Title: BRIGHTNESS CONTROL FOR AN LED DISPLAY

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Abstract: Described is a system and method for controlling the brightness of an LED display employing a combination of current and PWM dimming of the LEDs in order to control brightness without losing control of the resolution of control of the brightness or its calibration.

[Continued on next page]

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BRIGHTNESS CONTROL FOR AN LED DISPLAY

RELATED APPLICATION

This application claims priority of provisional application 61/893,795 filed on 21 October 2013.

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention generally relates to means for controlling the brightness of a video display, specifically to a method for adjusting the output from an LED based display unit without losing resolution or calibration of the display.

BACKGROUND OF THE INVENTION

[0002] Video display units for entertainment, architectural, and advertising purposes are commonly constructed of arrays of light emitting elements such as LEDs mounted onto panels. The LEDs can be individually and selectively controlled to create patterns, graphics and video displays for both informational and aesthetic purposes. Figure 1 illustrates an example of such a display 10 where arrays of LEDs 14 are mounted on panels 12.

[0003] The LEDs in these displays are commonly made up of multiple colors, typically at least three colors including red, green, and blue arranged in a group to form a single pixel or picture element of the entire display. By controlling the light output level of each of the red, green, and blue LEDs of each pixel separately the pixel may be made to appear in any color through mixing of the three primary colors. A standard method for controlling the brightness of the individual LEDs is through pulse width modulation (PWM). Figure 2 illustrates how PWM may be used to dim an LED. With PWM control
the current through the LED is rapidly switched between zero and a full level value. By altering the ratio of the ‘on’ time to the ‘off’ time the pulsing of the LED will be perceived by the eye as a continuous light source that varies in brightness. For example, in the top chart of Figure 2, the LED current is at full current for 10% of the time, and zero for 90% of the time. If the pulsing frequency is fast enough, the result to the human eye will be that of a continuous LED at 10% brightness. Similarly, in the center chart of Figure 2, the LED current is at full for 50% of the time, and zero for the remaining 50%. This produces a result that appears to be a continuous light at 50% brightness. Finally, in the bottom chart of Figure 2, the LED is at full current for 90% of the time, and zero for the remaining 10%. The human eye will perceived this as a continuously illuminated LED at 90% brightness.

[0004] A problem with the prior art systems using such a method occurs when it is desired to reduce the overall brightness of the display. For example, many LED displays are now bright enough to be used outdoors on a sunny day and still remain visible. This means that those same displays are often much too bright when used indoors or when being viewed by video cameras. The user then naturally wishes to reduce the overall brightness of the display. A common way of doing this in the prior art is by reducing the allowed range of the PWM control. For example, instead of it being allowed to run all the way from 0% to 100%, it may be restricted to running from 0% to 50%, producing a corresponding 50% reduction in brightness. In this case the control circuitry, which is typically digital, will scale the incoming data by a factor of 0.5 to accommodate this change. However, this has the unwanted secondary consequence of also reducing the possible brightness resolution by that same factor of 2. If we originally had eight bits, or 256 levels, of brightness control between full on and full off, after scaling we now only
have seven bits, or 128 levels, of brightness control. This causes the display to be of a perceived lower quality and images can appear uneven and jerky. In extreme cases, where the desired screen brightness is only a small fraction, say 5%, of the screen's maximum brightness, many more bits of brightness resolution can be lost producing totally unacceptable results. With a reduction to 5% brightness we would lose between 4 and 5 bits of brightness resolution, potentially reducing our display to only 8 or 16 levels of brightness. At that point the display is effectively useless. It would be advantageous to have a method for reducing the maximum brightness of the LEDs and the display without losing brightness resolution and smoothness of control.
BRIEF DESCRIPTION OF THE DRAWINGS

[0005] For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings in which like reference numerals indicate like features and wherein:

[0006] FIGURE 1 illustrates a general view of a typical LED display screen;

[0007] FIGURE 2 illustrates conventional PWM dimming of LEDs;

[0008] FIGURE 3 illustrates the non-linearity of current control of LED brightness, and;

[0009] FIGURE 4 illustrates modified PWM dimming.

DETAILED DESCRIPTION OF THE INVENTION

[0010] Preferred embodiments of the present invention are illustrated in the FIGURES, like numerals being used to refer to like and corresponding parts of the various drawings.

[0011] The present invention generally relates to means for controlling the brightness of a video display, specifically to a method for adjusting the output from an LED based display unit without losing resolution or color calibration of the display.

[0012] The color calibration of a display is necessary because of the variability of various components of the system including at least the electronics and the output LEDs. This may vary from LED to LED, from module to module, from color to color, and from system to system. Accordingly a mapping of these variabilities is measured so that they...
may be nullified and there is a one-to-one relationship between the required light output level from the source video signal, and the actual light output from the display. This mapping may be stored and used as the color calibration. A color calibration is specific to a certain set of parameters including, but not limited to, the type of LEDs, temperature of LEDs, temperature of electronics, the drive current being used, the age of the system and many others.

[0013] As described above, the use of PWM to control LED brightness is common, and is widely used in preference to linear control of the current through the LED. A problem with linear current control is illustrated in Figure 3 which shows a graph of luminous flux output from an LED against the current passing through the LED. As can be seen in Figure 3, this relationship is not linear. The luminous flux output at point A, where the current is 100% is also defined as 100%; however, if we reduce the current to 50%, as shown as point B, the luminous flux output drops to 65%, not to 50% as might be expected. This non-linearity varies between different colors of LEDs and is commonly most prevalent in red LEDs.

[0014] Because of this non-linear response we cannot just reduce the maximum LED current to dim the LED display; if we do so then the calibration of the display will be affected as we move down the non-linear response curve. For example, the red output at 50% current may be 65% of full as shown in Figure 3, while the green and blue outputs may be closer to 55%. The net result would be a shift towards the red for all colors and the whole display would obtain a pinkish tone.

[0015] The disclosed invention solves this problem by applying a new calibration to the LED drive circuitry that compensates for and negates the non-linear dimming of the individual LEDs. In one embodiment of the invention the display may have a full output
mode where the PWM signals are as shown in Figure 2. It may also have a lower brightness mode where the PWM signals are as shown in Figure 4. In this case the LED drive current is reduced to half of its full value, such that the PWM signal transitions between zero current and half current instead of to full current. For example, as shown in Figure 4, a 10% PWM output combined with 50% drive current results in 5% electrical output from the drive system, a 50% PWM output results in 25% electrical output, and a 90% PWM output results in 45% electrical output. At the same time as this change is made, instead of scaling the input signals to 50% as in the prior art, the input signals may be modified through calibration data so as to allow for the non-linear response of the LEDs as shown in Figure 3. The net result is that the display is dimmed, but we retain substantially all the brightness resolution of the full brightness display and still have high quality and smooth control of the LEDs. The modification to levels is much smaller than the overall brightness reduction and typically results in the loss of less than one bit of brightness resolution.

[0016] In further embodiments of the invention there may be multiple modes of operation, each at a different LED drive current/brightness level, where each LED drive current/brightness mode has an associated calibration correction that may be applied to the input signals. The associated calibration correction may compensate for multiple operational parameters including, but not limited to; the response of LED output with drive current, the response of LED output with duty cycle, the response of LED output with die temperature, the response of LED primary wavelength and half power bandwidth with drive current, the response of LED primary wavelength and half power bandwidth with die temperature, the response of all LED parameters to LED life, and the use of different response curves for different LED die colors.
In yet further embodiments the LED drive current/brightness may be continuously varied with associated continuous variation in the color calibration correction applied to the input signals. For example, a system of the invention may dynamically adjust the LED drive current and/or the color calibration on a frame-by-frame basis dependent on the content of each video frame. In such a system, when a dark scene is being shown, the LED current may be reduced in order to improve the brightness resolution of the image. Conversely, in bright scenes, the LED current may be increased. In all cases the system of the invention will adjust the color calibration so that it always matches the LED current being used.

The data for the calibration associated with each LED drive current/brightness level may be stored in a look-up table, may be calculated dynamically by the system, or may be communicated to the system from an external controller. Methods for dynamically calculating the calibration data may include, but are not limited to; interpolation between measured calibration corrections for intermediate LED drive current/brightness levels, or adjusting a single calibration correction based on known LED parameters for factors such as temperature, life, output droop, drive current non-linearity and other parameters affecting the output, wavelength, or bandwidth of an LED emitter. In yet further embodiments the parameters such as temperature, which are inputs to the dynamic calculation of calibration data, may be derived as average values for a system, or may be derived on a more granular level to compensate for temperature variations across the video display. In even further embodiments the color calibration for the system may be adjusted directly by these same input parameters, even in cases where the LED drive current is not altered. For example, this would allow a system to remain
calibrated at different operating temperatures where the response curve of the LEDs varies, even though the LED drive current has not been changed.

[0019] While the disclosure has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised which do not depart from the scope of the disclosure as disclosed herein. The disclosure has been described in detail, it should be understood that various changes, substitutions and alterations can be made hereto without departing from the spirit and scope of the disclosure.
WHAT IS CLAIMED IS:

1. An LED brightness control system dims the light output of the LED's through a combination of both current and PWM.

2. The LED brightness control system of claim 1 where the relative degree of current dimming and the degree of PWM dimming is dependent on the color of the LED.

3. The LED brightness control system of claim 1 where the relative degree of current to PWM dimming for red LED's is lower than the relative degree of current to PWM dimming for green or blue LED's.
FIG 2

FIG 3
FIG 4
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

**INV. H05B33/08**

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)

H05B

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)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>EP 1 689 212 AI (PATENT TREUHAND GES FUER ELEKTRISCHE GLUEHLAMPE MBH [DE]; OSRAM SPA [ ]) 9 August 2006 (2006-08-09) pages 2-4; figures 4-6</td>
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<td>Wo 2011/024101 AI (KONINKL PHI LI PS ELECTRONICS NV [NL]; CLAUBERG BERND [US]; GREISCHAR RI) 3 March 2011 (2011-03-03) the whole document</td>
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Further documents are listed in the continuation of Box C.

**Further search"**

"Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) one or more of which is cited to establish the publication date of another citation or other special reason (as specified).

"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance; the claimed invention cannot be considered without it.

"Y" document of particular relevance; the claimed invention cannot be considered without it and if the application referred to in the search report is the priority application of the application claiming the invention

"Z" document member of the same patent family

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