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(54) **Method and apparatus for dimming a lamp in a backlight of a liquid crystal display**

(57) Methods and apparatus are disclosed for dimming a display having a plurality of illumination sources. The display is preferably configured to illuminate the plurality of illumination sources to provide a first intensity

level; dim the illumination sources to provide a predetermined intensity level; turn off a selected number of illumination sources; and raise the intensity level of the remaining illumination sources to provide again approximately the predetermined intensity level.

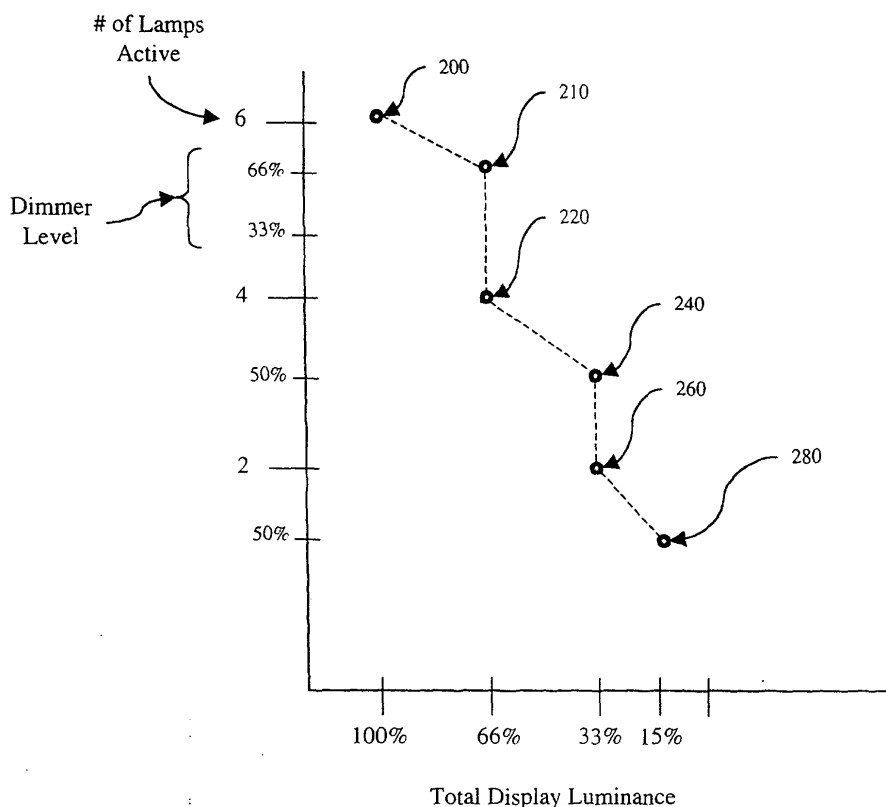


FIG. 2

Description

Field of the Invention

[0001] The present invention relates generally to managing the brightness of displays such as flat-panel displays.

Background of the Invention

[0002] Liquid Crystal Displays (LCDs) are fundamentally transmissive devices, requiring a backlight assembly to produce light that is then either transmitted or blocked on a pixel-by-pixel basis. This is typically done by forming a light distribution system behind the LCD pixels that extends the full length and width of the pixel array. Sometimes, the backlight can simply be a reflector for collecting light that comes from the front of the display and redirecting it back out (typically called reflective or transmissive displays), but for high-quality AM-TFT-LCDs the source of the light in the backlight is usually one or more fluorescent lamps of various sizes or shapes, usually of the type CCFL (Cold Cathode Fluorescent Lamp), also called CCFT (Cold Cathode Fluorescent Tube).

[0003] As LCDs get larger and/or require more luminance (brightness) at their output, a standard method of producing the additional light is to add more CCFTs. This makes for a brighter display, but has several consequences, including increased power consumption, and added difficulty in dimming the lamps to low enough levels to compensate for low-level ambient illumination conditions.

[0004] CCFTs are high voltage AC devices that need special circuits to produce the required voltages and frequencies to drive them properly. For the CCFTs commonly found, such as for industrial home/business lighting needs, large ballast devices are commonly used for driving the lamps at 50 or 60Hz. However, for LCD displays, additional demands require sophisticated solutions to problems such as having a low voltage DC source, small size requirements for implementation, higher frequencies to ensure no optical interference with the display, and preferably a wide range of dimming.

[0005] A wide range of dimming is often desirable as LCD displays may be used in dim environments, and the default output can be quite bright for some users. Currently, LCD displays cannot be dimmed over a range comparable to standard CRT displays, yet their brightness can be several times that of CRTs. The most common method of dimming the CCFTs for most high-quality LCD assemblies is an inverter, an inverse method of common power conversion, in that it takes DC as its input and converts it to AC output. Common inverters are used to convert automobile battery voltages to AC 115 voltages, such as for using normal home appliances in vehicles. In these cases, output level control is rarely needed, and if so, then only over a limited voltage range.

[0006] The inverter used for CCFTs for LCDs is typically much more specialized, taking DC levels and converting them to high AC voltages, usually well over 1kVolt, with a waveform optimized for the types of fluorescent lamps or other illumination sources for which they were designed. Unlike their vehicle counterparts, these inverters are generally required to provide a wide range of dimming. This is quite a challenging task, and the dimming limits are usually much less than would be desired. This can have a number of negative effects, as will be explained in more detail below.

[0007] Typically, there are two types of inverter dimming methods. The first is direct AC supplied voltage amplitude attenuation, and the second involves temporal signal processing, such as by chopping the lamp waveform, like PWM (pulse-width modulation).

[0008] However, both of these methods suffer from limitations that occur when dimming the lamps to their lower levels. Currently, undesirable side effects are often produced at low levels, such as output luminance nonuniformities, degraded lamp life, and visual artifacts, including temporal instabilities or optical interference seen in the LCD displayed content. In such cases, controlling these side effects results in compromises, often dimming the lamps to an extent less than desirable.

Summary of the Invention

[0009] The invention is as defined in the appended claims.

Brief Description of the Figures

[0010] Various embodiments of the invention will now be described in detail by way of example only, with reference to the following drawings:

Figure 1 is a front view of an LCD display in accordance with one embodiment of the present invention; Figure 2 is a graphical representation of a dimming method in accordance with one embodiment of the present invention; and

Figure 3 is another graphical representation of a dimming method in accordance with one embodiment of the present invention.

Detailed Description

[0011] Figure 1 is a front view of a display 100 in accordance with one embodiment of the invention. Display 100 includes a screen 105 disposed within a housing 110, which may be mounted on a base 115 or a multitude of other arrangements. The screen 105 may comprise a screen requiring a backlight for proper display, such as an LCD or TFT-LCD screen or any other type of transmissive display technology as is known in the art or may be developed.

[0012] The display 100 includes circuitry 125 contain-

ing a processor, memory, and associated circuitry as is known in the art for operating the display 100 as described herein. The display 100 also includes connectors and circuitry (not shown) known in the art for interfacing with sources of video, such as computers. The dimming method described herein may be implemented by way of discrete circuitry as is known in the art. Alternatively, the dimming method may be implemented as a microprocessor-based solution, typically with machine-readable instructions stored in the circuitry 125. The process may also be implemented as a combination of both discrete circuitry and software as desired.

[0013] The display 100 also includes a ballast 130 for driving CCFTs 120. With the advent of larger high quality LCDs, such as used for monitors, wall-mounted displays, home entertainment, etc., more illuminance may be desired. In order to generate this high brightness, often the number of CCFTs is increased to 2, 4, 6, 8 or even more. Typically, but not always, the lamps are distributed in pairs, such as pair 120a, such that one pair member is deployed about the top or side of the display at the edge of the light distribution system, known as the backlight (not shown), with the other pair member deployed on the opposite side of the display. Such an arrangement can more evenly distribute the light across the light distribution system.

[0014] Though three pair sets of CCFTs are shown in FIG. 1, any number of pairs may be employed as appropriate. The lamps may also be distributed in a non-symmetrical manner, such as on various sides, in the rear of the LCD (rather than top, bottom, or side lit). Furthermore, the lamps may comprise non-conventional CCFT light sources, including serpentine or random configurations, flat lamps, LEDs, ELs or other types of light-generating sources, including potentially a combination of illumination sources of different types or technologies. Other potential methods of generating light in the backlight assembly include various types of incandescent arrays, and even pixelated emissive sources as in other display types, and so forth. It should also be noted that not all the fluorescent lamps need be straight or of lengths that nearly match the horizontal or vertical dimensions of the LCDs for side or backlighting methods. Thus the approach described herein may apply to any variation or type of lighting for LCDs, when the lighting scheme involves multiple or sectionalized illumination sources (such as multiple cathode/anode devices, pixelated devices, and so forth).

[0015] In one embodiment described herein, pairs of lamps are utilized by taking advantage of their numbers and selectively turning some off, while leaving others lit, so as to minimize the amount of dimming work done by the inverters or other types of lamp controllers. However, as stated, an analogous approach may be used for any configuration in which multiple light sources are used to comprise an entire backlighting, sidelighting, etc. system.

[0016] An inverter in existing systems is typically used

to drive lamps to their lower extremes using the methods described above, resulting in reduced performance in a number of areas and a limited range of dimming. However, lamps and other illumination sources typically perform best when driven at some optimum level of operations, often at or near their highest output. Thus the prior art methods generally degrade a lamp's performance by dimming the lamp to low operating levels, thereby reducing the quality of a display compared to having lamps in their optimal (non-dimmed) states.

[0017] The present approach provides for decreasing the brightness of a display with little degradation of the lamps or their visual quality. It is to be understood that such an approach may be used in conjunction with certain known prior art dimming methods, thereby complementing them and extending their range dramatically. In addition, although one embodiment of the invention uses a conventional inverter dimmer circuit, non-inverter dimmer methods could be used instead where appropriate for the type of illumination source employed.

[0018] In accordance with one embodiment of the present invention, a display may be dimmed by selectively turning off some lamps, often in symmetrical sets, such as pairs, to help balance more easily the luminance distribution. Depending upon a number of light distribution or optical transmission characteristics, configuration dependencies, and electronic circuit variables, the disclosed methods may potentially decrease the luminance by a factor of n/m , where m is the total number of lamps or light sources, and n is the number turned off. For one example, if a backlight assembly has 6 lamps in 2 balanced sets of 3 and one lamp is turned off in each set, then the resultant luminance output might be $4/6$ or 66.7% of the initial brightness, assuming perfect optical transmission and electrical efficiency, and other factors being constant.

[0019] FIG. 2 illustrates a dimming process in accordance with one embodiment of the invention, typically utilized in conjunction with the display 100 of FIG. 1, which includes a backlight assembly comprising 6 CCFTs 120, with 3 pair members each being disposed about the top and bottom of the display 105, and an inverter 130 configured to dim the output of the display to 50% of its initial luminance level.

[0020] FIG. 2 is a graphical representation of one aspect of the dimming process, with the x-axis representing the overall output intensity of the display. The intensity decreases from the brightest at the left to the dimmest level at the right. The y-axis represents the number of lamps operating, with the level of dimming provided by the dimming circuitry indicated.

[0021] At the beginning of the process of FIG. 2, at marker 200, the display is illuminated to a first intensity state, typically with all lamps on, and the inverter dimming is off, providing the highest output intensity for the display. To begin dimming the intensity level of the display, the inverter drives the lamps down to a predetermined level at marker 210. This level is preferably cho-

sen to provide a satisfactory output while not driving the lamps too close to their degraded performance level. In the example of Figure 2, this level occurs at marker 210, representing about 2/3 or 66% of the lamps' original intensity. In this example, where a dimmer circuit is used that is capable of dimming by a total of 50%, a superior result is provided by driving the luminance down only 33%, since the lamps and displays are not being driven close to their degraded performance level.

[0022] If it is desired to dim the display further, the process continues to marker 220. At this point, a pair of lamps (preferably one on top and one on the bottom) is turned off, and the inverter is brought back to a full illumination state. The overall intensity level at marker 220 is preferably close to the overall intensity level at marker 210. Thus, the dimming level at marker 210 may also be chosen to correspond to the intensity level provided when a first set of lamps is turned off, and the remaining lamps are being driven at their full output level at marker 220.

[0023] At marker 220, the inverter is now driving only 4 of the 6 lamps, and the total output luminance is again reduced by about 33%. To further dim the display, the conventional dimming method is used again to drive the remaining 4 lamps to approximately 40-50% of their full level. This takes us to the position of marker 240.

[0024] To further dim the display again, a next set of lamps is turned off (another pair in this example) at marker 260, and the dimming circuit is reset for maximum output, driving the 2 remaining lamps at full brightness. Thus, at marker 260, only 2 lamps are being driven, providing about 33% of the original brightness. As mentioned above for marker 220, the dimming level at marker 240 may be chosen to correspond to the intensity level provided when the next set of lamps is turned off (at marker 260).

[0025] To dim the display to the lowest output level, a conventional dimming method may be used to dim the remaining 2 lamps to approximately 50% of their level at marker 280, potentially achieving an overall luminance level of 0.33×0.5 , or 0.165, i.e. approximately 16.5% of the original output. Note that such a luminance reduction technique provides luminance reduction over a range that is 3 times greater than the 50% range that the dimmer alone is able to provide by dimming all 6 of the lamps together.

[0026] As will be appreciated by those of ordinary skill in the art, the specified output levels and level of extending dimming mentioned in respect of the example of Figure 2 will vary with the types of lamps used, the dimmer circuitry employed, or the overall number of lamps or types of illumination sources employed in the display.

[0027] It will be appreciated that the staggered dimming process described in relation to Figure 2 provides a wide range of luminance, while conserving power, lamp life, and minimizing optical degradation or interference, since the components of the display are not driven too near their respective degradation points.

[0028] To minimize any noticeable steps in luminance when lamps are turned off, luminance balancing should be predicted and accounted for in the level of luminance reduction before lamps are turned off. Such balancing may be achieved through an electro-optical prediction of the voltage-luminance transfer function. Alternatively, an empirical characterization of the electro-optical system may be used to determine the luminance levels at which the dimmed level matches the lamp cutoff level.

[0029] Additionally, to provide adequate control of the conventional dimming method for the individual lamps, while avoiding undesirable effects when the CCFT lamp loads are unbalanced, such as bleeding, crosstalk, leakage, or arcing, a feedback or loading control as is known in the art may be implemented to allow for balanced drive of illuminated lamps when others are turned off.

[0030] While the example of FIG. 2 shows the lamps being progressively dimmed the same approach may be used to raise or lower the intensity level of the display as the user desires. Additionally, it is contemplated that the system may be configured to store the present intensity state of the display for recall on power up.

[0031] Figure 3 is another graphical representation of a dimming method in accordance with one embodiment of the present invention. Figure 3 shows the number of illumination sources turned on along the x-axis, and the overall luminance along the y-axis. FIG. 3 again provides an example utilizing 6 lamps as the illumination source, though any illumination source and corresponding dimming circuitry may be employed.

[0032] The typical range of a prior art dimming method is illustrated in FIG. 3 as the range from marker 300, with all lamps turned on at 100% illumination, to marker 304, where all lamps are dimmed to 50% using the dimming circuitry. This results in a total illumination range of approximately 50%.

[0033] Using the staggered dimming approach disclosed herein, the range of dimming is increased from marker 300, with all lamps on at 100%, to marker 308, where two lamps are dimmed to 50%, resulting in the ability to dim the display to approximately 16.7% of the total luminance.

[0034] As will be appreciated from FIG. 3, the staggered dimming method first uses conventional dimming methods to dim the display by 33% to approximately 66% of the total output at marker 302. This level corresponds to the total luminance provided by the display when the first set of two lamps is turned off. As mentioned throughout, this level may be chosen depending on the type and/or number of illumination sources utilized.

[0035] When the first set of lamps is turned off, the dimming circuits then provide a range of dimming from marker 302 to marker 306, extending from approximately 66% down to approximately 33% of total output luminance. If it is desired to dim the display down below 33%, the next set of lamps may be turned off, and the range of dimming extended from marker 306 to marker 308,

or approximately from 33% to approximately 16.7%.

[0036] While various embodiments and applications have been shown and described herein by way of illustration only, it will be apparent to those skilled in the art that many more modifications and improvements will suggest themselves to skilled persons having the benefit of this disclosure without departing from the scope of the appended claims and their equivalents.

Claims

1. A method of dimming a display having a plurality of illumination sources, said method comprising:

illuminating the plurality of illumination sources to provide a first intensity level;
dimming said plurality of illumination sources to provide a predetermined intensity level;
turning off a selected number of said plurality of illumination sources; and
raising the intensity level of said remaining illumination sources to provide approximately said predetermined intensity level.

2. The method of claim 1, wherein said first intensity level corresponds to the full intensity capability of said display.

3. The method of claim 1 or 2, wherein said predetermined intensity level prior to turning off a selected number of said plurality of information sources corresponds to a level at which performance degradation of the display is avoided.

4. The method of claim 3, wherein said predetermined intensity level is approximately 66% of said plurality of illumination sources' output at full intensity.

5. The method of claim 3, wherein said predetermined intensity level is approximately 50% of said plurality of illuminations sources' output at full intensity.

6. The method of any preceding claim, wherein the ratio of said predetermined intensity level to said first intensity level is approximately equal to the proportion of said plurality of illumination sources that are turned off.

7. An apparatus for dimming a display having a plurality of illumination sources, said method comprising:

means for illuminating the plurality of illumination sources to provide a first intensity level;
means for dimming said plurality of illumination sources to provide a predetermined intensity level;
means for turning off a selected number of said

plurality of illumination sources; and
means for raising the intensity level of said remaining illumination sources to provide approximately said predetermined intensity level.

8. A program storage device readable by a machine, tangibly embodying a program of instructions executable by the machine to perform a method of dimming a display having a plurality of illumination sources, said method comprising:

illuminating the plurality illumination sources to provide a first intensity level;
dimming said plurality of illumination sources to provide a predetermined intensity level;
turning off a selected number of said plurality of illumination sources; and
raising the intensity level of said remaining illumination sources to provide approximately said predetermined intensity level.

9. A program comprising instructions executable by a machine to perform a method of dimming a display in accordance with any of claims 1 to 6.

10. A display apparatus comprising:

a transmissive pixel array operatively disposed in a housing;
a backlight system optically coupled to said array including a plurality of illumination sources; dimmer circuitry operatively coupled to said plurality of illumination sources, wherein said dimmer circuitry is configured to illuminate the illumination sources to provide a first intensity level; to dim said plurality of illumination sources to provide a predetermined intensity level; to turn off a selected set of said plurality of illumination sources; and to raise the intensity level of the remaining illumination sources to provide approximately said predetermined intensity level.

11. The display of claim 10, wherein said plurality of illumination sources comprises a plurality of CCFTs (Cold Cathode Fluorescent Tubes).

12. The display of claim 10 or 11, wherein the display is configured to decrease the total luminance by a factor of n/m , where m is the total number of illumination sources, and n is the number of illumination sources turned off.

13. The display of any of claims 10 to 12, wherein said predetermined intensity level prior to turning off a selected number of said plurality of information sources corresponds to a level at which performance degradation of components of the display is

avoided.

14. The display of claim 13, wherein said predetermined intensity level is approximately 66% of said plurality of illumination sources' output. 5
15. The display of claim 13, wherein said predetermined intensity level is approximately 50% of said plurality of illumination sources' output. 10
16. The display of any of claims 10 to 15, wherein luminance of the display may be reduced to less than 20% of the display's total luminance.
17. The display of any of claims 10 to 16, wherein said plurality of illumination sources are arranged as pair sets located about said array. 15

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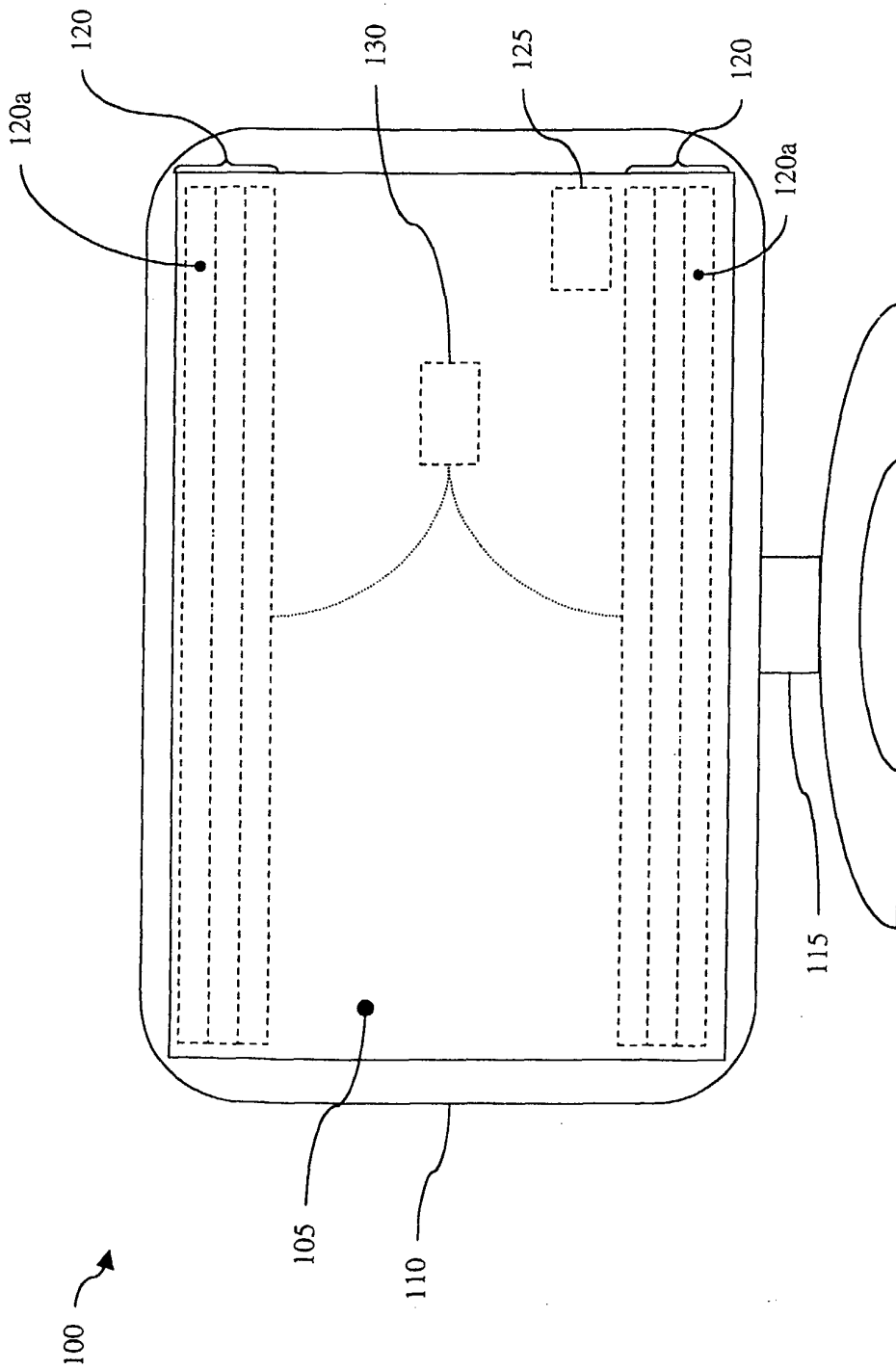


FIG. 1

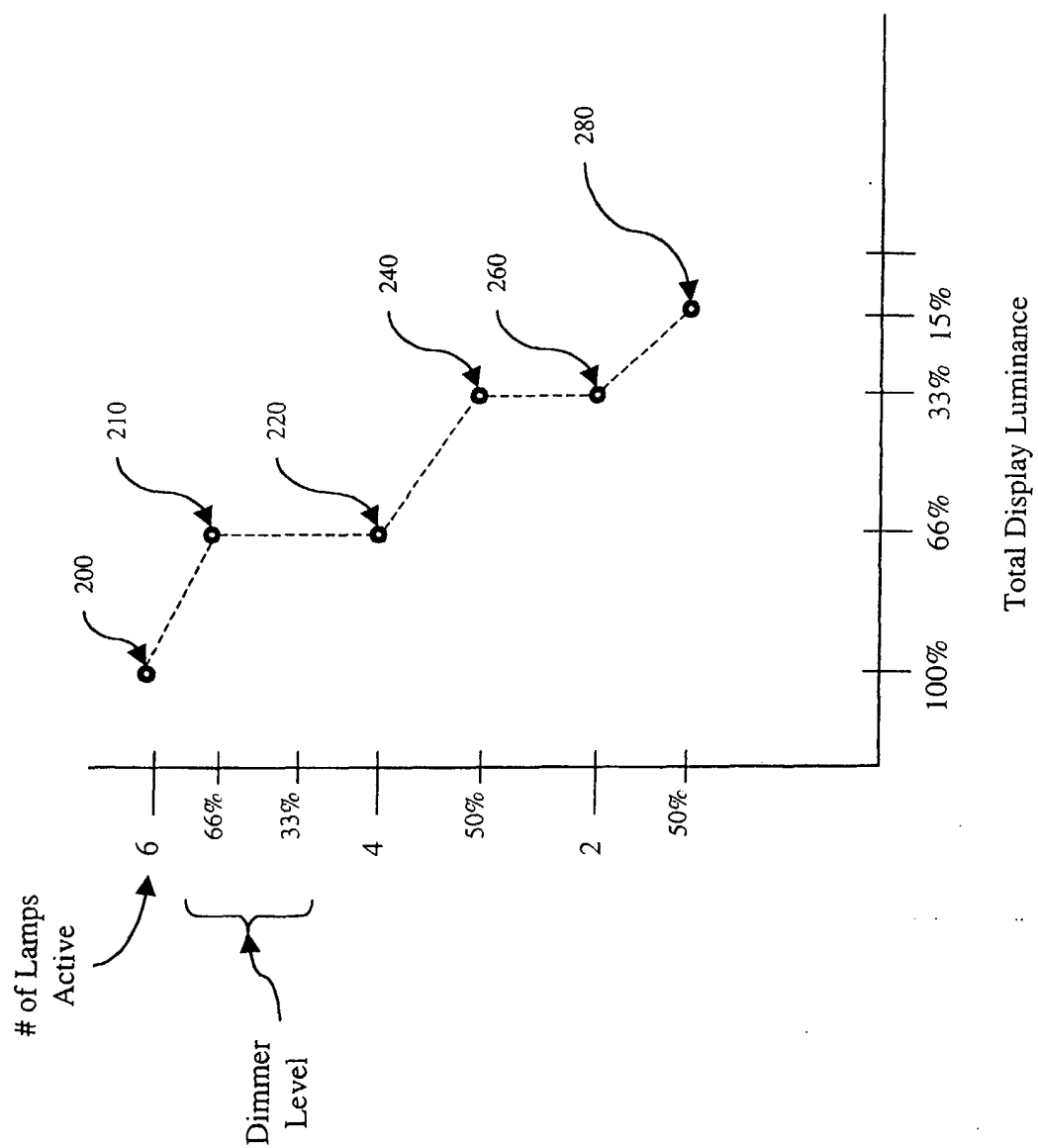


FIG. 2

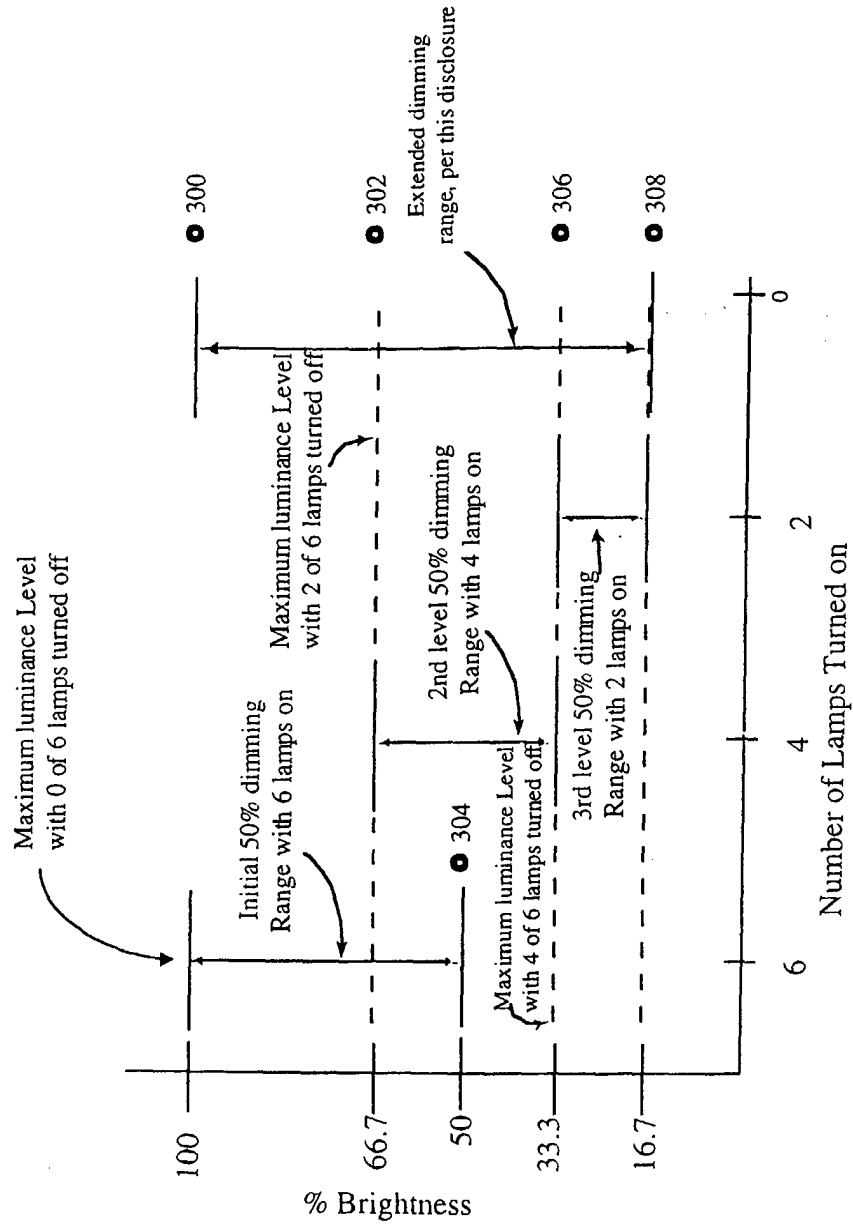


FIG. 3