiency gains, as the white backlight is used preferentially, with its corresponding better efficiency.

[0044] When 50% of the white LED devices of a conventional white backlight are replaced by RGB LED devices with a comparable brightness, for unsaturated colors the required white backlight is preferably generated using white LEDs as these are twice as power efficient, and these contribute 50% of the required maximum brightness (as shown in Figure 3 the white LEDs contribute one half of the maximum possible brightness, but this maximum is 150% of the maximum required brightness level). The other 50% luminance is contributed by the RGB LEDs driven R=G=B, consuming approximately twice the energy of a comparable white LED.

[0045] As local dimming will often reduce the required backlight luminance levels, most of the time the RGB LEDs will have only a small contribution to generate the backlight luminance for unsaturated regions. When driving all LEDs at maximum, 150% of the required brightness is generated, again as shown in Figure 3.

[0046] For very saturated colors the backlight output is generated with maximum use of one or two components of the RGB LEDs compensating for the lower LED power efficiency.

[0047] As the transparent sub-pixels also transmit the backlight color component, twice the transparency can be achieved for saturated colors. Taking blue for example, the blue LED has 25% of the possible output brightness (instead of 33% for an RGB backlight) but the pixel aperture available is 1/2 (B+W pixel aperture) instead of 1/3 (B pixel aperture only). Thus, also in this case, 150% of the required brightness can be generated at full saturation.

[0048] White LEDs are not required for extra brightness of saturated colors, as this would de-saturate the required colors. As the displayed colors of RGB LED primaries are often outside the sRGB color gamut, some de-saturation to increase the brightness can be taken as a small additional benefit.

[0049] As often the required backlight color will not be fully saturated, white LEDs will be used an addition to the saturated color component, provided by the RGB LEDs.

[0050] Thus, in this example, the installed capacity of LEDs in a backlight for RGBW displays can be split into 50% RGB LEDs and 50% White LEDs (or more particularly a 50% contribution to the total possible output intensity from white LEDs and a 50% contribution to the total possible output intensity from the RGB LEDs in combination), providing an optimal match with the sRGB standard.

[0051] With respect to an RGB LED backlight this leads to about 25% cost reduction of the backlight (as respectively cheaper or less LED devices are required), as well as approximately 25% average power reduction. With respect to a white LED backlight (without Boosting LED technology) this leads to about the same backlight cost and power consumption, but now with the support of wide color gamut.

[0052] The invention is of particular interest for color sequential display panels. There is less brightness for unsaturated colors and more brightness for saturated colors. An advanced Color Sequential Dimming algorithm is required.

[0053] Figure 4 shows a cross section of the color space for a known advanced color field sequential display.

[0054] Compared to the basic RGB system of Figure 1 (plot 40), the white can be generated with 3 times the brightness. The saturated primary color (e.g. blue) has 9 times the brightness.

[0055] When compared to a normal LCD system, a system using a color filter-less display panel, driven with color sequential dimming technology has the capability to create a factor 1.5 more brightness for pixels showing saturated secondary colors (a color which is simply a combination of two primaries) and a factor 3 more brightness for pixels showing saturated primary colors than the brightness for pixels showing unsaturated colors.

[0056] By using dimming backlight technology as represented by arrows 42, the color profile can be reshaped to match the sRGB standard (or other desired standard).

[0057] By replacing a part of the RGB LEDs with white LEDs, locally the unsaturated backlight colors can be generated much more efficiently, at the cost of maximum brightness for the saturated colors. For example, if in a region a lot of unsaturated pixels need to be rendered, then locally the white LEDs can create this light, yet at the same time the reduced number of RGB LEDs can create less saturated light.

[0058] When in a region a lot of un-saturated pixels need to be rendered, then locally the white LEDs should create this light, as it is the most efficient light source, yet at the same time the contribution of the blue, green and red LEDs, can be dimmed as these light sources are less efficient in making white light.

[0059] Figure 5 shows a cross section of the color space for a color sequential panel using an RGBW backlight of the invention.

[0060] The loss in relative brightness for saturated colors brings the profile 50 in accordance with the shape of the sRGB profile . Thus, the efficiency improvement is gained without compromising the desired output gamut.

[0061] In the example of Figure 5, 50% of the RGB LED devices are replaced by white LED devices with the same brightness (the same ratio as for the RGBW panel example above). This again provides an optimal match with the sRGB standard.

[0062] For very saturated colors the backlight is generated with maximum use of one or two components of the RGB LEDs, as these are more power efficient due to the color-dimming effect, as there will be less cross-color due to light of the other components leaking through the LC of the pixels, as well as the fact that the transparent pixels are transmitting the desired color component at the highest efficiency since there are no color filters involved. This creates up to a factor 3 extra brightness due to the aperture benefit. The reduced RGB LED count causes a reduction of the maximum luminance for saturated colors, reducing the surplus of saturated brightness to 300% for secondary and 450% for primary colors.

[0063] For unsaturated colors, the required white backlight is generated with maximum use of the white LEDs as these are more power efficient, together with the RGB LEDs driven R=G=B. They provide can provide 300% brightness for unsaturated colors. As local dimming will often reduce the required backlight luminance levels, most of the time only the white LEDs will generate the backlight luminance for unsaturated regions.

[0064] With respect to an RGB LED backlight this leads to about 25% additional cost reduction of the backlight, as well as around 25% additional power reduction.

[0065] The implementation of the backlight is straightforward.

[0066] Figure 6 shows in schematic form an RGB LED backlight, in which red 60, green 62 and blue 64 LED die are mounted in a single package. When R,G and B LEDs are turned on they generate light with a spectrum with peaks at red, green and blue wavelengths, corresponding to the driving levels of the red, green and blue LEDs, creating colored or white light. The design should have some optical crosstalk between the LED packages to guarantee a uniform luminance exposure of the LCD panel.

[0067] Figure 7 shows in schematic form a white LED backlight. When LEDs 70 are turned on they generate light with a spectrum with peaks at blue wavelengths, and a red, green wavelength distribution corresponding to the phosphor of these LEDs, creating white light. The design should have some optical crosstalk between the LED packages to guarantee a uniform luminance exposure of the LCD panel.

[0068] Figure 8 shows in schematic form an RGBW backlight of the invention.

[0069] The backlight comprises individually addressable portions of three different colors and white. There are white backlight segments 80 and RGB backlight segments 82, with the RGB segments having red 84 green 86 and blue 88 LEDs.

[0070] When the R,G and B LEDs are turned on they generate light with a spectrum with peaks at red, green and blue wavelengths, corresponding to the driving levels of the red, green and blue LEDs, creating colored or white light.

[0071] When white LEDs are turned on they generate light with a spectrum with peaks at blue wavelengths, and a red, green wavelength distribution corresponding to the phosphor of these LEDs, creating white light. In Figure 8, the ratio is 1:1 of white LEDs luminance to RGB LED luminance.

[0072] An alternative luminance ratio between RGB and white as mentioned above can instead be achieved by distributing RGB and white LED packages in a different ratio, preferably evenly spatially distributed. Another easy way of providing uniform spatial distribution is a package distribution of 1:1 (such as shown in Figure 8) but a luminance distribution per package of 2:1. As in this option the RGB LEDs are not often driving white, they can have relaxed thermal requirements and therefore have higher maximum brightness to obtain the desired 2:1 ratio.

[0073] The design should have some optical crosstalk between the LED packages to guarantee a uniform luminance exposure of the LCD panel for both the RGB LED packages as well as the white LED packages, which implies also a uniform distribution of the combined light sources.

[0074] However, for local dimming applications, the optical crosstalk needs to have limited range so that local illumination can be reduced as different backlight segments can be driven independently. By gaining the related video-data, the local LC pixels are at the same time driven to more transparent levels to compensate for the reduced brightness of the backlight segments.

[0075] In addition to the physical backlight design, the invention requires an algorithm which will split the nominal backlight requirement into a RGB as well as a white component. As the color of the white LED is known and corresponding to one specific ratio of the red, green and blue primaries, the most effective implementation is to calculate the desired amount of white light from the white LED and subtract this from the nominal required backlight luminance.

[0076] The remainder part, including the luminance which is desired from the white LEDs but not delivered (clipping), is to be generated by the RGB LEDs.

[0077] As the white LEDs are more power efficient than the RGB LEDs, this is the preferred light source. Hence all the unsaturated colors should primarily be driven by the white LEDs. The saturated colors are primarily by the R,G or B LEDs.

[0078] An example of procedure for rendering RGBW backlight is as follows:

1. Determine RGB color dimming values for the red green and blue backlight components. The method can be equivalent to the algorithms used for local color dimming (histogram analysis).
2. Determine the minimum value of the local RGB segment. For example, RGBmin value of color for (RGB: 0.4, 0.2, 0.8) = 0.2, related to the green LED primary.
3. Calculate the amount of white light, corresponding to the color of the white LED to provide the color component required for the RGBmin value. For example, the white LED is driven with value 0.2.
4. Subtract the luminance provided by the white LED from the RGB luminance values. For example the Red LED is driven with 0.4 - 0.2 = 0.2; Green LED is driven with 0.2 - 0.2 = 0.0; Blue LED is driven with 0.8 - 0.2 = 0.6.

[0079] This analysis assume normalised backlight luminance levels, so that for example RGB: 0.4, 0.2, 0.8 corresponds to RGBW: 0.2, 0.0, 0.6, 0.2.

[0080] To enable RGBW rendering with an optimal Picture Quality using a White LED backlight, extra luminance is required for the source images containing bright saturated colors (compared to a traditional RGB panel). As it is known that there is only a small statistical chance on having bright and saturated pixels in average input video-data, for RGBW displays it will be very attractive to use the Boosting LED technology and allow for a cost-effective implementation LED backlight implementation, as less LEDs are required.

[0081] Besides the local dimming technology, which on average increases the contrast and reduces power consumption, the RGBW rendered images on average allow for extra dimming of the backlight, saving more power and increasing the contrast, depending on the saturated and bright image content.

[0082] A control process can be used to provide optimal use of the driving range of the individual LEDs, to provide local dimming and boosting of the backlight. The LEDs should not be driven beyond their maximum specified temperature, as they will start degrading a lot faster once driven for a long time at a much higher temperature.

[0083] For local dimming or boosting, the backlight portions are independently addressable. One backlight segment can correspond to an area of hundreds or thousands of display pixels, so that the local dimming or boosting is not on a per-pixel basis, but is on a per-image-segment basis. Indeed, as the backlight segments need to merge to provide a uniform output, the control of the backlight portions can be in groups of segments.

[0084] The backlight portions (normally called segments) in a local dimming backlight typically range in number from 8 (1 D or edge lit systems) to 1024 (for full

2 Megapixel full HD display panel). Each LED segment may itself typically comprises between 1 and 64 LEDs.

[0085] The local dimming is not essential to the invention, and the selection of the brightness for the RGB and white LEDs can be on the basis of a full image.

[0086] For the RGBW panel implementation (of Figure 3) there are various RGBW pixel layouts.

[0087] Figure 9 shows the so-called L6W pixel layout, in which 9 pixels are represented a regular pattern of 9*2 sub-pixels. This has the same virtual resolution as a RGB stripe configuration (Figure 10), but has a 10% larger sub-pixel aperture and 33% less column drivers. Other RGBW (and RGBY, RGBC, RGBM) pixel structures can be used.

[0088] Known RGBW display panels can be combined with any backlight type. However, the real benefits become more apparent for local dimming backlight systems. These are also preferred for use with the RGBW backlights of the invention.

[0089] The overall power efficiency of an LCD-TV display system is highly dependent on the power-efficiency of the light-source of the backlight and its dimming capabilities.

[0090] Traditional CCFL backlight lamps are very power efficient, but have limited local-dimming capabilities. White LEDs have about the same power efficiency as CCFL, their big advantage in a backlight system is local dimming, proving up to a factor 2 relative power savings. This combines very well with the main requirements of the RGBW display panel, power efficiency. RGB LEDs have a poor power efficiency compared to CCFL, their big advantage in a backlight system is local color dimming, proving up to a factor 2.5 relative power savings.

[0091] This only compensates for their low power efficiency. The extra transmission due to the RGBW display panel can make the system more power efficient, yet it will remain expensive.

[0092] When the RGBW backlight of the invention is used in combination with color sequential dimming, the overall power-efficiency makes such a system economically attractive.

[0093] Power efficiency is not only a society trend, stimulated by energy-labels like 'Energy Star' but is will also be enforced by law, like the 'Californian Energy Council' and 'European Union energy label'. There is a demand for energy efficient LCD-TVs, and hence also for energy efficient backlight systems. This will drive the market to using RGBW displays.

[0094] As the input images generated by TV and computer systems are sRGB (EBU / ATSC) compliant, these images must be rendered accordingly. For (spatial and temporal) RGBW displays this implies that the relative brightness artefact needs to be compensated for.

1D dimming (i.e. control of the backlight output for the full display area) can provide efficiency improvements, but these are much greater with 2D local dimming.

2D local dimming is most effective at locations other than where bright saturated colors occur. The statistical distribution of average video-data has a strong preference for unsaturated colors above saturated colors, enabling a significant power saving, specifically when these segments are rather small.

[0095] The use of backlight boosting can also improve efficiency and cost to provide a power-efficient and cost-efficient solution. A higher power efficiency for saturated colors is achieved by changing the white-point color of the backlight, by driving relative more current trough the RGB LEDs. A saturated color of the backlight can be very efficient, as it can pass through a sub-pixel with color-filter as well as through the white sub-pixel.

[0096] Figure 11 shows an alternative 2 dimensional representation of the 3 dimensional color space. It only shows two primaries (red and green) as it is projected along the blue primary axis. Corresponding diagrams can be used to represent blue-green and blue-red. A color made from the two primaries being plotted is a location in the graph. The dashed (y=x) line represents grey, the angle at the origin (black) represent the saturation and the distance away from this point is indicative of the brightness. An RGB panel with white backlight can generate color points in a square area. The addition of a white primary in the panel stretches the possible output gamut as shown.

[0097] Figure 12 shows one mapping of RGB space (the square) into RGBW space. If the intention is to scale the brightness of all colors, then some colors become out of range of the RGBW space, such as color point 120. These colors can be clipped back into the available color space at the cost of some Picture Quality.

[0098] Figure 13 shows RGB to RGBW mapping which makes use of backlight dimming to save power and backlight boosting to bring points into range.

[0099] This enables mapping of the RGB square to a larger (i.e. brighter) square 132. The other area 134 that was in the RGBW gamut is used to save backlight power with backlight dimming, and backlight boosting is used to recover the areas 136. In this case Picture Quality is not compromised.

[0100] The combination of local dimming and RGBW backlight is a combination which improves the performances and power efficiency of LCD-TV with various panel technologies.

[0101] Figure 14 shows the effect of this backlight dimming 140 and boosting 142 on the color space, and enables the luminance of the image to be mapped to sRGB color space.

[0102] Figure 15 shows schematically the display device of the invention, comprising a display panel 150, the backlight 152 and a controller 154 for controlling the panel and backlight. The controller implements the method of the invention using software. Thus a computer program is run or implemented by the controller for controlling the display panel and the backlight to provide the desired output color gamut. As shown, schematically, the backlight is arranged as segments, and these are independently controllable to enable local backlight dimming and/or boosting to be employed. They may each comprise a single set of RGBW LEDs (1 per color) or group of multiple LEDs per color (e.g. up to around 64 of each color).

[0103] A backlight may comprise White LEDs, RGB LEDs, or a combination of both. The ratio of intensity of the RGB LED part of the backlight relative to the White LED part of the backlight is preferably 1:1. However, this is not essential. For example a ratio between 0.7:0.3 and 0.3:0.7 can be used. With the backlight fully on, the white LEDs may typically contribute 50% to the total output light intensity.

[0104] The preferred example is an RGBW arrangement of backlight. However, the invention could be implemented using different phosphor based LEDs, having alternative spectrum and white-point.

[0105] Alternatively, the invention could be implemented in a color subtraction display with Cyan Magenta and Yellow backlight colors with the additional white. The exact color point of the individual colors is not relevant to the invention, it will be apparent that the colors should be selected so that a desired output gamut can be obtained.

[0106] Various modifications will be apparent to those skilled in the art.

Claims

1. A color display, comprising:

a backlight (152); and
a display panel (150) for modulating the backlight output,
wherein the backlight comprises portions (80,84,86,88) of four different colors, wherein the intensity of each color is independently controllable.

2. A display as claimed in claim 1, wherein the backlight portions comprise three non-white colors (84,86,88) and white (80).

3. A display as claimed in claim 2, wherein the contribution to the maximum output intensity of the backlight from the white portions (80) is approximately 50%.

4. A display as claimed in claim 2 or 3, wherein the backlight portions (80,84,86,88) are red, green, blue and white.

5. A display as claimed in any preceding claim, wherein the backlight portions (80,84,86,88) comprise LEDs.

6. A display as claimed in any preceding claim, wherein the display panel (150) comprises an LCD panel.

7. A display as claimed in any preceding claim, wherein the display panel (150) comprises RGBW pixels.

8. A display as claimed in any one of claims 1 to 5, comprising a color field sequential display and the display panel has no color filtering.

9. A display as claimed in any preceding claim, wherein the backlight comprises segments, wherein the intensity of the four colors within each segment can be controlled independently of the other segments.

10. A display as claimed in claim 9, the backlight has local dimming and local boosting capability, wherein all RGB gamut colors can be mapped into the display output gamut.

11. A display as claimed in any preceding claim, comprising means for converting an input according the sRGB standard into an output gamut of the display such that it matches the sRGB standard.

12. A method of controlling a display device, comprising:

providing a backlight output as portions of four different colors, and independently controlling the intensity of each color; and
modulating the backlight output using a display panel.

13. A method as claimed in claim 12, wherein the backlight portions comprise three non-white colors and white, wherein the method further comprises selecting the desired white component based on the lowest intensity required by the three colors depending on an image or image portion to be displayed, and deriving the required non-white components therefrom, such that the maximum white component is used.

14. A computer program comprising computer program code means adapted to control a display panel and backlight using the method of claim 12 or 13 when said program is run on a display device controller.

15. A computer program as claimed in claim 14, embodied on a computer readable medium.

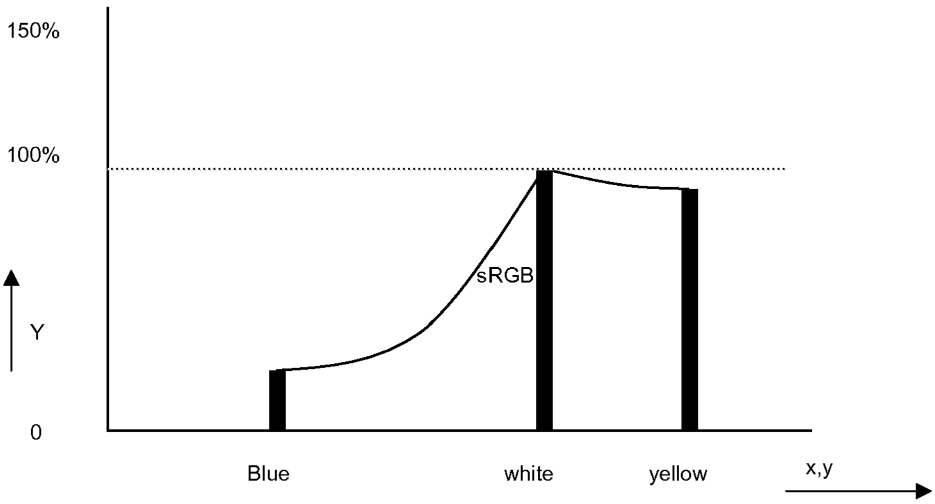

150%
100%
sRGB
Y
0
Blue
white
yellow
x,y

FIG. 1

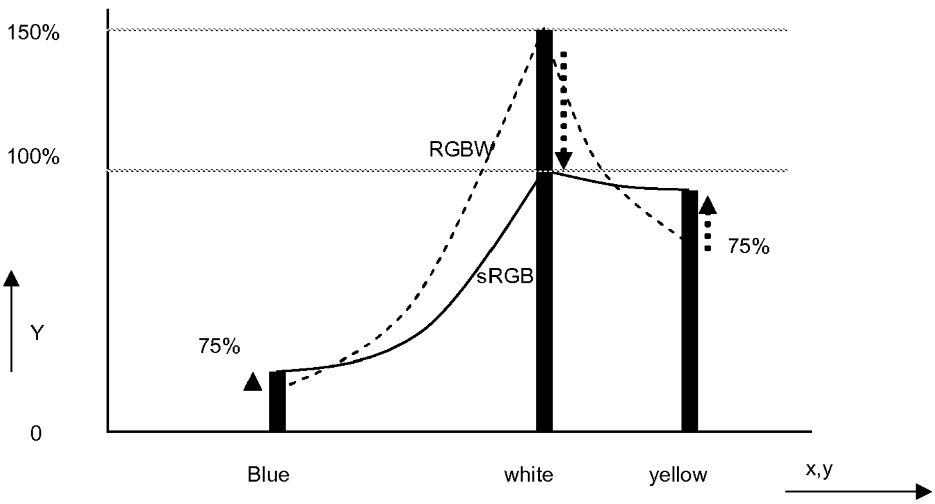

150%
RGBW
100%
75%
sRGB
Y
75%
0
Blue
white
yellow
x,y

FIG. 2

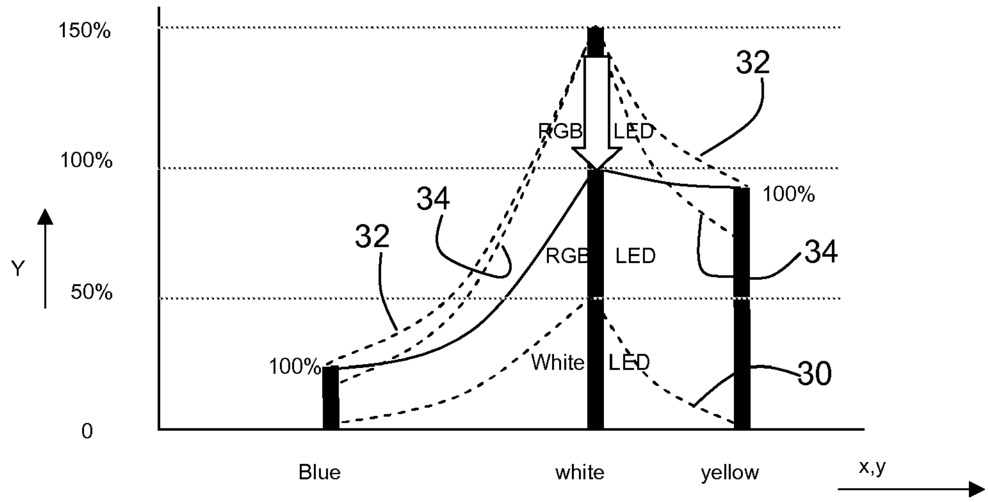

150%
100%
50%
0
Y
32
34
32
34
30
RGB LED
RGB LED
White LED
100%
100%
100%
Blue
white
yellow
x,y

FIG. 3

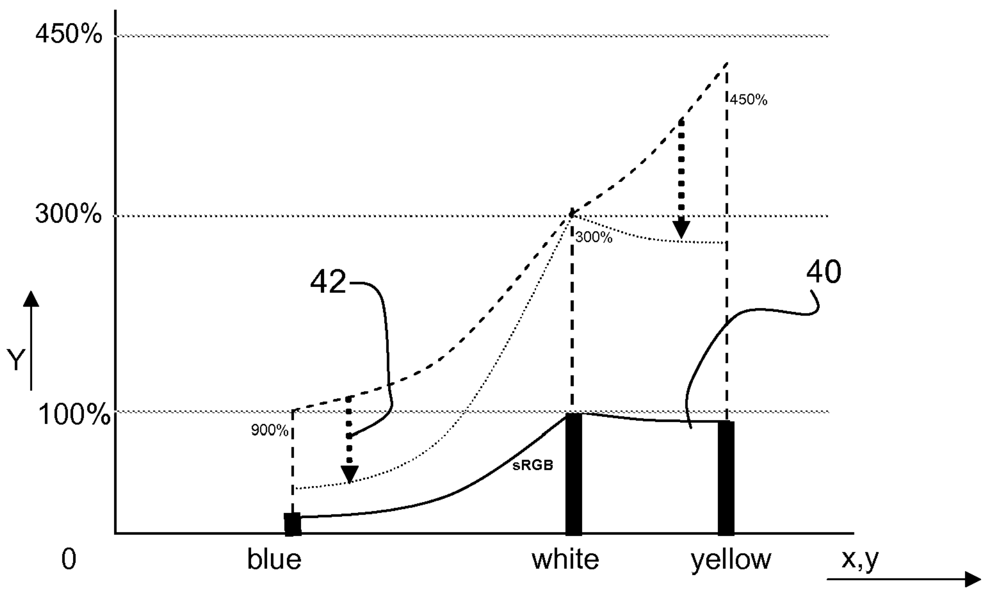
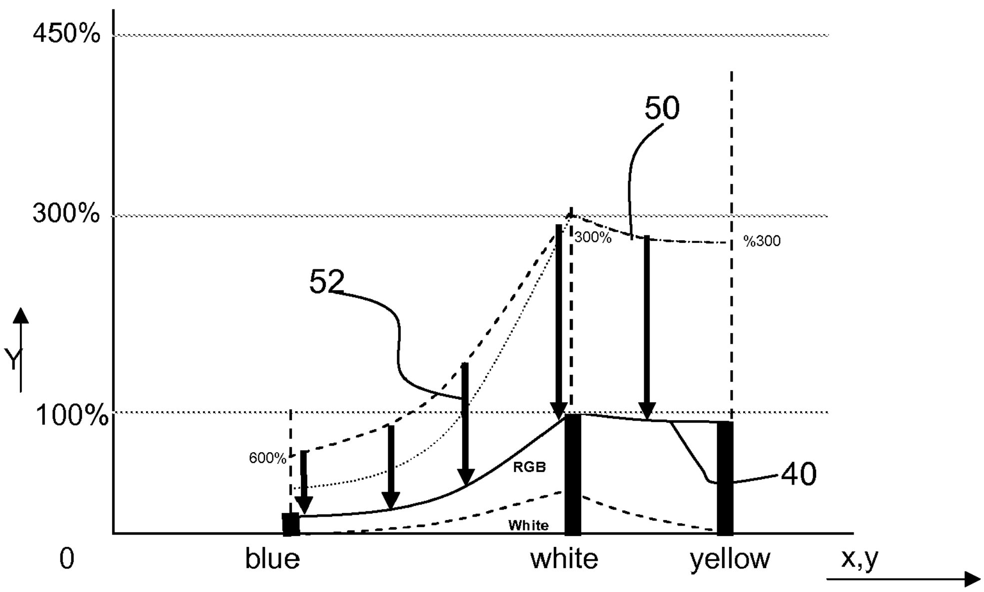

450%
300%
100%
0
Y
42
40
450%
300%
900%
sRGB
blue
white
yellow
x,y

FIG. 4



450%
300%
100%
Y
0
50
52
40
300%
%300
600%
RGB
White
blue
white
yellow
x,y

FIG. 5

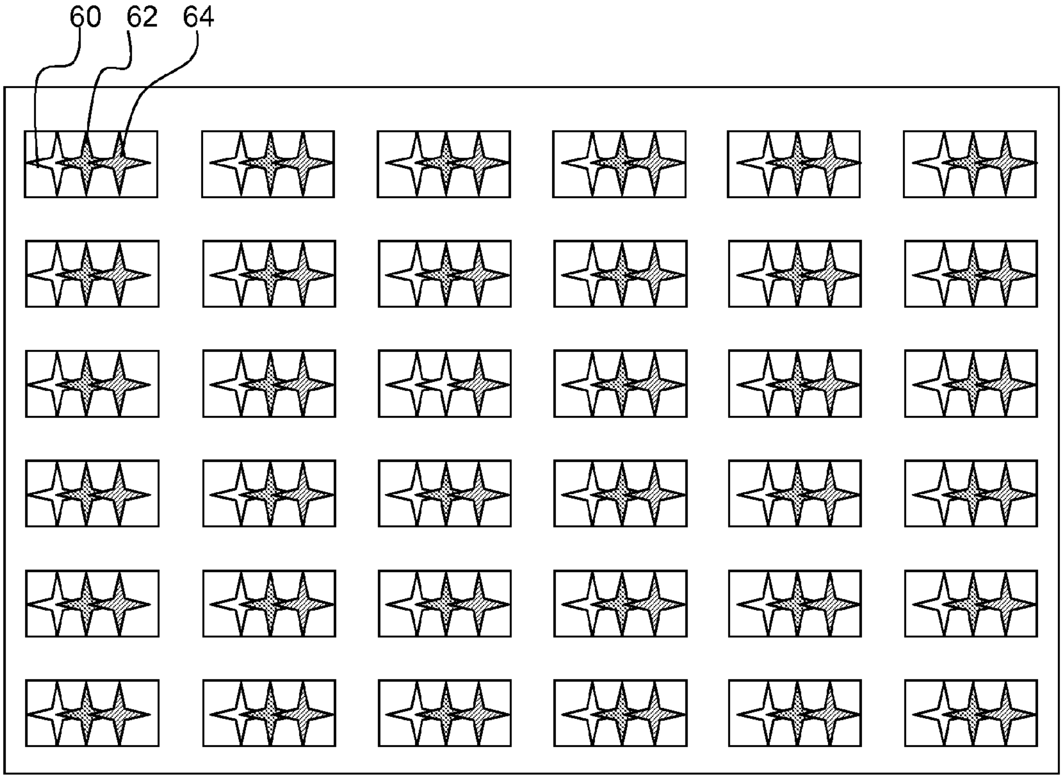


FIG. 6

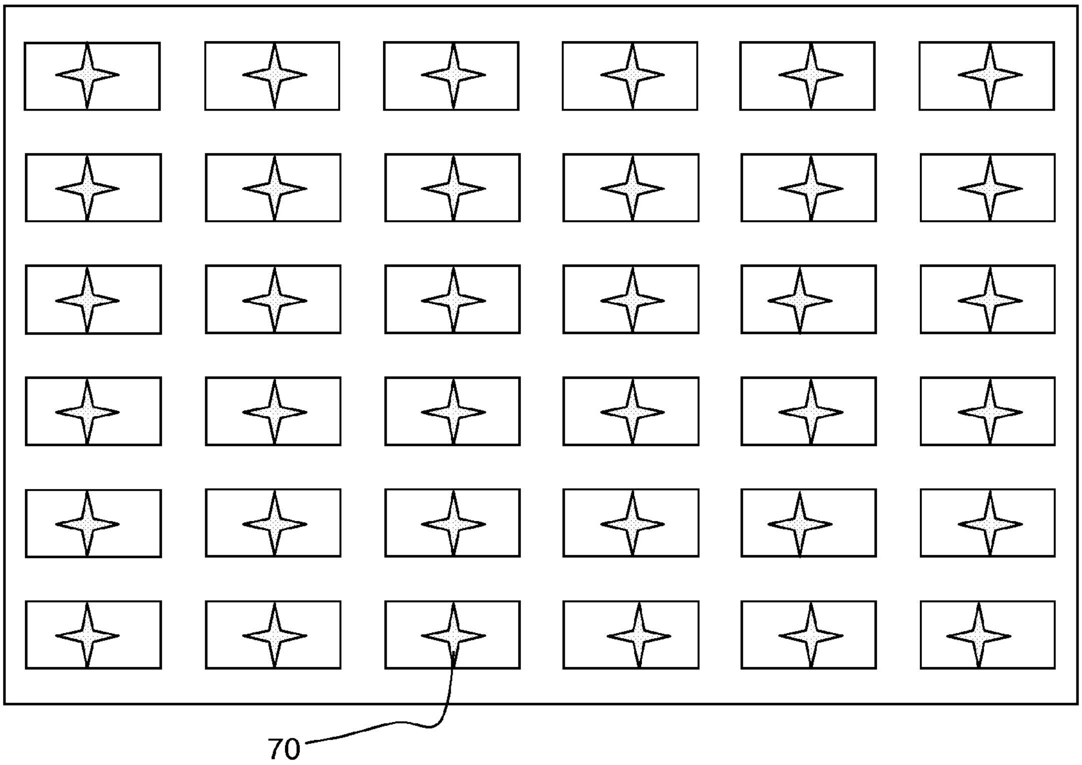


FIG. 7

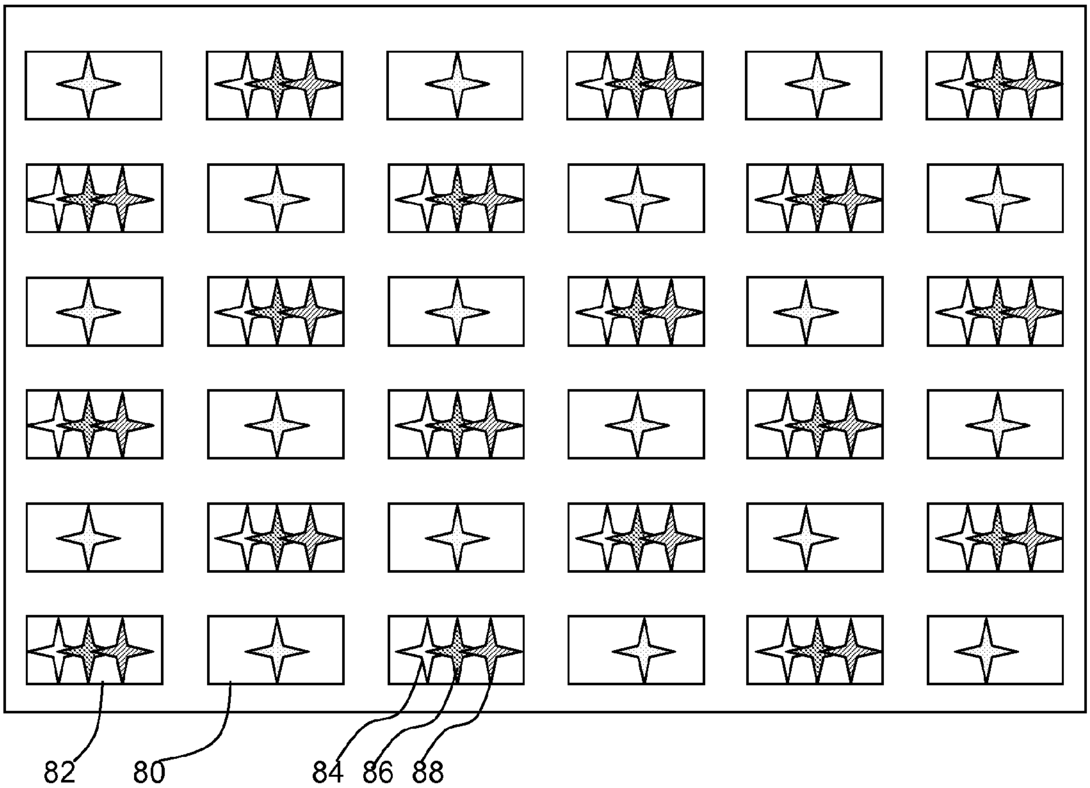


FIG. 8

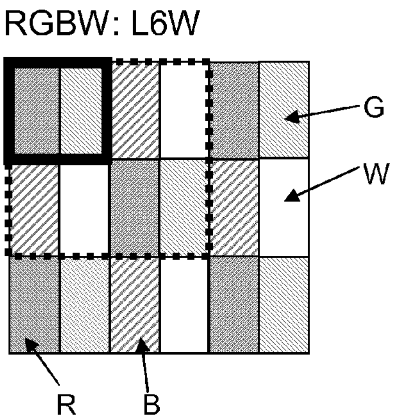


FIG. 9

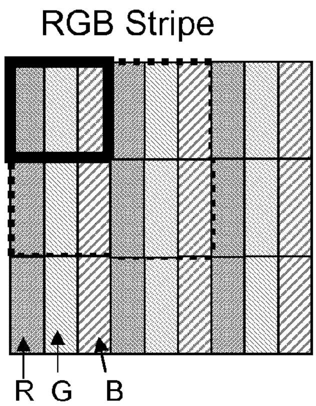


FIG. 10

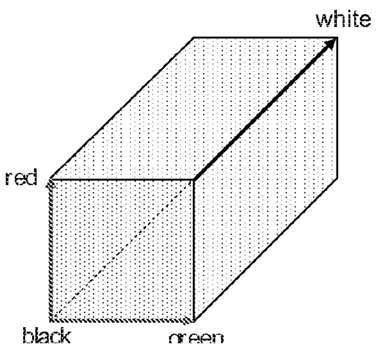


FIG. 11

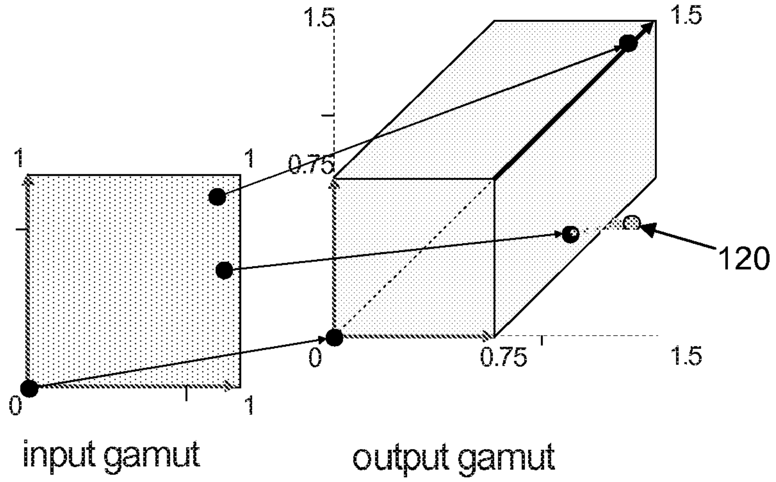

1.5
1.5
1
1
0.75
120
0
0.75
1.5
0
1
input gamut
output gamut

FIG. 12

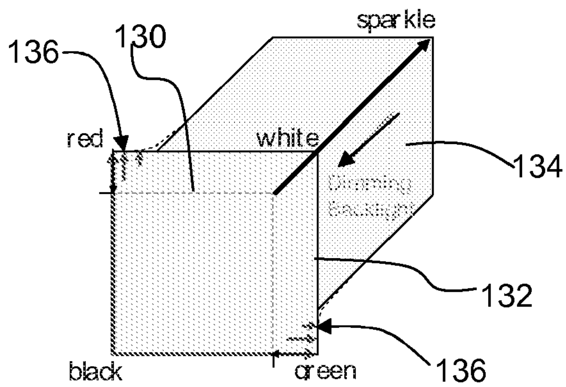

sparkle
136
130
red
white
134
Dimming backlight
132
black
green
136

FIG. 13

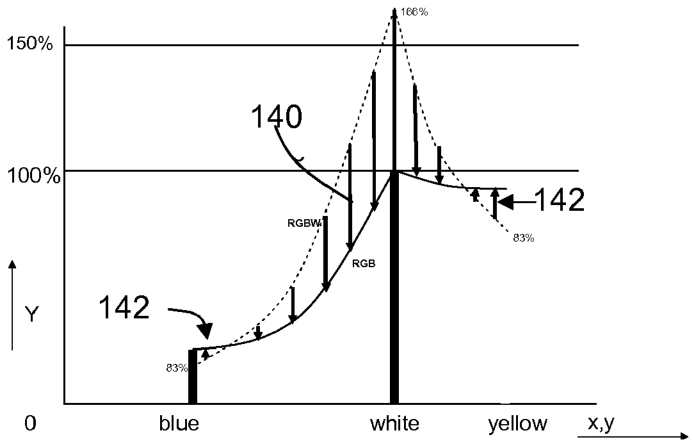

166%
150%
140
100%
142
RGBW
RGB
83%
Y
142
83%
0
blue
white
yellow
x,y

FIG. 14

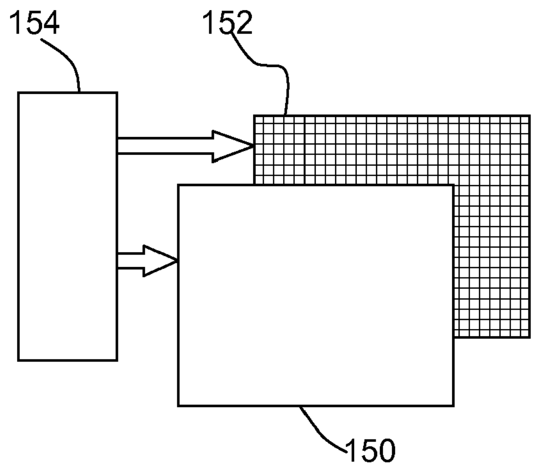

154
152
150

FIG. 15

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EUROPEAN SEARCH REPORT

Application Number
EP 09 17 9604

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2003/214725 A1 (AKIYAMA TAKASHI [JP]) 20 November 2003 (2003-11-20) * figures 2,7,10 * * paragraph [0002] * * paragraph [0023] * * paragraph [0051] * * paragraph [0073] - paragraph [0075] * * paragraph [0084] - paragraph [0088] * -----	1-6,8, 12-15 11	INV. G09G3/36 G09G3/34
X Y	WO 2007/132364 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; VAN BEEK WILHELMUS H M [NL]; OEPT) 22 November 2007 (2007-11-22) * figures 1,2 * * page 3, line 12 - line 29 * * page 4, line 10 - line 21 * * page 5, line 29 - line 32 * * page 7, line 9 - line 11 * -----	1-2,4-6, 9-10, 12-15 11	
X	US 2007/152953 A1 (HONG HEE JUNG [KR] ET AL) 5 July 2007 (2007-07-05) * figure 8 * * paragraph [0052] * * paragraphs [0061] - [0062] * -----	1-2,5-7, 12-15	TECHNICAL FIELDS SEARCHED (IPC) G09G
X Y	US 2009/267879 A1 (MASUDA TAKESHI [JP]) 29 October 2009 (2009-10-29) * figures 1-3 * * figures 9-12 * * paragraph [0078] * * paragraph [0165] * ----- -/--	1-2,4-6, 9-10,12, 14-15 11	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	12 February 2010	Husselin, Stephane

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EUROPEAN SEARCH REPORT

Application Number
EP 09 17 9604

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	Michael Stokes,Matthew Anderson,Srinivasan Chandrasekar,Ricardo Motta: "A Standard Default Color Space for the Internet - sRGB" 5 November 1996 (1996-11-05), XP002568510 Retrieved from the Internet: URL:http://www.w3.org/Graphics/Color/sRGB> [retrieved on 2010-02-12] * the whole document * -----	11	
A	Pierre de Greef and Hendriek Groot Hulze: "Adaptive Dimming and Boosting Backlight for LCD-TV Systems"; "1" In: "SID Symposium Digest of Technical Papers" May 2007 (2007-05), SID , XP002565813 vol. 38, , pages 1332-1335 * paragraph [03.2] - paragraph [03.4] * * paragraph [05.2] - paragraph [05.3] * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	12 February 2010	Husselin, Stephane

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003214725 A1	20-11-2003	JP 4113017 B2	02-07-2008
		JP 2004004626 A	08-01-2004
WO 2007132364 A1	22-11-2007	CN 101443836 A	27-05-2009
		EP 2024957 A1	18-02-2009
		JP 2009536367 T	08-10-2009
		KR 20090010107 A	28-01-2009
		US 2009160756 A1	25-06-2009
US 2007152953 A1	05-07-2007	CN 1991519 A	04-07-2007
		KR 20070071183 A	04-07-2007
US 2009267879 A1	29-10-2009	WO 2008050506 A1	02-05-2008

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