

(51) Int.Cl.5	Identification Code	JPO File No.	FI	Technical Disclosure
G09F 9/00	337	7610-5G		
G02F 1/133	535	9226-2K		
	580	9226-2K		

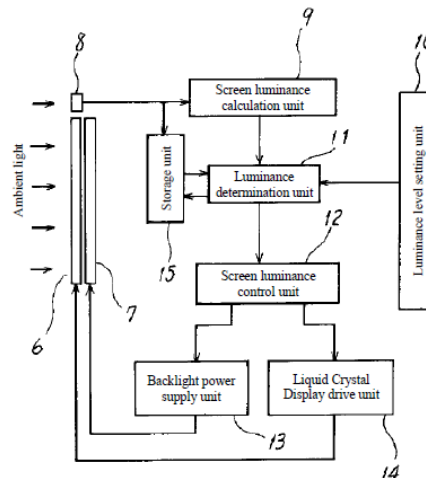
Examination Request: Not requested Number of Claims: 5 OL (total of 11 pages)

(21) Application No.	Japanese Patent Application No. H5[1993]-96349	(71) Applicant	000005821 Matsushita Electric Industrial Co., Ltd. 1006 Oaza-Kadoma, Kadoma City, Osaka, Japan
(22) Application Date	April 23, 1993	(72) Inventor	Yoko Shimomura 1006 Oaza-Kadoma, Kadoma City, Osaka, Japan
		(72) Inventor	Matsushita Electric Industrial Co., Ltd. Shiro Otake 1006 Oaza-Kadoma, Kadoma City, Osaka, Japan
		(72) Inventor	Matsushita Electric Industrial Co., Ltd. Teruaki Shigeta 1006 Oaza-Kadoma, Kadoma City, Osaka, Japan
		(74) Representative	Matsushita Electric Industrial Co., Ltd. Patent Attorney, Yoshihiro Morimoto
			Continue to last page
		(72) Inventor	Tetsuji Takeuchi 1006 Oaza-Kadoma, Kadoma City, Osaka, Japan Matsushita Electric Industrial Co., Ltd.

(54) [Title of Invention] DISPLAY DEVICE**(57) [Abstract]**

[Purpose] To provide a display device in which displayed characters and graphics are easily and visually recognized by a user at all times by automatically varying the screen luminance of a screen in accordance with the intensity of ambient light in the vicinity of the display screen.

[Constitution] An ambient light receiving unit 8 detects the brightness in the vicinity of a display screen 6; a screen luminance calculation unit 9 calculates a light-adjusting screen luminance band so as to secure and maintain a certain legibility of displayed characters and graphics based on the illuminance value in the vicinity of the display screen detected by the ambient light receiving unit 8; a luminance determination unit 11 compares and determines the light-adjusting screen luminance band calculated by the screen luminance calculation unit 9 with a set value in the past of the illuminance value stored in a storage unit 15 and a screen luminance control unit 12 controls the light. In this way, a certain legibility is secured, which takes into consideration the characteristics of the human eye under various illumination environments.



6 --- Display screen
7 --- Backlight
8 --- Ambient light receiving unit

[SCOPE OF PATENT CLAIMS]

[Claim 1] A display device, which is equipped with an ambient light receiving unit is placed near a display screen and facing the observer, a screen luminance calculation unit that calculates the range of light-adjusting screen luminance L relative to the ambient light illuminance I shown in (Formula 1) based on the output signal from the ambient light receiving unit, a luminance level setting unit that sets the screen luminance desired by the user, a storage unit that is composed of a rewritable storage medium, a luminance determination unit that determines the screen luminance value based on the output signals from the screen luminance calculation unit, the luminance level setting unit, and the storage unit, and a screen luminance control unit that controls the luminance of the display screen based on the output signal from the luminance determination unit, wherein the storage contents of the storage unit are rewritten based on the signal from the ambient light receiving unit and the signal from the luminance determination unit.

(Formula 1)

$$18 I^{0.139} \leq L \leq 53 I^{0.113}$$

[Claim 2] The display device as described in Claim 1, wherein the screen luminance value L is rewritten for the entire band of ambient light illuminance I in the storage unit from the relationship between the ambient light illuminance I' obtained by the signal from the ambient light receiving unit, the screen luminance L' set by the luminance level setting unit, and (Formula 2) and (Formula 3).

(Formula 2)

$$\log L' - (0.139 - 0.026a) \log I' \\ = \log (18 + 35a)$$

(Formula 3)

$$L = (18 + 35a) I^{0.139 - 0.026a}$$

In the above formula, a is a coefficient.

[Claim 3] The display device as described in Claim 1 or Claim 2, wherein a display superimposing unit is provided on the output side of the luminance determination unit, which rewrites the storage contents in the storage unit corresponding to the signal from the ambient light receiving unit in the luminance determination unit if the signal from the luminance level setting unit is within the range of values indicated by the screen luminance calculation unit, and outputs a signal suggesting a review of the optical environment before rewriting the storage contents if the signal is not within the aforesaid range.

[Claim 4] The display device as described in Claim 3, wherein the display screen is a Liquid Crystal Display, which is provided with a backlight integrating unit that integrates the usage time of the backlight that illuminates the Liquid Crystal Display and a Liquid Crystal Display usage time integrating unit that integrates the usage time of the Liquid Crystal Display; if the signal from the luminance level setting unit exceeds the upper limit of the value range indicated by the screen luminance calculation unit and the output signal from either of the aforesaid time integrating units exceeds the preset time as the lifetime of the backlight, before rewriting the storage contents in the storage unit, a signal is sent to the display superimposing unit to warn about maintenance of the backlight or the Liquid Crystal Display of the display screen.

[Claim 5] The display device as described in Claim 1 or Claim 2, wherein the relationship between the ambient light illuminance stored in the storage unit and the output signal of the ambient light receiving unit

is stepwise, and the aforesaid step width is obtained by calculating the screen luminance L for the ambient light illuminance I according to (Formula 5), calculating the luminance difference discrimination threshold ΔL for the screen luminance L according to (Formula 4), and calculating the new ambient light illuminance I for the new screen luminance L which added the luminance difference discrimination threshold ΔL to the ambient light illuminance L according to (Formula 6), to determine the storage address of the storage unit.

$$\Delta L = 0.05936 L \{ (1.639 / L)^{0.4} + 1 \}^{2.5}$$

(Formula 5)

$$L = 181^{0.139}$$

(Formula 6)

$$I = (L / 18)^{7.2}$$

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Fields of Industrial Application] This invention relates to a display device that has a function to automatically control the brightness of the display screen according to changes in the brightness of the surrounding area of the display device, thereby making it easier for the user of the display device to see displayed characters and graphics in various illumination environments.

[0002]

[Conventional Technology] In recent years, display devices, which have been applied to personal computers, word processors, and engineering workstation terminals, have come to be used not only in offices but also in residences, etc.

[0003] These display devices include Cathode Ray Tubes (CRTs), Liquid Crystal Displays (LCDs), Plasma Display Panels (PDPs), Electroluminescent (ELs), and other light-emitting and non-light-emitting devices, and these devices are arranged in a flat array as multiple pixels to present a display screen.

[0004] In these display devices, the user of the display device can set the brightness of the display screen as desired by operating an adjustment switch that switches the brightness of the display screen in steps, or an adjustment knob that continuously changes the brightness of the display screen so that the displayed characters and graphics are always easy to see in response to various changes in the illumination environment.

[0005] However, such a method requires the user to continuously set the brightness of the display screen each time in response to changes in the surrounding illumination environment, and there is the problem that the user often forgets to do so or it takes time to set the brightness.

[0006] As a solution to these problems, a method has been proposed to detect the brightness (illuminance) of the front side of the display screen presented on the display device at the light-receiving unit and automatically adjust the brightness of the display screen according to the detected brightness (for example, JP-A-4[1992]-20924, JP-A-4[1992]-75321, etc.).

[0007] Figure 9 is a diagram showing the principle of the conventional method. In Figure 9, 1 is the display screen of an Liquid Crystal Display device (Liquid Crystal Display is used) used as an example of a display device, 2 is a light-receiving amount detection unit arranged on the side that transmits through the display

screen 1 (back side), 3 is a backlight unit placed on the side that transmits through the display screen 1, and 4 is a backlight power supply unit that adjusts the voltage applied to the backlight unit 3, and 5 is a processor that controls the backlight power supply unit 4 by signals from the light-receiving amount detection unit 2. [0008] In such a configuration, the operation is as follows. First, the light-receiving amount detection unit 2 receives the transmitted light from the front side of the display screen 1, and then the processor 5 controls the backlight power supply unit 4 to adjust the voltage applied to the backlight unit 3 based on the light-receiving amount detection signal S issued therefrom. In response to this control operation, the brightness of the backlight unit 3 automatically changes according to the brightness of the front side of the display screen 1.

[0009] Conventionally, these automatic control features are designed to extend the life of the display device's backlight unit 3. For example, in the aforesaid Liquid Crystal Display device, if the front side or surroundings are bright enough, the brightness of the backlight unit 3 is controlled to be suppressed, thereby extending the lifetime of the backlight unit 3.

[0010]

[Problems to be Solved by the Invention] However, in the above conventional display device, the brightness of the backlight unit is controlled to be suppressed when the brightness around the display device becomes brighter, and conversely, the brightness of the backlight unit 3 is controlled to be increased when it becomes darker, which is not necessarily in accordance with the characteristics of the human eye.

[0011] Although this prolongs the lifetime of the backlight unit 3 and saves power, it causes the display device user to have difficulty seeing characters and graphics because the brightness of the display screen is too low, or conversely, the brightness of the display screen 1 is too high, causing glare and other problems that reduce work efficiency, cause eye strain, and promote mental fatigue.

[0012] In addition, the luminous intensity of the backlight unit 3 and other light-emitting parts in Liquid Crystal Display devices generally decreases with the passage of time. Therefore, there was a problem that even if the screen luminance is set high in advance and sufficient legibility is obtained in the initial state, the screen becomes difficult to see over time.

[0013] This invention is to provide a display device that can ensure legibility in consideration of changes in the characteristics of the human eye and can present characters and graphs that are easy for the user to see by evaluating the legibility of the display screen in response to changes in the illumination environment by using visibility and controlling the luminance of the display screen.

[0014]

[Means for Solving the Problems] In order to achieve the above-mentioned purpose, the display device of this invention is equipped with an ambient light receiving unit that is placed near the display screen and facing the observer, a screen luminance calculation unit that calculates the range of light-adjusting screen luminance L relative to the ambient light illuminance I shown in Formula (1) based on the output signal from the ambient light receiving unit, a luminance level setting unit that sets the screen luminance desired by the user, a storage unit that is composed of a rewritable storage medium, a luminance determination unit that determines the screen luminance value based on the output signals from the screen luminance calculation unit, the luminance level setting unit, and the storage unit, and a screen luminance control unit that controls the luminance of the display screen based on the output signal from the luminance

determination unit, wherein the storage contents of the aforesaid storage unit are rewritten based on the signal from the ambient light receiving unit and the signal from the luminance level setting unit.

[0015]

$$18 I^{0.139} \leq L \leq 53 I^{0.113} \quad \dots (1)$$

Furthermore, the display device of this invention is a device wherein the screen luminance value L is rewritten for the entire band of ambient light illuminance I in the storage unit from the relationship between the ambient light illuminance I' obtained by the signal from the ambient light receiving unit, the screen luminance L' set by the luminance level setting unit, and Formula (2) and Formula (3).

[0016]

$$\begin{aligned} \log L' &= (0.139 - 0.026a) \log I' \quad \dots (2) \\ &= \log (18 + 35a) \end{aligned}$$

In the above formula, a is a coefficient.

[0017]

$$L = (18 + 35a) I^{0.139 - 0.026a} \quad \dots (3)$$

Furthermore, the display device of this invention is a device wherein, if the signal from the luminance level setting unit is within the range of values indicated by the screen luminance calculation unit, the storage contents in the storage unit are rewritten corresponding to the signal from the ambient light receiving unit in the luminance determination unit, and if the signal is not within the aforesaid range, a signal suggesting a review of the optical environment is outputted before rewriting the storage contents, and the user is notified by display or other means.

[0018] Furthermore, the display device of this invention is a device wherein the display screen is a Liquid Crystal Display, and this device is provided with a backlight usage time integrating unit and a Liquid Crystal Display usage time integrating unit; if the signal from the luminance level setting unit exceeds the upper limit of the value range indicated by the screen luminance calculation unit and the output signal from either of the aforesaid time integrating units exceeds the preset time as the lifetime of the backlight, before rewriting the storage contents in the storage unit, a signal is sent to warn about maintenance of the backlight or the Liquid Crystal Display.

[0019] Furthermore, the display device of this invention is a device wherein the relationship between the ambient light illuminance stored in the storage unit and the output signal of the ambient light receiving unit is stepwise, and the aforesaid step width is obtained by calculating the screen luminance L for the ambient light illuminance I according to Formula (5), calculating the luminance difference discrimination threshold ΔL for the screen luminance L according to Formula (4), and calculating the new ambient light illuminance I for the new screen luminance L, which added the luminance difference discrimination threshold ΔL to the ambient light illuminance L according to Formula (6), to determine the storage address of the storage unit.

[0020]

$$\Delta L = 0.05936 L \{ (1.639/L)^{0.4} + 1 \}^{2.5} \quad \dots (4)$$

$$L = 18 I^{0.139} \quad \dots (5)$$

$$I = (L/18)^{7.2} \quad \dots (6)$$

[0021]

[Operation] In the above configuration, based on the illumination value near the display screen detected by the ambient light receiving unit, the screen luminance calculation unit calculates the light-adjusting screen luminance band to ensure and maintain a certain legibility of displayed characters and graphs, the luminance determination unit compares and determines the light-adjusting screen luminance band calculated by the said screen luminance calculation unit and the user's preferred screen luminance using the luminance level set in the luminance level setting unit and the past settings stored in the storage unit, and the screen luminance control unit adjusts the light. In this way, it is possible to ensure a certain legibility that takes into account the characteristics of the human eye under various illumination environments, and always provide good legibility for the environment in which it is used.

[0022] Furthermore, after taking into account the ambient light illuminance I' obtained by the signal from the ambient light receiving unit and the screen luminance L' set by the luminance level setting unit, by rewriting the screen luminance value L for the entire band of ambient light illuminance I in the storage unit, the screen luminance can be adjusted so that the screen luminance does not change drastically in response to slight changes in the ambient light illuminance. Furthermore, if the signal from the luminance level setting unit is not within the range of values indicated by the screen luminance calculation unit, a signal is outputted to suggest a review of the optical environment before rewriting the storage contents, to inform the user not to unnecessarily increase the screen luminance.

[0023] Furthermore, in a backlight-type Liquid Crystal Display device, it is possible to clearly indicate to the user when the light source used for the backlight and the Liquid Crystal Display should be replaced, and it is also possible to simplify the screen luminance calculation unit by creating a stepwise relationship between the ambient light illuminance stored in the storage unit and the output signal of the ambient light receiving unit, which can simplify the design of the screen luminance calculation unit and ensure that the screen luminance does not change drastically in response to slight changes in the ambient light illuminance.

[0024]

[Embodiments] The following is a description of one embodiment of this invention with reference to the figures. Figure 1 is a block diagram showing a schematic of the display device, which is the first embodiment of this invention. In Figure 1, 6 is a display screen consisting of a transmissive Liquid Crystal Display element; 7 is a backlight arranged behind the display screen 6 and illuminating the display screen 6, and 8 is an ambient light receiving unit that is arranged near the display screen 6 toward the person using the display device and that receives ambient light (illumination light, natural light, etc.) irradiated on the display screen 6, and consists of a silicon photodiode with a photosensitivity correction applied to the photosensitive surface and an amplifier to receive light illuminance. The specific position of the ambient light receiving unit 8 depends on the external shape of the main body of the display device, but it is desirable to place it where the illuminance value corresponding to the user's eye adaptation state can be obtained.

[0025] In addition, the time constant of ambient light receiving unit 8 is set between 10 and 1000 seconds. This corresponds to a characteristic of adaptation by the human eye of about 130 seconds (e.g., Rushton (1958), Ann. N.Y. Acad. Sci., Vol. 74, p 291-304). If the time constant is longer than this range, the effect of this invention cannot be expected to be sufficient. If the time constant is shorter than this range, it will be sensitive to subtle changes in the ambient light, resulting in flickering on the display screen.

[0026] 9 is a screen luminance calculation unit that inputs the luminance signal from ambient light receiving unit 8 and calculates the screen luminance range of display screen 6 based on the previously set function; 10 is a luminance level setting unit that allows the user to input the user's preferred luminance level with a knob or button and outputs a signal of the same luminance level unless it is inputted again; this luminance level setting unit 10 is preferable to have three or more levels, an average level, a higher level, and a lower level, to take the user's preferences into account.

[0027] 11 is a luminance determination unit that determines the optimum value based on the screen luminance band from the screen luminance calculation unit 9 and the luminance level signal from the luminance level setting unit 10; 12 is a screen luminance control unit that outputs signals to control the brightness (luminance) of display screen 6 and backlight 7 based on the determination results of luminance determination unit 11; 13 is a backlight power supply unit that supplies power to the backlight 7 and controls the luminance of the backlight 7 by receiving signals from the screen luminance control unit 12; 14 is a Liquid Crystal Display drive unit that drives the Liquid Crystal Display elements used in display screen 6 and adjusts the transmittance of the Liquid Crystal Display elements; and 15 is a storage unit. The storage unit 15 outputs the stored contents at the address corresponding to the signal from the ambient light receiving unit 8 to the luminance determination unit 11, and the storage contents at the address corresponding to the signal from ambient light receiving unit 8 are rewritten based on the determination result of the luminance determination unit 11.

[0028] The operation of the display device configured in a manner as described above is described below. Figure 2 shows the relationship between screen illuminance and screen luminance for ensuring legibility, which is the basic concept of the function incorporated in the screen luminance calculation unit 9, and it is obtained through experiments and theoretical support. In the experiment, nine observers between the ages of 24 and 43 were asked to subjectively evaluate the visibility and glare of the screen under various screen illuminance conditions, and then to determine whether the observers found the screen to be optimal for easy reading of the text. This was done in order to obtain the screen luminance required to make the displayed text sufficiently easy to read using the adjustment method in addition to the subjective evaluation method. The experimental conditions were set to 5 conditions including 10, 30, 100, 300, and 1000 lx (lux) for screen luminance, under such conditions, it is slightly difficult to see in a dark environment, sufficiently easy to see in a bright environment, and possible to perceive glare in a relatively dark environment, so the screen luminance used was 10, 20, 40, 80, and 160 cd/m² (candela per square meter). Subjective evaluation items were 6 items, and each item was evaluated on a 7-level scale, and an adjustment method was used for each screen illuminance, which is the same as the subjective evaluation.

[0029] Figure 2 shows the results of the experiment. In Figure 2, curve A is the average result of the screen luminance obtained by the adjustment method for nine observers. Assuming that the reading easiness is maximized at the screen luminance obtained by the adjustment method, the hatched range surrounded by curve B, which indicates the upper limit of screen luminance, and curve C, which indicates the lower limit of screen luminance, is a relationship between screen illuminance and screen luminance obtained from two conditions: a condition that results in a range of $\pm 50\%$ of that screen luminance, and a condition of screen luminance that results in a reading easiness of $3/4$ or more of the maximum. The screen luminance at 10 lx is 40 ± 20 cd/m², the screen luminance at 100 lx is 60 ± 25 cd/m², and the screen luminance at 1000 lx is

115 ± 40 cd/m². If the luminance in the hatched range formed by curve B and curve C is achieved, the obtained legibility is almost satisfactory.

[0030] This means that when automatically adjusting the light for screen luminance, consideration must always be given to the sensitivity of the human eye, and visibility VI is currently used to quantitatively evaluate this legibility. Visibility VI is a quantitative expression of the legibility (visibility) of the object being viewed. Visibility VI is quantified by the ratio of the luminance contrast C of the object being viewed to its background compared to the minimum luminance contrast that the human eye can distinguish in the viewing environment (called the luminance contrast discrimination band Cmin). In other words, visibility VI is defined as the ratio (C/Cmin) of the contrast C between the object and its background to the contrast limit Cmin possible for discrimination. In this case, the contrast C is as shown in formula (7), where Lo is the object luminance, Lb is the background luminance, and Leq is the equivalent light curtain luminance value that takes into account the scattered light in the eye from lights other than the object.

[0031]

$$C = |L_b - L_o| / (L_{eq} + L_b) \quad \dots (7)$$

Regarding the relationship between Cmin and Lb, the International Commission on Illumination has reported standard human eye characteristics as shown in formula (8) below.

[0032]

$$C_{min} = 0.05936 \{ (1.639 / L_b)^{0.4} + 1 \}^{2.5} \quad \dots (8)$$

Therefore, visibility VI is as shown in formula (9).

$$VI = 16.846 \{ (1.639 / L_b)^{0.4} + 1 \}^{-2.5} \times C \quad \dots (9)$$

Formulas (7), (8), and (9) can be found in IES, Lighting Handbook, 1984, Reference Edition, Chapter 3 (IES, LIGHTING, HANDBOOK, 1984, REFERENCE, VOLUME). When visibility VI is calculated based on these formulas, visibility VI is almost constant (7 to 10) for each screen illuminance. Therefore, by adjusting the light within the hatched range between curve B and curve C obtained experimentally in Figure 2, a certain legibility can be ensured, and by adjusting the light within this range, differences in light adjustment levels due to individual preferences can also be taken into account.

[0033] Furthermore, the screen luminance L of the hatched range can be expressed from the illuminance I by the formula (1) shown earlier.

$$18 I^{0.139} \leq L \leq 53 I^{0.113} \quad \dots (1)$$

The screen luminance calculation unit 9 finally calculates the function of formula (1) based on the signal from the ambient light receiving unit 8, or stores it in advance, and outputs the light-adjusting range to the luminance determination unit 11. In addition, the storage unit 15 initially stores an arbitrary value (e.g., lower limit) of the range determined based on the formula (1) in the address for the signal from the ambient light receiving unit 8.

[0034] The operation of the luminance determination unit 11 is described based on Figure 3. First, the signal Lm from the storage unit 15 is inputted. Then, the signal from the luminance level setting unit 10 is inputted. If there is no signal from the luminance level setting unit 10, i.e., "No" in Figure 3, the signal Lm from the storage unit 15 is outputted to the screen luminance control unit 12 as is. In this case, the storage unit 15 is not rewritten. When there is a signal from the luminance level setting unit 10, i.e., "Yes" in Figure 3, the signal corresponding to the screen luminance band from the screen luminance calculation unit 9 is inputted.

The luminance value L_d corresponding to the signal from the luminance level setting unit 10 is determined from the said screen luminance band. Then, the said value L_d is outputted to the storage unit 15 and the screen luminance control unit 12. In this case, the storage unit 15 replaces only the stored contents of the address corresponding to the signal from the ambient light receiving unit 8 with L_d . The above operations provide good legibility in the environment of use.

[0035] Next, the operation of the second embodiment of this invention is described. The configuration of the display device is the same as the first embodiment. The difference is that the contents of the storage unit 15 are all rewritten in Figure 3. This difference in operation is described using Figure 4. In Figure 4, curve B is the upper limit of screen luminance and curve C is the lower limit of screen luminance. Suppose that curve C is entered as the default setting for the display device in the first embodiment, and that the value of γ is set at a screen illuminance of 50 lx. Here, suppose that the user sets the value γ' under the optical environment with a screen illuminance of 50 lx. In this case, the contents of the storage unit 15 will be dominated by curve C, and only the value for a screen illuminance at 50 lx will have a value different from the value on curve C. In a display device adjusted in this way, there is a problem that a slight deviation from the screen illuminance of 50 lx causes a sudden change in the screen luminance. There is also a problem that the user is required to operate the luminance level setting unit 10 each time the screen illuminance changes to a different light environment, which is inconvenient. In the second embodiment, the visibility constant curve C' passing through γ' in Figure 4 is obtained by interpolating curve B and curve C using formula (2) and formula (3) shown above.

[0036]

$$\log L' = (0.139 - 0.026a) \log I' \\ = \log (18 + 35a) \quad \dots (2)$$

$$L = (18 + 35a) I^{0.32 - 0.06a} \quad \dots (3)$$

In the above formula, L' is the screen luminance value set by the luminance level setting unit 10, I' is the screen illuminance value measured by the ambient light receiving unit 8 at that time, and a is the coefficient for interpolation. The coefficient a is determined based on formula (2), and the curve C' is obtained by determining the screen luminance value L in the entire band of ambient light illuminance I at the storage unit 15 based on formula (3).

[0037] Figure 5 shows the method to obtain the coefficient a from formula (2). In Figure 5,

$$f(a) = \log L' - (0.139 - 0.026a) \log I' \quad \dots (10)$$

$$g(a) = \log (18 + 35a) \quad \dots (11)$$

Find the intersection of these curves, i.e., the point where $f(a) = g(a)$, and the value of a at that point is the solution of formula (2). f_1 is $f(a)$ when screen luminance L' is 50 cd/m² and screen luminance I' is 100 lx, and in this case, $a = 0.26$. Also, f_2 is $f(a)$ when screen luminance L' is 50 cd/m² and screen illuminance I' is 300 lx, and in this case, $a = 0.14$. As it is clearly shown from the figure, curve g is independent of screen illuminance and screen luminance. The use of this property simplifies the solution, and thus simplifies the circuit when, for example, the luminance determination unit 11 is composed of an electric circuit.

[0038] Next, the third embodiment of this invention is described. Figure 6 shows a block diagram of the display device of the third embodiment. 16 is a display superimposing unit that superimposes a message on a part of the display screen of the Liquid Crystal Display to indicate whether the optical environment is

appropriate or not, based on the results from the luminance determination unit 11. The operation of luminance determination unit 11 takes advantage of the fact that the function $g(a)$ in Figure 5 is a monotonically increasing function. That is, $f(1) > g(1)$ indicates that the ambient light illuminance is too high to obtain appropriate screen luminance (e.g., when a light fixture (not shown in the figure) is reflected on the display screen 6). In this case, the display superimposing unit 16 outputs a message "Check to confirm that there is no reflection of a lighting fixture" and the Liquid Crystal Display drive unit 14 displays this message on a part of the display screen 6. Moreover, either this message may be displayed as text at the edge of the display screen 6, or the message may be displayed as a character, icon, image, or the like. Although it is not shown in the figure, the message may also be conveyed to the user by a light sound, or by any other means.

[0039] Next, the fourth embodiment of this invention is described. Figure 7 is a block diagram showing the schematic configuration of the display device of the fourth embodiment. 17 is a backlight usage time integrating unit that integrates the backlight usage time in the Liquid Crystal Display device and outputs a signal to the display superimposing unit 16 only when the lifetime of the backlight exceeds the preset lifetime of the backlight. 18 is a Liquid Crystal Display usage time integrating unit that integrates the usage time of the Liquid Crystal Display and outputs a signal to the display superimposing unit 16 only when the lifetime of the Liquid Crystal Display exceeds the preset lifetime.

[0040] Regarding the lifetime that is preset in the backlight usage time integrating unit 17, if the light source for the backlight is a combination of a fluorescent lamp and a reflector, the lifetime of the backlight is the life of the fluorescent lamp. This life varies depending on the lamp specifications and operating environment, but ranges from 5,000 to 10,000 hours for cold cathode fluorescent lamps and from 2,000 to 5,000 hours for hot cathode fluorescent lamps. This is defined as the time when the luminous flux drops to 50% of the initial luminous flux. For this reason, if the luminous flux can be sufficiently low, the lamps can be used for a longer period of time than the above lifetime values. Therefore, it is not practical to determine whether or not the life has substantially come to its end by simply assuming that the integrated usage time has exceeded the lifetime value, but should be determined from the perspective of whether or not adequate screen luminance can be obtained in the light environment in which it is being used. The backlight usage time integrating unit 17 sets the backlight lifetime value defined above in advance, integrates the usage time, and outputs a signal to the display superimposing unit 16 only when the integrated time exceeds the aforesaid set value.

[0041] Regarding the lifetime that is pre-set in the LCD usage time integrating unit 18, the lifetime of the Liquid Crystal Display device is determined by the Liquid Crystal Display element itself. This lifetime varies depending on the type of Liquid Crystal Display device and the environment in which it is used but is approximately 5,000 to 10,000 hours. This is the lifetime that the shutter mechanism of the Liquid Crystal Display element works. The Liquid Crystal Display usage time integrating unit 18 integrates the usage time independently from the backlight usage time integrating unit 17 and sends signals to the display superimposing unit 16 only when the integrated time exceeds the preset lifetime.

[0042] At the display superimposing unit 16, if the signal from luminance level setting unit 10 exceeds the upper limit of the range of values indicated by the screen luminance calculation unit 9, i.e., $f(1) > g(1)$, and if there is a signal from backlight usage time integrating unit 17 or Liquid Crystal Display usage time integrating unit 18, a message suggesting "replacement of backlight" or "replacement of Liquid Crystal

Display" will be displayed instead of the message in the third embodiment. In this way, it becomes clear to the user which of the light environment, backlight or Liquid Crystal Display, needs to be changed in order to obtain appropriate usage conditions.

[0043] Next, the fifth embodiment of this invention is described. It relates to the address of the storage unit 15 of the first embodiment and the second embodiment of this invention. The storage contents in the storage unit 15 may store the screen luminance value in a stepless manner for screen illuminance I. However, even if the screen luminance value is stored using nonvolatile memory, etc., if the number of addresses is kept finite and as small as possible, it may be possible to simplify the device. The fifth embodiment is to perform this address division in steps so that humans do not perceive any difference in screen luminance. From formula (7) and formula (8), the luminance difference discrimination threshold ΔL for the screen luminance L, as shown in formula (4) above is obtained.

[0044]

$$\Delta L = 0.05936 L \{ (1.639/L)^{0.4} + 1 \}^{2.5} \quad \dots (4)$$

In addition, from the left-hand side of formula (1), formula (5) shown earlier is obtained.

$$L = 18 I^{0.139} \quad \dots (5)$$

Formula (8) shows curve C in Figure 2. In addition, formula (6) is obtained as the inverse function of formula (5).

[0045]

$$I = (L/18)^{7.2} \quad \dots (6)$$

The division of addresses is described based on Figure 8. Figure 8 shows an example of address division based on the fifth embodiment. For the lower limit I_n of the nth screen illuminance step, the nth screen luminance L_n is calculated using the right-hand side of formula (5). For this screen luminance L_n , find the increment of the limit where the luminance difference is not perceived based on formula (4). If the increment ΔL_n of the step is smaller than the increment of the limit where the luminance difference is not perceived, screen luminance changes caused by slight changes in the optical environment can be made imperceptible to the user. In Figure 8, the increment is half of the luminance difference threshold calculated from formula (4). The (n+1)th screen luminance is obtained by $L_{n+1} = L_n + \Delta L_n$. The upper limit of the nth screen illuminance I_n is equal to the lower limit of the (n+1)th screen illuminance I_{n+1} , and therefore the (n+1)th screen illuminance I_{n+1} is obtained by the (n+1)th screen luminance L_{n+1} using formula (6). The above operation simplifies the screen luminance calculation unit and ensures that the screen luminance does not change drastically in response to slight changes in the ambient light illuminance.

[0046]

[Effect of the Invention] As described above, the display device of this invention can automatically control the screen luminance under various levels of brightness, and by taking into account changes in the sensitivity of the human eye, it can provide the user with a screen where characters and figures are easy to see. This can improve work efficiency, reduce eye strain, and alleviate mental fatigue.

[BRIEF DESCRIPTION OF THE FIGURES]

[Figure 1] It is a block diagram showing a schematic diagram of the display device of one embodiment of this invention.

[Figure 2] It is a diagram showing the relationship between the screen illuminance and the light-adjusting screen luminance, which is a basic concept of the display device of one embodiment of this invention.

[Figure 3] It is a flow chart showing the operation of the display device of one embodiment of this invention.

[Figure 4] It is a diagram showing the relationship between the screen illuminance and the light-adjusting screen luminance, which is a basic concept of the display device of one embodiment of this invention.

[Figure 5] It is a diagram showing the relationship between the functions that control the basic operation of the display device of one of the embodiments of this Invention.

[Figure 6] It is a block diagram showing a schematic of the configuration of the display device of another embodiment of this invention.

[Figure 7] It is a block diagram showing a schematic of the configuration of the display device of yet another embodiment of this invention.

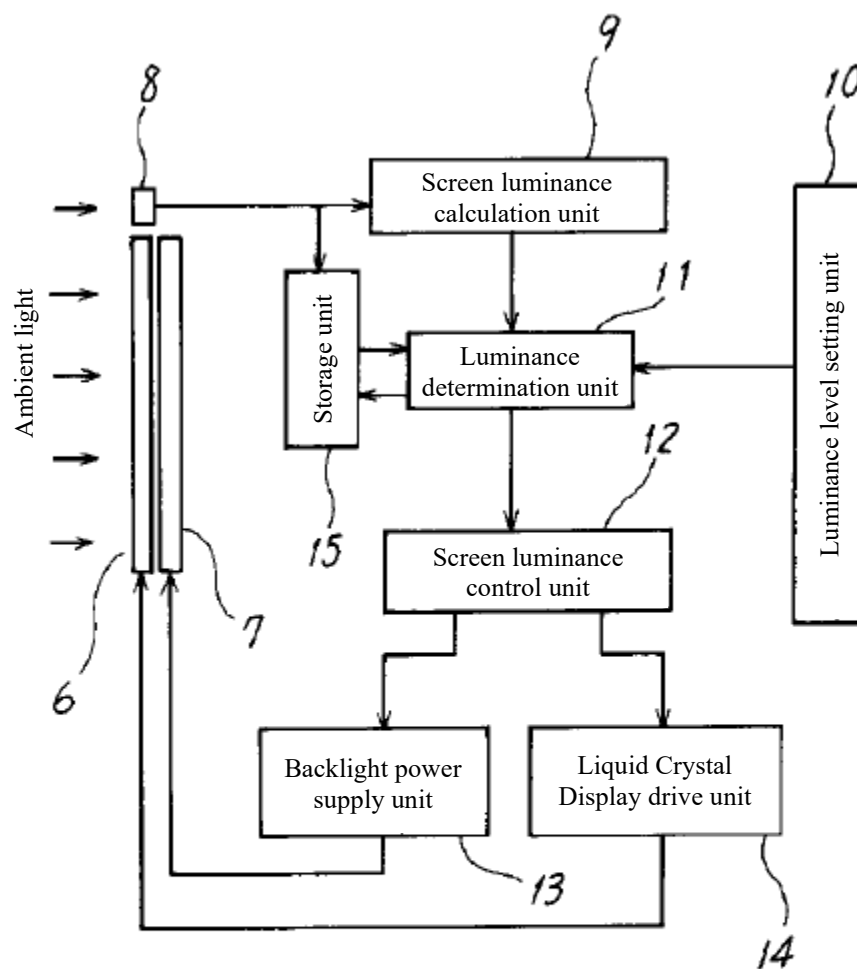
[Figure 8] It is a diagram showing the relationship between the screen illuminance and the light-adjusting screen luminance, which is a basic concept of the display device of yet another embodiment of this invention.

[Figure 9] It is a block diagram showing a schematic of the configuration of a conventional display device.

[Description of the Reference Numerals]

- 6 Display screen
- 7 Backlight
- 8 Ambient light receiving unit
- 9 Screen luminance calculation unit
- 10 Luminance level setting unit
- 11 Luminance determination unit
- 12 Screen luminance calculation unit
- 13 Backlight power supply unit
- 14 Liquid Crystal Display drive unit
- 15 Storage unit
- 16 Display superimposing unit
- 17 Backlight usage time integrating unit
- 18 Liquid Crystal Display usage time integrating unit

[FIGURE 1]

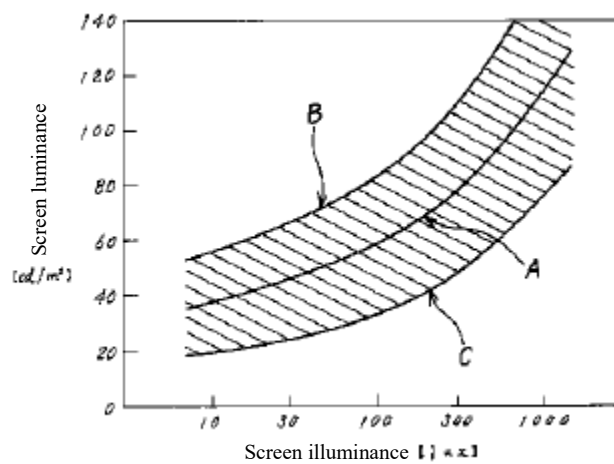


6 --- Display screen

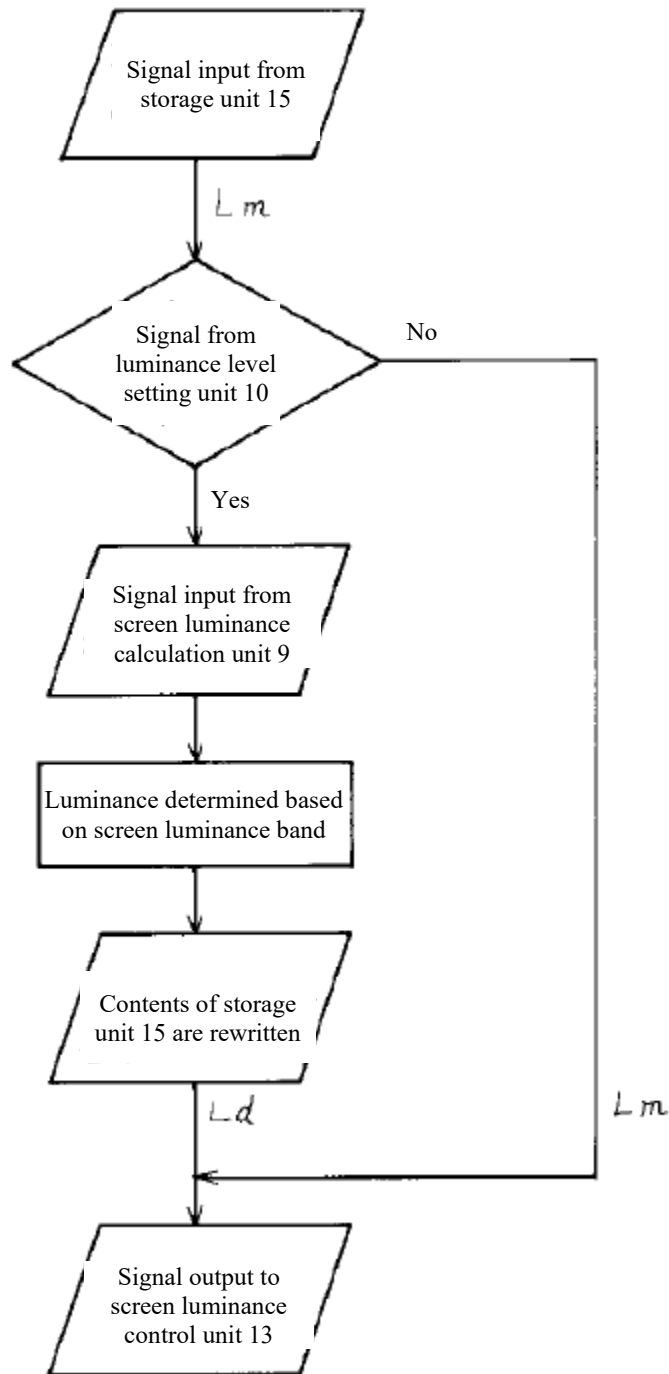
7 --- Backlight

8 --- Ambient light receiving unit

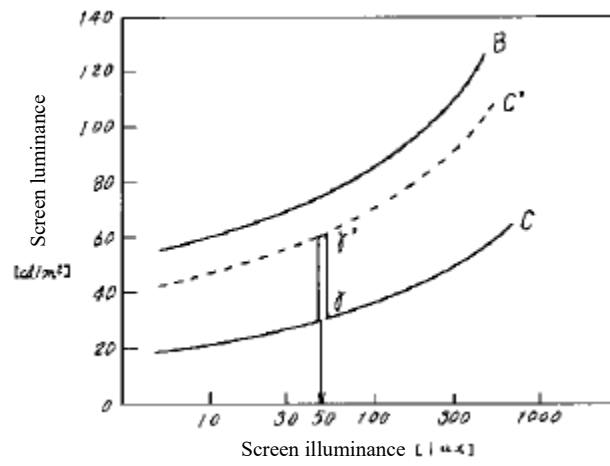
[FIGURE 2]



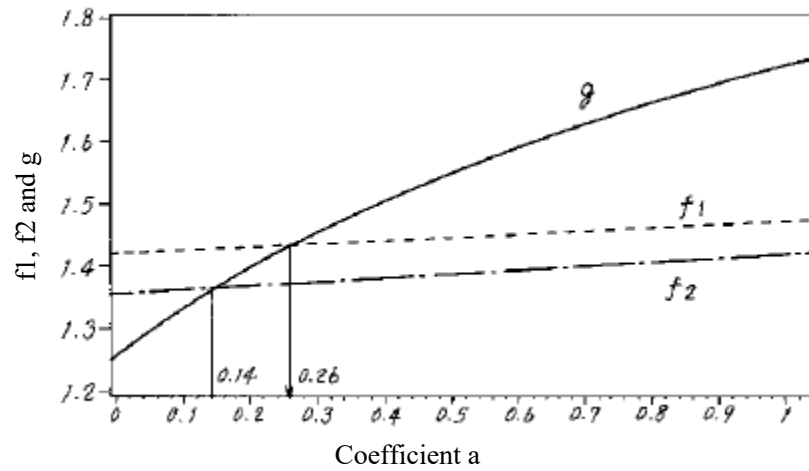
[FIGURE 3]



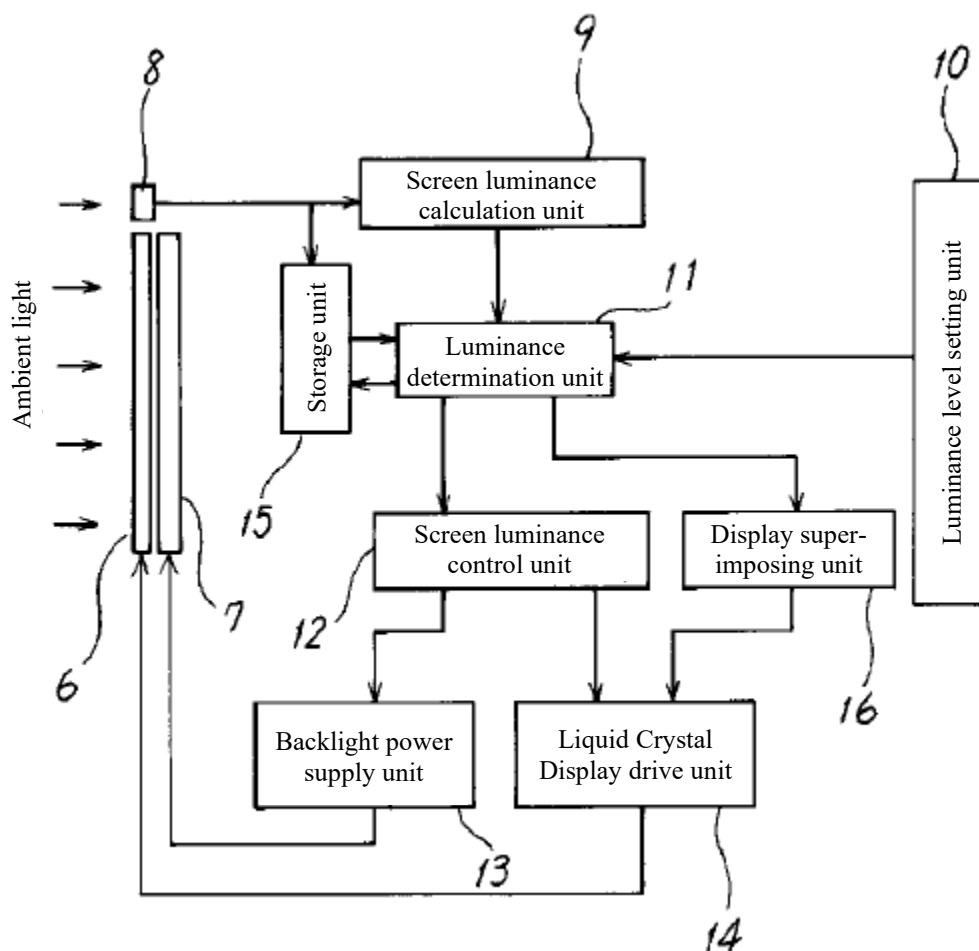
[FIGURE 4]



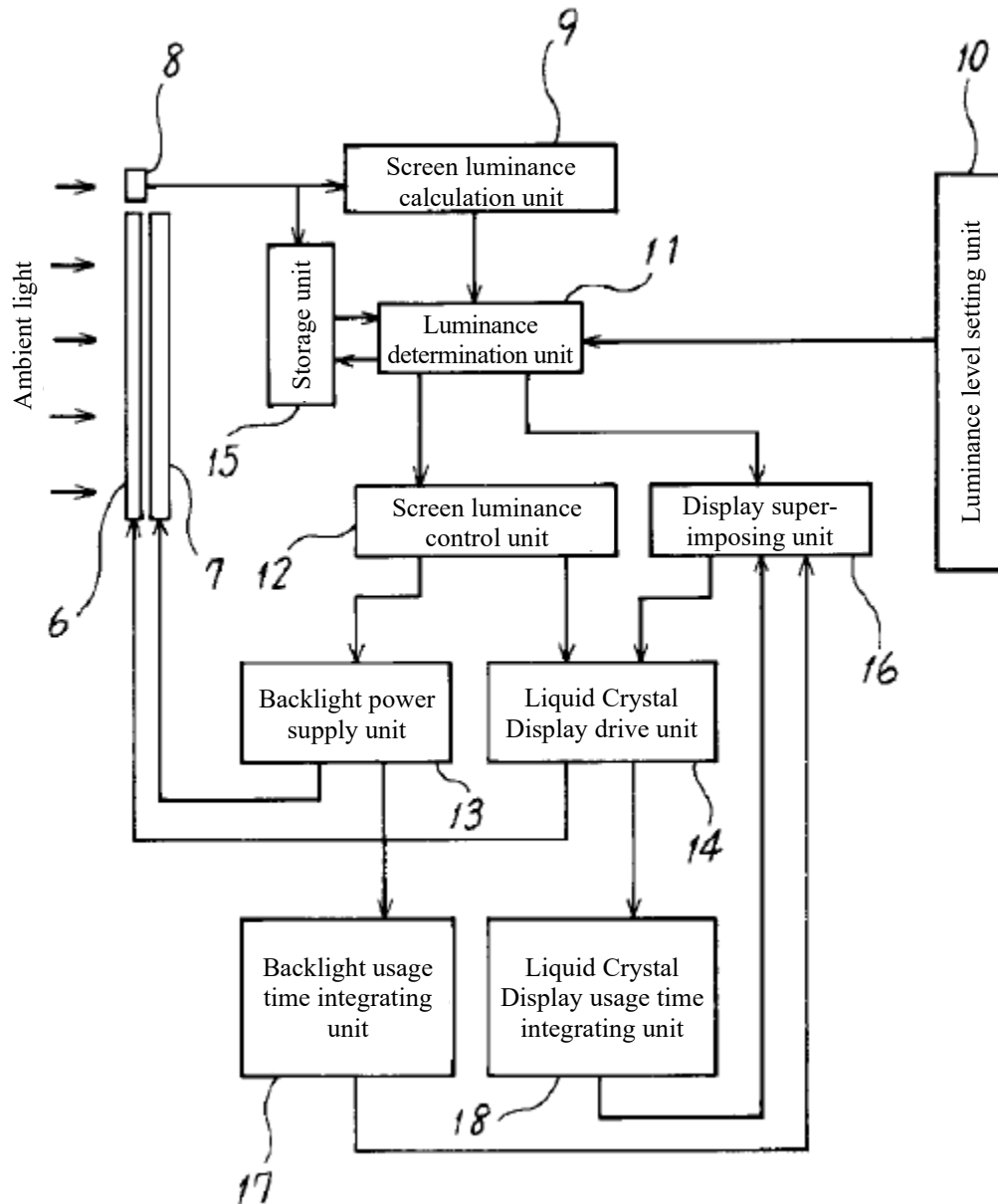
[FIGURE 5]



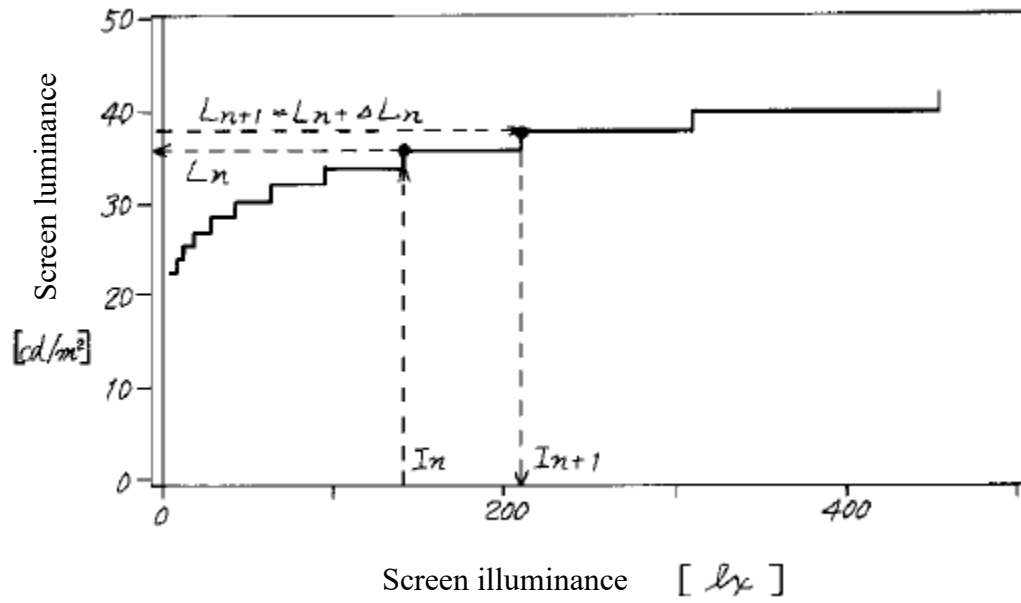
[FIGURE 6]



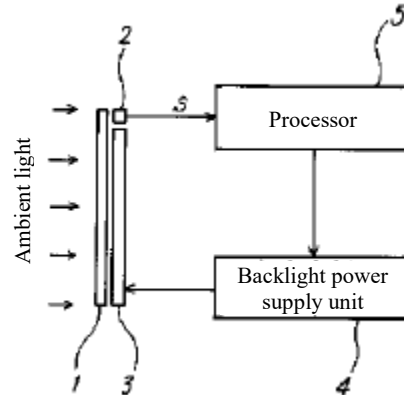
[FIGURE 7]



[FIGURE 8]



[FIGURE 9]





December 5, 2022

Re:JPH06308891A_Original_document_Shimomura

To Whom It May Concern:

This is to certify that the above-referenced documents (**390-45104_JPH06308891A_Original_document_Shimomura_JA into EN**) have been translated from Japanese into English by a professional translator on our staff who is skilled in the Japanese language.

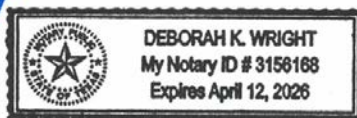
The English translation conforms essentially to the original Japanese except for those words or phrases for which there are no equivalents. Such words or phrases are noted in the translation along with the best English meaning.

All statements made in this declaration of our own knowledge are true, and all statements made on information and belief are believed to be true. We certify these statements under the understanding that willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. 1001). To the best of our knowledge, the aforementioned documents are a true, full, and accurate translation into English of the specified document.

Tonja Shepard
TONJA SHEPARD

Subscribed and sworn to before me on December 5, 2022.

Deborah K. Wright
Deborah K. Wright
Notary Public, State of Texas



My commission expires on April 12, 2026