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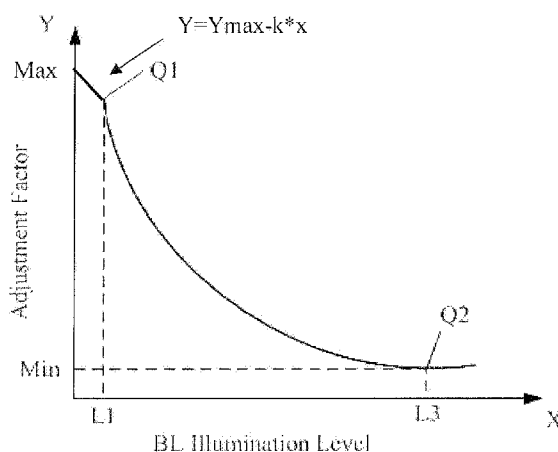


Figure 1

(57) Abstract: A method and apparatus for image enhancement in a display illuminated by a lighting device. Enhancement is via use of a non-linear mapping function. An illumination level for the lighting device is determined and used with the mapping function to find a compensation factor for each pixel of the image. The brightness property of each pixel is adjusted by its compensation factor.

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Method and apparatus for enhancing an image displayed on an LCD device

Background to the invention

5 1. Field of the Invention

The current invention relates to liquid crystal display (LCD) devices that use a light source for viewing of an image. More particularly, the invention relates to a method and apparatus for enhancing an image displayed on a LCD panel illuminated by a lighting device.

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2. Background information

Various liquid crystal display (LCD) devices use a lighting source to either project an image onto a display surface such as a screen or have the light source positioned behind the LCD panel for direct viewing of an image produced on the LCD panel. A desire to reduce power consumption and improve the contrast of images displayed by LCD technology has led to various techniques for dynamically varying the light intensity of the light source and/or backlight of such LCD devices. Typically such variations in intensity of the light source results in a net dimming of the displayed image below the light intensity at which it was designed to be viewed.

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In order to overcome this problem various compensation techniques have been proposed for an image being displayed. Techniques such as those described in US patent publications 2006/0268180 and 2007/0092139 use tone-scale mapping to compensate the video signal for lower backlight intensity. These tone-mapping techniques utilise histogram analysis of the video image which requires high real-time computing power. Tone mapping is also suitable for whole backlight dimming, but is less suitable for dynamic and localised dimming techniques.

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Another technique has been proposed in US 2007/0041636 which utilises two sequential mapping functions. A first mapping value is determined by substituting RGB values into the first mapping function and a second enhanced mapping value is obtained by substituting the first mapping value into the second mapping function. Again such a technique has a high real-time computational overhead and while being

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suitable for whole backlight dimming is not a suitable for dynamic or localised dimming techniques.

Summary of the Invention

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Accordingly, is an object of the present invention to provide a backlight device for providing backlighting to a liquid crystal display panel and a method of controlling brightness of a liquid crystal display panel which overcomes or substantially ameliorates the above problems.

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There is disclosed herein a method for image enhancement in a display illuminated by a lighting device. The method comprises providing a non-linear mapping function, determining an illumination level for the lighting device, determining by use of the mapping function and illumination level a compensation factor for each pixel, and
15 adjusting brightness properties of each pixel by its compensation factor. There is also disclosed herein an apparatus having components for carrying out the method.

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The mapping function relates a lighting device illumination level to a compensation factor. It may be a single dimensional lookup table having a plurality of predetermined compensation factors or an equation.

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Preferably, the lighting device for the display has a plurality of illumination regions each have an illumination level and illuminating one or more pixels and the compensation factor of each pixel is determined based on the illumination level of the illumination region illuminating the pixel.

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More preferably, the method and/or apparatus are practiced in an LCD panel illuminated by a dynamically illuminated backlight device having a plurality of independently controllable illumination regions.

Further aspects of the invention will become apparent from the following description.

Brief description of the Drawings

An exemplary form of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

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Figure 1 is a graphical representation of a mapping function of the invention,

Figure 2 is a schematic overview of an LCD TV employing a method and apparatus of the invention,

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Figure 3 is a schematic illustration of image enhancement, and

Figure 4 is a schematic block diagram of a brightness and image enhancement controller of Figure 1.

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Description of the Exemplary Embodiments

Reference will now be made in detail to an exemplary embodiment of the present invention, an example of which is illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

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The described exemplary embodiment illustrates the invention as practiced in a backlit LCD display, for example an LCD TV, used to show video images comprising a plurality of sequential frames each made up of a plurality of pixels. This is not intended to limit the scope of use or functionality of the invention. The invention is equally applicable to the enhancement of static images displayed on an LCD screen. For example, many organisations, advertisers or artisans use LCD screens to display static, albeit periodically changing, information, advertisements and/or photographs and images of artwork. The invention can equally be used to enhance the appearance on the screen of such information, advertisements and/or images.

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Likewise, that the invention is exemplified as practiced in a backlit LCD display is not intended to limit the scope of use or functionality of the invention. The invention can equally be practiced in any display apparatus that uses a light source to project an

image onto a projection surface or a flat panel display that uses a backlight to display images for direct viewing. Such displays include digital micro-mirror device displays (DMDs), liquid crystal on silicon (LCOs) displays and of course LCD displays.

- 5 In its earlier United States patent application serial number 11/707,517, the entire contents of which are incorporated herein by reference, applicant describes an LCD display device having a backlight divided into a plurality of individually controllable illumination regions. Luminance of each illumination region is controlled in accordance with video signal properties for a corresponding region of the LCD
- 10 display. If an area of the displayed image is bright then the corresponding illumination region of the backlight has high luminance and if a region of the image is dark then the corresponding illumination region of the backlight has no or low luminance. By dynamically controlling luminance of each illumination region of the backlight in accordance with properties of a corresponding part of the displayed
- 15 image the contrast and dynamic range of the displayed image is improved. Additionally, each individually controllable illumination region of the backlight may comprise a variable colour lighting source, such as clusters of individually controllable red, green and blue (RGB) LEDs thus allowing the illumination region to be controlled from dark (black) through the colour spectrum to white. The backlight
- 20 luminance and colour can be dynamically controlled in accordance with properties of the corresponding part of the displayed image in order to improve both colour contrast and colour dynamic range.

- In US patent application 11/707,517 the LEDs of the backlight are individually
- 25 controlled and thus the brightness of the backlight is not uniform and varies with the image. Another benefit of this system is that the whole backlight brightness is generally dimmer than that of prior art constant backlight systems. This is because in the white or bright areas of the display image the backlight will be at its maximum value, which might typically be the same brightness as a prior art constant backlight
- 30 systems, however significant portions of the image will have lower brightness and thus the backlight will be dimmer. In order to keep the viewable brightness of the image noticeably unchanged on the screen the LCD pixel transmittance is adjusted in accordance with backlight brightness levels. In this invention, after the backlight illumination level for each illumination region of the backlight is determined (the

illumination of each backlight block/region varying with brightness of corresponding blocks of the image) an adjustment or compensation factor is determined for pixels illuminated by that block using a mapping function, and the transmittance of the relevant pixels adjusted by the adjustment or compensation factor.

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The transmittance of a pixel in an LCD panel is controlled by the incoming RGB video signal according to the equation

$$T = T_{max} \times (I / 255)^\gamma$$

where T is LCD transmittance, I is the RGB digital code value

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corresponding to that pixel and γ is from the LCD panel gamma curve.

The apparent brightness of an image when viewed on the LCD display is a function of the backlight luminance and the LCD transmittance, which is given by the equation

$$L = BL \times T$$

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where L is the apparent brightness of an image, BL is the backlight luminance and, again, T is the LCD transmittance.

Substituting for T we get

$$L = BL \times T_{max} \times (I / 255)^\gamma$$

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To keep the image brightness constant with any variance of the backlight illumination level we require that

$$L' = L$$

$$BL' \times (I' / 255)^\gamma = BL \times (I / 255)^\gamma$$

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$$I' = I \times [BL / BL']^{1/\gamma}$$

$$I' = [I^\gamma / \chi]^{1/\gamma}$$

where L' is the apparent brightness of the image after compensation, BL' is the new backlight luminance, I' is the RGB digital code value after compensation and χ is a adjustment factor related to the change in backlight luminance.

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The relationship between adjustment factor χ and backlight illumination level is graphically illustrated in Figure 1 wherein the X-axis represents backlight illumination level BL' and the Y-axis represents the pixel transmittance adjustment factor χ . The curve of Figure 1 can be defined by a mapping function of the form:

$$Y = \begin{cases} Y_{\min} & L3 < x \leq L_{\max} \\ 1/(x + a) & L1 < x \leq L3 \\ Y_{\max} - K \times x & 0 \leq x \leq L1 \end{cases}$$

When the overall backlight illumination level is high ($>L3$) the adjustment factor is at a minimum and when the backlight illumination level is low ($<L1$) the adjustment factor is linearly decreased from maximum to a certain value. While the backlight illumination level is moderate, the adjustment factor is inversely proportional to the illumination level with an offset constant, a . The value of constant a is determined based on the LCD display properties.

This mapping function may be stored in the brightness controller as a function for determination of the adjustment factor by calculation. However, in the preferred embodiment the mapping function is stored as a single dimension look-up table (LUT) in which a corresponding adjustment factor for the full range of backlight illumination levels from 0 to $L_{\max}$ are given. After determination of the appropriate adjustment factor each pixel in the image is adjusted by the adjustment factor.

Referring to Figure 2 there is shown a schematic overview of a backlit LCD display, in this instance a LCD TV, of the type described in US patent application 11/707,517. The display comprises an LCD panel 1 located in front of a backlight 2. The backlight 2 is divided into a plurality of individually controllable illumination regions. In the illustrated embodiment there are only 5 x 7 regions shown for clarity. In the preferred embodiment of the invention each region comprises a cluster of red 3, green 4 and blue 5 LEDs so that the region light output can be from black to white through the colour spectrum. This is not essential to the invention and in other embodiments the backlight regions comprises just white LEDs or other light sources. The LCD panel is notionally, but not physically, divided into an equal number of display regions 6. The TV board 7 receives image signals from various video sources such as

PC, DVD player, Cable TV and so on, through analog or digital interfaces as is known. After processing the incoming signals, the TV board generates video signals 8 in RGB format and passes the video signal 8 to a brightness controller 9. The brightness controller 9 analyses the incoming video signal 8 and provides driving
5 signals to LED drivers of the individual illumination regions of the backlight 2. This function of the brightness controller 9 is in accordance with that described in US patent application 11/707,517. The brightness controller 9 then enhances the video signal, and in particular compensates brightness information of the signal so that brightness of the overall displayed image is not affected by the overall brightness, or
10 dimness, of the backlight 2. A compensated video signal 11 from the brightness controller 9 goes to the timing controller 12 which issues vertical 13 and horizontal 14 signals to corresponding liquid crystal drivers.

Figure 3 is a signal flow diagram of LCD compensation. The code value I of the video
15 signal is converted to a gamma value using a gamma look up table (LUT) 40. An adjustment factor χ is determined using an adjustment factor look up table 45 and the backlight illumination level BL' . The gamma value is adjusted by the adjustment factor at a multiplying junction and then the compensated gamma value is converted back into a video signal code value via an inverse gamma look up table 41. In the current
20 embodiment of the invention, which comprises a color backlight with red, blue and green LEDs, the illumination level of the individual red, green and blue LEDs of the backlight will vary depending on the determined color and light intensity of the backlight. In order to maintain the best image quality each color channel of the video signal for the LCD display should be compensated separately in accordance with the respective
25 illumination level of the red, green or blue component in the backlight.

In an alternative embodiment of the invention the backlight is a simple white color although it is divided into different backlight illumination regions so that different areas can be illuminated at different brightness levels. In this embodiment of this invention
30 there is only one brightness level for each region of the backlight and so each color channel of the RGB video signal for the LCD display is adjusted by the same adjustment factor.

Figure 4 shows the individual block components of the brightness controller 9. The brightness controller performs image enhancement, backlight illumination simulation and LCD pixel compensation functions. The backlight illumination simulation component 20 operates in accordance with the details provided in US patent application 11/707,517. Image enhancement and image signal compensation are performed in components 21 and 22.

An example and exemplified embodiment of the invention have been described above. This is not intended to limit the scope of use or functionality of the invention. It should be appreciated that modifications and alternations obvious to those skilled in the art are not to be considered as beyond the scope of the present invention.

What is claimed is:

1. A method for image enhancement in a display illuminated by a lighting device,
the image comprising a plurality of pixels having pixel brightness properties, the
5 method comprising:
 providing on a machine readable storage medium a non-linear mapping
function,
 determining an illumination level for the lighting device,
 determining by use of the mapping function and illumination level a
10 compensation factor for each pixel, and
 adjusting the brightness properties of each pixel by its compensation factor.
2. The method of claim 1 wherein the mapping function relates a lighting device
illumination level to a compensation factor.
- 15 3. The method of claim 2 wherein the compensation factor decreases or keeps
with the increasing illumination level.
4. The method of claim 1 wherein the mapping function is a single dimensional
20 lookup table relating lighting device illumination levels to compensation factors.
5. The method of claim 1 wherein the first mapping function is expressed by an
equation of the form $y = \frac{1}{(x+a)}$, where y is the compensation factor, x is the
illumination level of the lighting device and a is a constant.
25
6. The method of claim 5 wherein a is determined based on the display
characteristics.
7. The method of claim 1 wherein the lighting device comprises a plurality of
30 illumination regions each have an illumination level and illuminating one or more
pixels, and wherein the compensation factor of each pixel is determined based on the
illumination level of the illumination region illuminating the pixel.

8. The method of claim 7 wherein the mapping function maps an illumination level to a corresponding compensation factor.

9. The method of claim 1 when practiced in a LCD panel illuminated by a dynamically illuminated backlight device having a plurality of independently controllable illumination regions.

10. The method of claim 1 wherein the image is a video image in which the plurality of pixels comprising a plurality of sequential video image frames.

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11. A method for dynamically adjusting a video signal to be displayed on a LCD panel illuminated by a dynamically illuminated backlight device having a plurality of independently controllable illumination regions, the video signal comprising a plurality of sequential video frames each comprising a plurality of image pixels having pixel brightness properties, the method comprising:

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determining a plurality of adjustment factors based on illumination levels of the backlight and storing said adjustment factors in a machine readable form, and for each pixel in the video signal:

determining a corresponding illumination level for the lighting device,

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determining from the stored adjustment factors, an pixel adjustment factor for the corresponding illumination level, and

adjusting pixel brightness properties of the pixel by the pixel adjustment factor.

12. The method of claim 11 wherein the plurality of adjustment factors are stored in a single dimensional lookup table.

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13. An image enhancement apparatus for a display illuminated by a backlight device, the image comprising a plurality of image pixels having pixel brightness properties, the apparatus comprising:

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a machine readable medium storing a mapping function relating illumination levels of the backlight to viewed brightness of a pixel displayed on the display,

a first component which determines illumination levels of the backlight illumination regions,

a second component which uses the mapping function and illumination levels to determine an adjustment factor for each pixel in the image, and

a compensator that adjusts the brightness properties of each pixel by the determined adjustment factor.

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14. The apparatus of claim 13 wherein the mapping function is a single dimensional lookup table comprising a plurality of predetermined adjustment factors.

15 The method of claim 14 wherein the compensation factor decreases or keeps
10 with the increasing illumination level.

16. The apparatus of claim 13 wherein the first mapping function is expressed by an equation of the form $y = \frac{1}{(x+a)}$, where y is the compensation factor, x is the illumination level of the lighting device and a is a constant.

15

17. The apparatus of claim 16 wherein a is determined based on the display characteristics.

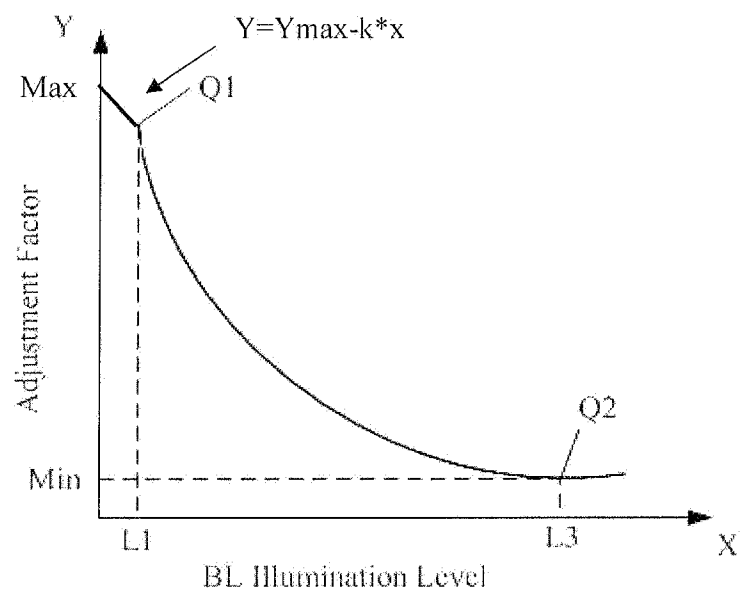
18. The apparatus of claim 13 wherein the lighting device comprises a plurality of
20 illumination regions each illuminating one or more pixels, and wherein the adjustment factor of each pixel is determined based on the illumination level of the illumination region illuminating the pixel.

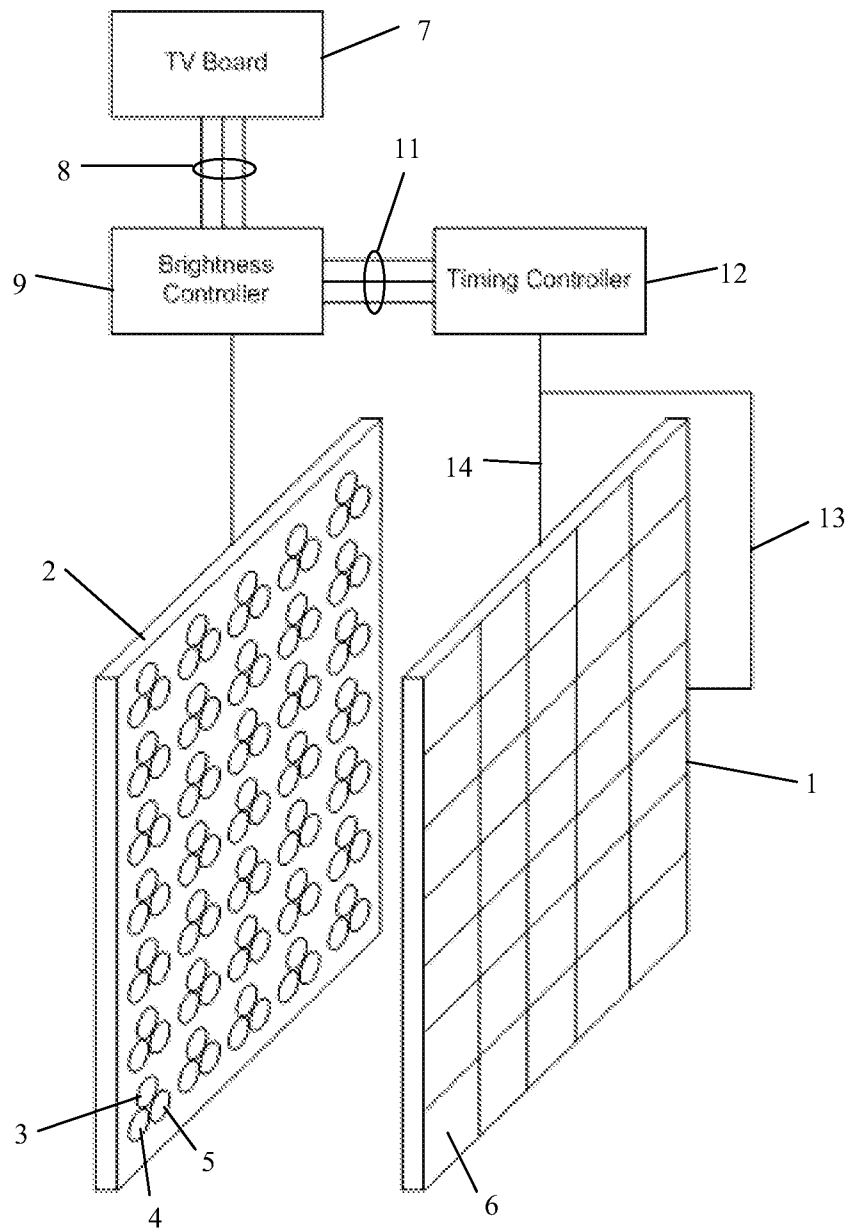
19. The apparatus of claim 18 wherein the mapping function maps an illumination
25 level to a corresponding compensation factor.

20. The apparatus of claim 13 wherein the display is a LCD panel illuminated by a dynamically illuminated backlight device having a plurality of independently controllable illumination regions.

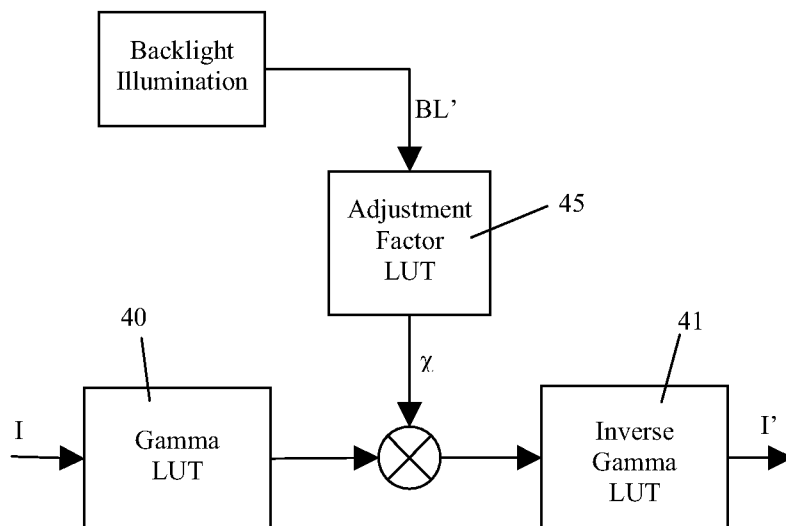
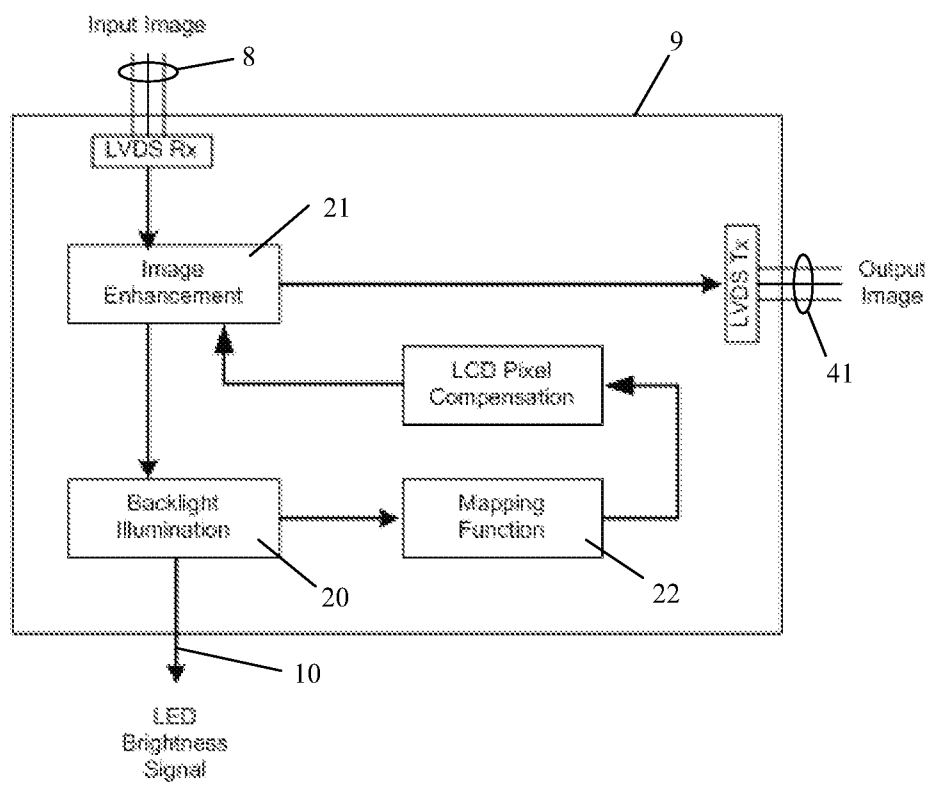
30

21. The apparatus of claim 13 wherein the apparatus is for enhancement of a video image in which the plurality of pixels comprising a plurality of sequential video image frames.

**Figure 1**

**Figure 2**

3 / 3

**Figure 3****Figure 4**

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

G09G3/36 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G09G3, G02F1, H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CPRS, EPODOC, WPI, PAJ: crystal, display, backlight, source, bright, light, illuminate, adjust, compensate, map

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN101042841A (QUANTA COMP INC) 26 Sep. 2007(26.09.2007) the whole document	1-21
A	CN1379596A (THOMSON LICENSING) 13 Nov. 2002(13.11.2002) the whole document	1-21
A	CN1462026A (MATSUSHITA ELECTRIC IND CO LTD) 17 Dec. 2003(17.12.2003) the whole document	1-21
A	US20070120806A1 (HONEYWELL INTERNATIONAL, INC) 31.May 2007(31.05.2007) the whole document	1-21
A	JP2007219468A (QUANTA COMP INC) 30 Aug. 2007(30.08.2007) the whole document	1-21

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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INTERNATIONAL SEARCH REPORT
Information on patent family members

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Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN101042841A	26 Sep. 2007(26.09.2007)	none	
CN1379596A	13 Nov. 2002(13.11.2002)	US2002126079A	12 Sep. 2002(12.09.2002)
		KR20020072503A	16 Sep.2002 (16.09.2002)
		EP1249817A	16 Oct. 2002(16.10.2002)
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		US7309851 B	18 Dec. 2007(18.12.2007)
		TW271686B	21 Jan. 2007(21.01.2007)