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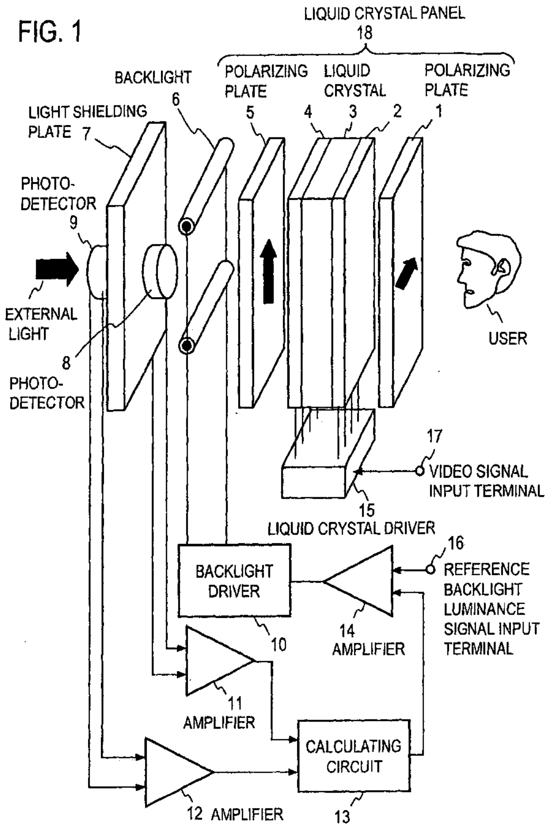
(54) **LIQUID CRYSTAL DISPLAY AND ITS CORRECTING METHOD**

(57) The quantity of light from a backlight is monitored by a first photodetector, and the environment on the part of a user is monitored by a second photodetector disposed in the rear of a liquid crystal panel, not on the front thereof. It is possible to exclude the influence of external light from the user side on the first photodetector which detects the quantity of light from the backlight.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a technique for implementing a liquid crystal display equipped with functions of controlling the quantity of light from a backlight with high precision and capturing information about user image in front of the liquid crystal display screen and about the illuminance on the display screen and a technique of calibrating the display with high-level gray scale.

BACKGROUND ART

[0002] In recent years, liquid crystal displays have come into wide use in home TVs, computers, picture-phones, and so forth. Such liquid crystal displays are mostly backlight displays. Since the reproducibility of image is needed especially in the fields of printing, medical care, etc., it is customary in the art to monitor the quantity of light from the backlight by a photodetector placed in the rear of the liquid crystal display and control the backlight accordingly. Since the light transmission characteristic of the liquid crystal panel greatly varies nonlinearly with working temperature and due to age deterioration, there is a limit to enhancement of the gray scale from the practical point of view. Further, there have also been developed liquid crystal displays provided with means for monitoring a user image and illuminance in the use environment, but in many cases an image sensor or photodetector is disposed behind or beside the display screen, or a manual sensor is mounted on the display screen for manual calibration.

[0003] However, in the case of monitoring the quantity of light from the backlight by the photodetector mounted in the liquid crystal display as in the prior art, there arises a problem that no appropriate monitoring of the quantity of light is possible since the amount of light reflected rearwardly of the liquid crystal panel differs depending on whether the liquid crystal is transparent to light or not. Furthermore, depending on whether ambient brightness is high or low, the incidence of external light from the front of the liquid crystal panel disturbs monitoring by the photodetector, sometimes hindering appropriate luminance control of the backlight. It is also necessary to monitor the illuminance in the use environment. The photodetector or image sensor mounted on the front of the liquid crystal display for monitoring the illuminance and the user image in the use environment ruins the appearance of the display. Besides, since the optical transfer characteristic of the liquid crystal panel changes with aging or temperature, reproducibility of the gray scale of image may sometimes lower even if the quantity of light from the backlight is controlled to be constant; hence, it is to be wished that a high-precision calibration scheme be established.

DISCLOSURE OF THE INVENTION

[0004] The liquid crystal display of the present invention is provided with a photodetector for monitoring the quantity of light from a backlight and a photodetector for monitoring the use environment. The present invention adopts mainly two means, one of which is the photodetector disposed behind the liquid crystal panel, not on the front thereof, for detecting the quantity of light from the backlight, and the other of which is the photodetector for monitoring the use environment.

[0005] The one of the two means is a photodetector with a polarizing plate mounted thereon in the liquid crystal display device, by which the quantity of light from the backlight can be monitored irrespective of whether the liquid crystal is transparent or nontransparent to light. Since the polarizing plate is interposed between the backlight and the liquid crystal, reflected light from the liquid crystal has a characteristic that its polarization greatly changes under the influence of the polarizing plate, depending on whether the liquid crystal is transparent to light or not. Accordingly, provision is made to monitor polarization components based on signal intensities detected by a photodetector with a polarizing plate having the same polarization characteristic as that of the above-mentioned polarizing plate and a photodetector having mounted thereon a polarizing plate whose direction of polarization is orthogonal to that of the above-mentioned polarizing plate.

[0006] The other means is an arrangement in which a photodetector or image sensor is disposed behind the liquid crystal panel, as viewed from the user side, for monitoring the user image or illuminance in the use environment through the liquid crystal panel by making it transparent to light. Further, in the liquid crystal display equipped with the backlight, since reflected light having a fixed polarized light component enters the photodetector or image sensor even when the liquid crystal is light-transparent, the influence of backlight can be lessened by the above-mentioned polarizing plate mounted on the photodetector or image sensor. Of course, it is also possible to control the intensity of backlight by the combined use of photodetectors or image sensors having mounted thereon polarizing plates whose directions of polarization are orthogonal to each other.

[0007] With above-mentioned means, it is possible, in a liquid crystal panel with a fixed quantity of backlight, to obtain an appropriate image in accordance with the working conditions of the liquid crystal panel (working temperature and aging characteristic). By applying a specific video signal (for example, a staircase image signal whose stairsteps are increased or decreased) with a manual photodetector held in close contact with the display screen and detecting the signal output from the photodetector, it is possible to obtain an optical transfer characteristic of the liquid crystal panel. By preparing a function for converting the video signal or conversion table on the basis of the optical transfer characteristic of the panel, the image intended to display can be reproduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Fig. 1 is a block diagram of a liquid crystal display having built-in photodetectors according to a first embodiment of the present invention.
Fig. 2 is a block diagram of a liquid crystal display having built-in photodetectors according to a second embodiment of the present invention.
Fig. 3 is explanatory of the principles of the detection of quantity of light from a backlight and the detection of external light when different polarizing plates are used, A being the case where the backlight is OFF and B the case where the backlight is ON.
Fig. 4 is a block diagram of a liquid crystal display having a built-in photodetector according to a third embodiment of the present invention.
Fig. 5 is explanatory of the principle of capturing the image of a user by the image sensor in a fifth embodiment of the present invention.
Fig. 6 is a block diagram of a liquid crystal display having a built-in photodetector according to a fourth embodiment of the present invention.
Fig. 7 is explanatory of the principles of capturing the image of a user by the image sensor when the backlight is ON in the fourth embodiment of the present invention, A being the case of using a horizontally polarizing plate and B the case of using a vertically polarizing plate.
Fig. 8 is a block diagram of a conventional liquid crystal display having a built-in photodetector.
Fig. 9A is a block diagram for explaining a gray scale calibration method for a liquid crystal display by a photodetector disposed on its display screen, B is a diagram showing an input image signal, C is a diagram showing the light transmission characteristic of liquid crystal with respect to a staircase calibration signal, and D is a diagram showing, by way of example, the progression of repeated gray scale calibration.
Fig. 10A is a block diagram for explaining a gray scale calibration method for a liquid crystal display by a light emitting diode disposed on its display screen, B is a diagram showing an input image signal, and C is a diagram showing the light transmission characteristic of liquid crystal with respect to a staircase calibration signal.

BEST MODE FOR CARRYING OUY THE INVENTION

[0009] A detailed description will hereinafter be given, with reference to the accompanying drawings, of embodiments of the present invention.

(Embodiment 1)

[0010] Fig. 1 is a block diagram of a liquid crystal display having built-in photodetectors according to a first embodiment of the present invention. Backlights 6 and a light shielding plate 7 are disposed behind a liquid crystal panel 18 wherein a liquid crystal layer 3 oriented and sandwiched between a transparent electrode plate 4 and a counter electrode plate 2 containing a TFT driver circuit is interposed between polarizing plates 1 and 5, and photodetectors 9 and 8 are placed on the outside and inside of the light shielding plate 7, respectively. Image information input via a video signal input terminal 17 is sent, as a drive signal corresponding to the voltage necessary for liquid crystal driving and the scanning scheme used, from a liquid crystal driver 15 to the transparent electrode plate 4 and the counter electrode plate 2 containing a TFT driver circuit. The liquid crystal used in this embodiment is one that has a property of rotating the plane of polarization of incident light through 90 degrees. The photodetectors are silicon PNP junction diodes.

[0011] A description will be made below of the principle of controlling the backlight in the above configuration. The photodetector 8 changes its output current with the quantity of light from the backlight. External light in the user environment is also incident on the photodetector 8 through the liquid crystal panel. The quantity of light in the user environment can be monitored indirectly by the photodetector 9 placed on the outside of the light shielding plate. Accordingly, output signals from amplifiers (which are current-voltage type transimpedance amplifiers), which are supplied with signals from the photodetectors, are applied to a calculating circuit 13, in which the component of the quantity-of-light signal of the user environment is multiplied by a coefficient and then subtracted from the quantity-of-light signal of the backlight, and from which the calculated output is input to an amplifier 14. The amplifier 14 detects the difference between the input thereto and the luminance of the backlight set by a reference backlight luminance signal fed to an input terminal 16 and applies a signal to a backlight driver 10 to adjust the power supply to the backlight to provide a desired quantity of light. While the signals in the above are described as being handled in analog form, it is needless to say that it is also possible to employ a configuration in which the output signals from the amplifiers 11 and 12 are AD converted so that the entire signal processing including the calculating circuit is performed in digital form.

(Embodiment 2)

[0012] Fig. 2 is a block diagram of a liquid crystal display having built-in photodetectors according to a second embodiment. Backlights 26 and a light shielding plate 27 are disposed behind a liquid crystal panel 220 wherein a liquid crystal layer 23 oriented and sandwiched between a transparent electrode plate 24 and a counter electrode plate 2 containing a TFT driver circuit is interposed between a polarizing plate 21 (of a horizontally polarizing characteristic) and a polarizing plate 25 (of a vertically polarizing characteristic), and photodetectors 28 and 29 are placed on the inside of the light shielding plate 218 in opposing relation to a polarizing plate 219 (of a vertically polarizing characteristic), respectively. Image information input via a video signal input terminal 217 is sent, as a drive signal corresponding to the voltage necessary for liquid crystal driving and the scanning scheme used, from a liquid crystal driver 215 to the transparent electrode plate 24 and the counter electrode plate 22 containing a TFT driver circuit. The liquid crystal used in this embodiment is a liquid (for instance, TN liquid crystal) that has a property of rotating the direction of polarization of incident light through 90 degrees. The photodetectors are silicon PN junction diodes.

[0013] A description will be made below of the procedure for controlling the backlight in the above configuration. The photodetectors 28 and 29 change their output currents with the quantity of light from the backlight. External light in the user environment is incident on the photodetector 29 through the liquid crystal panel since the polarizing plate 219 that has the same direction of polarization as that of the polarizing plate 25, but the external light is not incident on the photodetector 28 since the polarizing plate 218 disposed opposite thereto has the direction of polarization orthogonal to that of the polarizing plate 25. In this case, the quantity of light in the user environment can be directly monitored by calculating the output signals from the photodetectors 28 and 29. Accordingly, output signals from amplifiers (which are current-voltage type transimpedance amplifiers), which are supplied with signals from the photodetectors 28 and 29, respectively, are applied to a calculating circuit 213, in which the component of the quantity-of-light signal in the user environment is multiplied by a coefficient and then subtracted from the quantity-of-light signal of the backlight, and from which the calculated output is input to an amplifier 214. Since the coefficient is dependent on the transmittance of the polarizing plate and the nonlinear transmittance of the liquid crystal, it can be predetermined by experimental calibration. The amplifier 214 detects the difference between the input thereto and the luminance of the backlight set by a reference backlight luminance signal fed to an input terminal 216 and applies a signal to a backlight driver 210 to adjust the power supply to the backlight to provide a desired quantity of light. While the signals in the above are described as being handled in analog form, it is needless to say that it is also possible to employ a configuration in which the output signals from the amplifiers 11 and 12 are AD converted so that the entire signal processing including the calculating circuit is performed in digital form.

[0014] This principle will be described in more detail with reference Fig. 3. A description will be given first of the case where the back light is OFF (Fig. 3A). When the direction of polarization of the polarizing plate disposed behind the liquid crystal panel is horizontal, external light is horizontally polarized and can be transmitted through a photodetector A having mounted thereon a horizontally polarizing plate, but it cannot be transmitted through a photodetector B having mounted thereon a vertically polarizing plate. In this instance, the external light component is detected only by the photodetector A.

[0015] Next, a description will be given of the case where the backlight is ON (Fig. 3B). When the direction of polarization of the polarizing plate disposed behind the liquid crystal panel is horizontal, the quantity of light reflected from the liquid crystal panel varies according to the state of transmission therethrough, but the reflected component generally contains a large amount of horizontally polarized component. Such reflected light is transmitted through the photodetector A with the horizontally polarizing plate mounted thereon, but it is not transmitted through the photodetector B with the vertically polarizing plate thereon. In this case, the external light component is the same as in the case where the backlight is OFF. Accordingly, the quantity of light from the backlight can be monitored by the photodetector having mounted thereon the vertically polarizing plate without being affected by the reflected light and external light. The external light component can be obtained by detecting the difference between the outputs from the photodetectors A and B. For convenience of description of the backlight-control principle, the above refers to the use of the difference between the outputs from the photodetectors; needless to say, however, it is possible to provide for increased accuracy in the detection of the external light component by processing that rejects the quantity of light reflected from the liquid crystal to the backlight and multiplies the remaining signal component by a coefficient which is predetermined by the transmission coefficients of the polarizing plates and liquid crystal actually used. The viewability of the display image can also be enhanced by changing the quantity of light from the backlight based on the quantity of external light obtained as mentioned above.

(Embodiment 3)

[0016] Fig. 4 is a block diagram of a liquid crystal display having a built-in photodetector according to a third embodiment of the present invention. Backlights 46 and a light shielding plate 47 are disposed behind a liquid crystal panel 418 wherein a liquid crystal layer 43 oriented and sandwiched between a transparent electrode plate 44 and a counter electrode plate 42 containing a TFT driver circuit is interposed between a polarizing plate 41 (of a horizontally polarizing characteristic) and a polarizing plate 45 (of a vertically polarizing characteristic), and an image sensor 49 is placed on the light shielding plate behind a condenser lens 48. Image information input via a video signal input terminal 217 is sent, as a drive signal corresponding to the voltage necessary for liquid crystal driving and the scanning scheme used, from a liquid crystal driver 415 to the liquid crystal panel 418. The liquid crystal used in this embodiment is a liquid that has a property of rotating the direction of polarization of incident light through 90 degrees. The image sensor is a silicon CCD or CMOS.

[0017] A description will be made below of the procedure of controlling the backlight in the above configuration. The image sensor 49 changes its output signal level in accordance with the quantity of light from the backlight. In this case, the quantity of external light in the user environment can be monitored directly through the liquid crystal panel. Accordingly, a video signal from the image sensor is input to a calculating circuit 413, from which a signal corresponding to the luminance of the video signal is provided to an amplifier 414. The content of such processing can be predetermined through experimental calibration, but it is also possible to obtain the image luminance signal by referring to a loop-up table which contains the quantity of light from the backlight and external light in the user environment. The amplifier 414 detects the difference between the input thereto and the luminance of the backlight set by a reference backlight luminance signal fed to an input terminal 416 and applies a signal to a backlight driver 410 to adjust the power supply to the backlight to provide a desired quantity of light. While the signals in the above are described as being handled in analog form, it is needless to say that it is also possible to employ a configuration in which signal processing by an image sensor control circuit 411 and the calculating circuit 412 is performed in digital form.

[0018] Referring to Fig. 5, a description will be given of the principle of capturing the image of a user by the image sensor. When the backlight is OFF and the liquid crystal panel is fully transparent to light, the user image is focused by a condenser lens onto the image sensor, by which image information about the user can be detected. This can be done by intermittently operating the backlight or in the initial state of starting image display.

(Embodiment 4)

[0019] Fig. 6 is a block diagram of a liquid crystal display having a built-in photodetector according to a fourth embodiment of the present invention. Backlights 66 and a light shielding plate 67 are disposed behind a liquid crystal panel 618 wherein a liquid crystal layer 43 oriented and sandwiched between a transparent electrode plate 64 and a counter electrode plate 62 containing a TFT driver circuit is interposed between a polarizing plate 61 (of a horizontally polarizing characteristic) and a polarizing plate 65 (of a vertically polarizing characteristic), and an image sensor 69 is placed on the light shielding plate behind a condenser lens 68 and a polarizing plate 619. A video signal for display input via a video signal input terminal 617 is sent, as a drive signal corresponding to the voltage necessary for liquid crystal driving and the scanning scheme used, from a liquid crystal driver 615 to the liquid crystal panel 618. The liquid crystal used in this embodiment is a liquid crystal that has a property of rotating the direction of polarization of incident light through 90 degrees. The image sensor is a silicon CCD or CMOS.

[0020] A description will be made below of the procedure of controlling the backlight in the above configuration. The image sensor 69 changes its output signal level in accordance with the quantity of light from the backlight. In this case, the quantity of external light in the user environment can be monitored directly through the liquid crystal panel. Accordingly, a video signal from the image sensor is input to a calculating circuit 613, from which a signal corresponding to luminance of the video signal is provided to an amplifier 614. The content of such processing can be predetermined through experimental calibration, but it is also possible to obtain the image luminance signal by referring to a loop-up table which contains the quantity of light from the backlight and the external light in the use environment. The amplifier 614 detects the difference between the input thereto and the luminance of the backlight set by a reference backlight luminance signal fed to an input terminal 616 and applies a signal to a backlight driver 610 to adjust the power supply to the backlight to provide a desired quantity of light. While the signals in the above are described as being handled in analog form, it is needless to say that it is also possible to employ a configuration in which signal processing by an image sensor control circuit 611 and the calculating circuit 612 is performed in digital form.

[0021] Referring to Fig. 7, a description will be given of the principle of capturing the image of a user by the image sensor when the backlight is ON. In this instance, two image sensors are prepared, on which a horizontally polarizing plate and a vertically polarizing plate are mounted, respectively. In the case of the image sensor having mounted thereon the horizontally polarizing plate, images of the user and user environment are focused by a condenser lens onto the image sensor as shown in Fig. 7A. In this instance, if the lens is focused on the user, then the backlight does not form its image. In the case of the image sensor having mounted thereon the vertically polarizing plate, backlight is similarly incident on the image sensor, but images of the user and use environment are not captured by the image sensor because the directions of polarization of the two polarizing plates are orthogonal to each other. The use of the latter permits detection of the quantity of light from the backlight without being affected by the external light. By detecting the difference between video signals available from the image sensors each having a different polarizing plate mounted thereon, the images of the user and use environment can be obtained without being affected by the backlight. By preparing two such image sensors or by preparing a liquid crystal panel configured to change the direction of polarization of the polarizing plate as by mechanical rotation, or a liquid crystal panel functioning also as a polarizing plate, it is possible to implement the above-mentioned function by one image sensor. For convenience of description of the user image capturing principle, the above refers to the use of the difference between the video signals available from the image sensors; needless to say, however, it is possible to provide for increased accuracy in the detection of the quantity of light from the backlight by processing of multiplying the image sensor output by a coefficient which is determined by the transmission coefficients of the polarizing plate and liquid crystal actually used.

(Embodiment 5)

[0022] Fig. 9A shows a method for calibrating a video signal in the liquid crystal display of each of Embodiments 1, 2, 3 and 4 described above. A photodetector 91 is mounted on the front of a liquid crystal display 92, and a light emitting diode or semiconductor laser 96 is disposed on the back of the liquid crystal panel. The photodetector 91 is a silicon PN junction diode, and the light emitting diode 96 is an assembly of four RGBW (red, green, blue and white) light emitting diodes arranged side by side. A 12-bit staircase signal for calibration (see Fig. 9B) is input to a video signal input terminal 93. The time width of the stairstep is 1 millisecond. At first, the signal is input intact to a liquid crystal driver 910 without referring to a conversion table 94 described later on, thereby changing the state of transmission of the liquid crystal display.

[0023] A modulation signal generator 98 generates sine-wave signals of four different frequencies (for example, 100 KHz, 200 KHz, 300 KHz, and 400 KHz), or four orthogonal patterns of pseudo-random sequences (such, for example, as the following 16-bit sequences obtainable from the Hadamard matrix. Reference document: Yukitoshi Sanada, "CDMA by MATLAB/ Simulink," Tokyo Denki Daigaku Press).

1 1 -1 -1 -1 -1 1 1 1 1 -1 -1 -1 -1 1 1
1 -1 -1 1 -1 1 1 -1 1 -1 -1 1 -1 1 1 -1
1 1 1 1 1 1 1 1 -1 -1 -1 -1 -1 -1 -1 -1
1 -1 1 -1 1 -1 1 -1 -1 1 -1 1 -1 1 -1 1

When product-sum operation is performed for these different sequences, the operation result is zero. In the case of the sine-wave signals of different frequencies, too, it is self-evident that when they are integrated for a period substantially equal to the minimum common multiplier of their cycle, the operation result is zero. That is, they all have a property that they are orthogonal to each other. Pulse modulation signals, which are on for 1 and off for -1, are produced and each assigned to one of four light emitting diodes. The time width of the minimum pulse is set to 1 microsecond. The modulation signals are each provided via a driver 99 to one of the light emitting diodes 96 to generate optical modulated signals. These optical modulated signals are detected by a photodetector 91 placed behind the liquid crystal panel. The output signal from the photodetector is input to a correlation detector 99. When the modulated signal is a sine wave, the correlation detector 99 can be regarded as a lock-in amplifier; by synchronizing the signal contained in the light emitted from each diode and the photodetector output at the same frequency, it is possible to detect the amplitude of each optical modulated signal without ambient noise. A description will be given of the operation of the correlation detector in the case where the modulated signals are pseudo-random sequences. A numerical value, obtained by A-D conversion of the photodetector output at a 10-MHz sampling frequency, and the pseudo-random sequence are correlated with each other. In this case, the correlation value is obtained, for example, by multiplying the pseudo-random sequence with 1 set at +1 and 0 at -1 (The Hadamard sequence may be held unchanged.) by the above-mentioned numerical value A-D converted at the sampling frequency, and then accumulating the product for a time that is an integral multiple of the cycle of the pseudo-random sequence. Since the frequencies or pseudo-random sequences allotted to the four colors RGBW are orthogonal to each other, it is possible to calculate the transmission coefficient of the liquid crystal for each light emitting diode even if four color components of the optical modulated signal are measured at the same time. Such a procedure is repeated for each stairstep of the staircase video signal until its final stairstep is reached, by which the light transmission characteristic of the liquid crystal for the staircase calibration signal, such as shown in Fig. 9C, is obtained for each color. The distortion of the transfer curve in Fig. 9C is caused by the transfer characteristic of the liquid crystal that varies with temperature or the degree of deterioration. The output from the correlation detector is input to a CPU 95, wherein it is standardized with the predetermined maximum intensity and compared with the staircase video signal for calibration and a conversion table (LUT, Look Up Table) is created. The thus obtained conversion table is input to a video signal converting circuit 94 to generate a signal based on the first LUT. Thereafter, a 12-bit staircase calibration signal is input again to the video signal input terminal as shown in Fig. 9D to generate a signal based on a second LUT in the same manner as mentioned above. By repeating this, the transfer characteristic of the liquid crystal gradually approaches the predetermined transfer characteristic. The calibration terminates with the generation of a signal based on an LUT at the point in time when the error between the both transfer characteristics becomes minimum. The quantity of light from the backlight is also detected and ground noise become large; the detection accuracy can be increased by turning OFF the backlight, but according to this method, since the background component is cancelled at the time of detection of the correlation when the optical modulated signal is demodulated, the LUT can be generated even when the backlight is ON. While this method has been described as being applied to the calibration for each color, it is needless to say that the method is applicable to the calibration of a monochromatic display.

(Embodiment 6)

[0024] Fig. 10A shows a method of calibration of an image signal in the liquid crystal displays of Embodiments 1, 2, 3 and 4 described above. A light source 101 is disposed toward the display screen of a liquid crystal panel 102. The light source 101 is housed in a hood-like canopy provided for the purpose of shielding the liquid crystal panel from external light, and hence it does not obstruct the user's view. This embodiment uses semiconductors of three kinds of colors such as red, blue and green. Since the semiconductor laser is capable of emitting light of a fixed direction of polarization, the emitted light can be transmitted through the liquid crystal panel with extremely high efficiency by making the direction of polarization of the laser the same as that of the polarizing plate on the display screen to be irradiated with the laser light. Moreover, two photodetectors having mounted thereon polarizing plates of different directions of polarization are placed at the position of irradiation with the semiconductor laser. A 12-bit staircase calibration signal (see Fig. 10B) is input to a video signal input terminal 93. The time width of each stairstep is set to 1 millisecond. At first, the signal is input intact to the liquid crystal without referring to a conversion table described later on, thereby changing the state of transmission of the liquid crystal.

[0025] A modulation signal generator 98 generates sine-wave modulation signals of different frequencies (for example, 100 KHz, 200 KHz, and 300 KHz), or three patterns of pseudo-random sequences (such, for example, as the following 16-bit sequences obtainable from the Hadamard matrix).

1 1 -1 -1 -1 -1 1 1 1 1 -1 -1 -1 -1 1 1
1 -1 -1 1 -1 1 1 -1 1 -1 -1 1 -1 1 1 -1
1 1 1 1 1 1 1 1 -1 -1 -1 -1 -1 -1 -1 -1

When a product-sum operation is performed for these different sequences, the operation result is zero. In the case of the sine-wave signals of different frequencies, too, it is self-evident that when they are integrated for a period substantially equal to the minimum common multiplier of their cycle. That is, they all have a property that they are orthogonal to each other. Pulse modulation signals, which are on for 1 and off for -1, are produced and each assigned to one of three light emitting diodes. The time width of the minimum pulse is set to 1 microsecond. The modulation signals are each provided via a driver 99 to one of the light emitting diodes 96 to generate optical modulated signals. The optical modulated signals are detected by the photodetectors 91 for backlight illuminance detection use described previously in Embodiment 2. As described in Embodiment 2, the difference between output signals from the two photodetectors is detected by a differential amplifier, by which it is possible to cancel the main component of backlight and measure the component of the semiconductor laser light. The output signal from the differential amplifier is applied to a correlation detector 99. When the modulation signals are sine-wave, the correlation detector 99 can be regarded as a lock-in amplifier; by synchronizing the signal contained in the light emitted from each diode and the photodetector output at the same frequency, it is possible to detect each optical modulation signal while canceling the noise input to each photodetector. A description will be given of the operation of the correlation detector in the case where the modulated signals are pseudo-random sequences. A numerical value, obtained by A-D conversion of the photodetector output at a 10-MHz sampling frequency, and the pseudo-random sequence are correlated with each other. In this case, the correlation value is obtained, for example, by multiplying the pseudo-random sequence with 1 set at +1 and 0 at -1 (The Hadamard sequence may be held unchanged.) by the above-mentioned numerical value A-D converted at the sampling frequency, and then accumulating the product for a time that is an integral multiple of the cycle of the pseudo-random sequence. Since the frequencies or pseudo-random sequences allotted to the four colors RGB are orthogonal to each other, it is possible to calculate the transmission coefficient of the liquid crystal for each light emitting diode even if the transmission coefficients for three color components of the optical modulated signal are measured at the same time. Such a procedure is repeated for each stairstep of the staircase video signal until its final stairstep is reached, by which the light transmission characteristic of the liquid crystal for the staircase calibration signal, such as shown in Fig. 10C, is obtained for each color. The distortion of the transfer curve in Fig. 10C is caused by the transfer characteristic of the liquid crystal that varies with temperature or the.degree of deterioration. The output from the correlation detector is input to a CPU 95, wherein it is standardized with the predetermined maximum intensity and compared with the staircase video signal for calibration and a conversion table (LUT, Look Up Table) is created. The thus obtained conversion table is input to a video signal converting circuit 94 to generate a signal based on the first LUT. Thereafter, as described with reference to Fig. 9, (A 12-bit staircase calibration signal is input again to the video signal input terminal to generate a signal based on a second LUT and a signal based on the second LUT in the same manner as shown in Fig. 9D. By repeating this, the transfer characteristic of the liquid crystal gradually approaches the predetermined transfer characteristic.) the calibration terminates with the generation of a signal based on an LUT at the point in time when the error between the both transfer characteristics becomes minimum. The quantity of light from the backlight is also detected by the photodetector and ground noise become large; the detection accuracy can be increased by turning OFF the backlight, but according to this method, since the background component is cancelled at the time of detection of the correlation when the optical modulated signal is demodulated, the LUT can be generated even when the backlight is ON. While this method has been described as being applied to the calibration for each color, it is needless to say that the method is applicable to the calibration of a monochromatic display. Since the photodetector also detects the quantity of light in the use environment, the background noise become large, but according to this method, since the background noise component is cancelled at the time of detection of correlation, the LUT can be generated in whatsoever working condition. While this method has been described as being applied to the calibration for each color, it is needless to say that the method is applicable to the calibration of a monochromatic display. Further, semiconductor lasers are used as the light emitting source 101, but light emitting diodes can similarly be used. While in the above the light source has been described as being housed in a hood-like canopy provided for the purpose of shielding the liquid crystal panel from external light, it is needless to say that a movable light source array can be mounted on the liquid crystal display screen for calibration.

[0026] With the use of the present invention, it is possible to exclude the influence of external light in the use environment on the photodetector for detecting the quantity of light form the backlight, permitting high-accuracy backlight control. An image sensor, which is a kind of photodetector, can be disposed behind the liquid crystal panel to capture image information about the user. In either case, by processing a plurality of signals from photodetectors or image sensors having mounted thereon polarizing plates of different directions of polarization with a view to utilizing the property of polarized light that is transmitted through the liquid crystal panel, it is possible to provide increased accuracy in the backlight control and in capturing the user image. Besides, stabilization of backlight by the present invention permits high accuracy calibration-this is of great industrial value when employed in a liquid crystal display for medical care that is required to have high-level gray scale and high degree of reproducibility and high precision/high-level-gray-scale liquid crystal display for design use.

Claims

1. A liquid crystal display, **characterized in that** the quantity of light from a backlight is controlled on the basis of a signal obtained by calculating two or more signals which are detected by a photodetector disposed behind a liquid crystal panel and directed toward the backlight and a photodetector disposed toward a direction different from the backlight.

2. A liquid crystal display, **characterized in that** the quantity of light from a backlight is controlled on the basis of a signal obtained by calculating two or more signals which are detected by photodetectors both disposed behind a liquid crystal panel, the photodetectors each having mounted thereon one of polarizing plates whose directions of polarization are identical with and orthogonal to the direction of polarization of a polarizing plate placed on the side of a backlight with respect to liquid crystal.

3. A liquid crystal display wherein an image sensor is disposed behind a liquid crystal panel and directed toward the display screen to capture image or illuminance information in the direction of the display screen when liquid crystal is made to transmit therethrough light.

4. A liquid crystal display wherein an image sensor is disposed behind a liquid crystal panel and directed toward the display screen to capture image or illuminance information in the direction of the display screen when liquid crystal is made to transmit therethrough light, the image sensor having mounted thereon a polarizing plate whose direction of polarization is identical with that of a polarizing plate on the side of a backlight with respect to liquid crystal.

5. The liquid crystal display recited in any one of claims 1 to 4, **characterized in that** the quantity of light from the backlight is controlled on the basis of ambient illuminance and the light intensity of the backlight detected by said photodetector or image sensor from the quantity of light transmitted from the liquid crystal display panel and the quantity of light reflected from the back of the liquid crystal panel.

6. A calibration method for the liquid crystal display recited in any one of claims 1 to 4, **characterized in that**: a second light source and a second photodetector are disposed behind the liquid crystal panel and on the display screen of the liquid crystal panel, respectively; when a calibrating image signal is input to the liquid crystal display, said second light source is modulated; light transmitted through liquid crystal is detected by the second photodetector; the modulated signal is demodulated to obtain the optical transfer characteristic of the liquid crystal; and a conversion function or conversion table of the calibrating image signal is obtained for calibration of the image display.

7. A calibration method for the liquid crystal display recited in any one of claims 1 to 4, **characterized in that**: a third light source formed by a light emitting diode or semiconductor laser is disposed on the display screen of the liquid crystal panel and directed toward the display screen, the light emitting diode

or semiconductor laser emitting light polarized in the same direction as the direction of polarization of the liquid crystal panel; when a calibrating image signal is input to the liquid crystal display, the light source is modulated; the modulated signal detected by a photodetector or image sensor disposed behind he liquid crystal panel is demodulated to obtain the optical transfer characteristic of the liquid crystal; and a conversion function or conversion table of the calibrating image signal is obtained for calibration of the image display.

FIG. 1

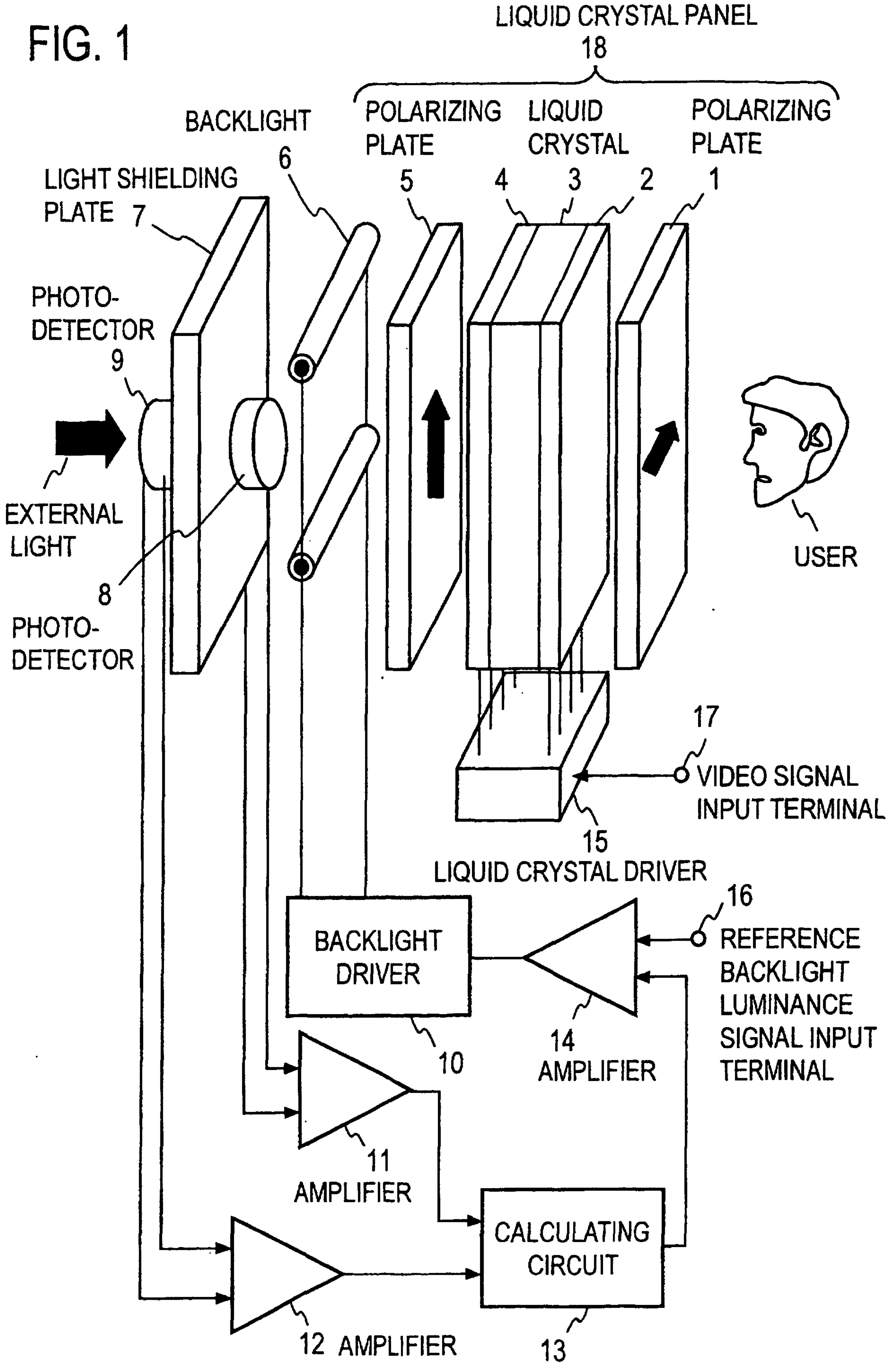

LIQUID CRYSTAL PANEL
18
BACKLIGHT
6
POLARIZING PLATE
5
LIQUID CRYSTAL
4
3
2
POLARIZING PLATE
1
LIGHT SHIELDING PLATE 7
PHOTO-DETECTOR
9
EXTERNAL LIGHT
8
PHOTO-DETECTOR
USER
17
VIDEO SIGNAL INPUT TERMINAL
15
LIQUID CRYSTAL DRIVER
16
REFERENCE BACKLIGHT LUMINANCE SIGNAL INPUT TERMINAL
BACKLIGHT DRIVER
10
14
AMPLIFIER
11
AMPLIFIER
CALCULATING CIRCUIT
12 AMPLIFIER
13

FIG. 2

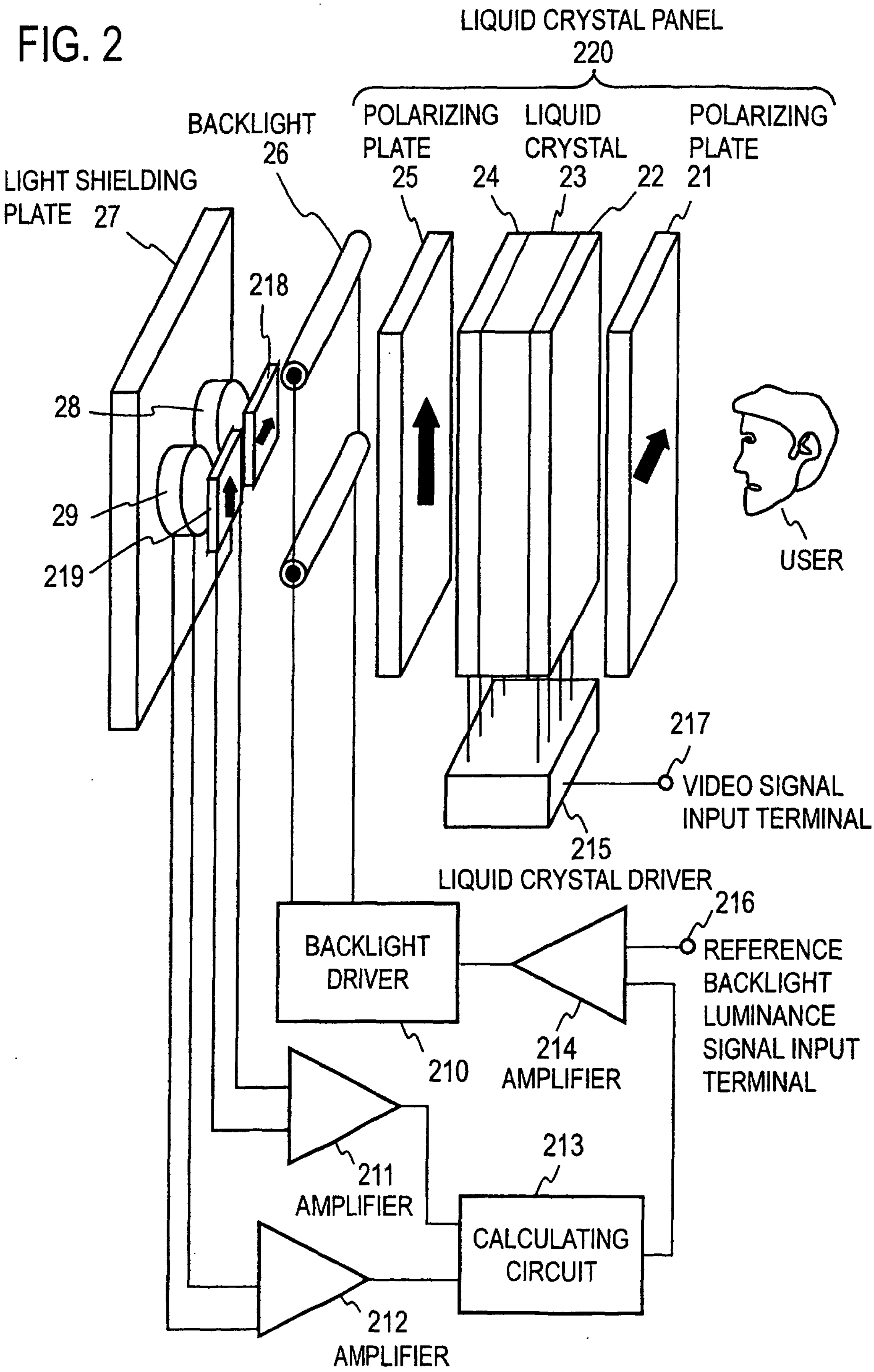

LIQUID CRYSTAL PANEL
220
BACKLIGHT
26
POLARIZING
PLATE
25
24
LIQUID
CRYSTAL
23
22
POLARIZING
PLATE
21
LIGHT SHIELDING
PLATE 27
218
28
29
219
USER
217
VIDEO SIGNAL
INPUT TERMINAL
215
LIQUID CRYSTAL DRIVER
216
BACKLIGHT
DRIVER
REFERENCE
BACKLIGHT
LUMINANCE
SIGNAL INPUT
TERMINAL
210
214
AMPLIFIER
213
211
AMPLIFIER
CALCULATING
CIRCUIT
212
AMPLIFIER

FIG. 3A

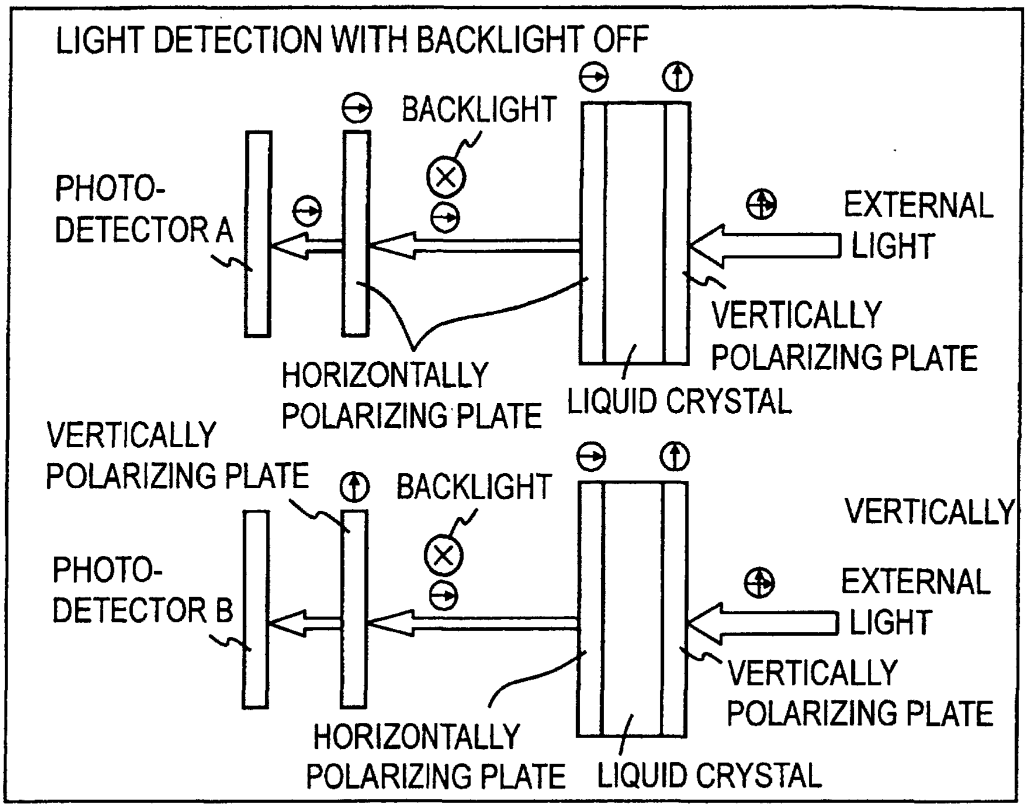

LIGHT DETECTION WITH BACKLIGHT OFF
BACKLIGHT
PHOTO-
DETECTOR A
EXTERNAL
LIGHT
VERTICALLY
POLARIZING PLATE
HORIZONTALLY
POLARIZING PLATE
LIQUID CRYSTAL
VERTICALLY
POLARIZING PLATE
BACKLIGHT
VERTICALLY
PHOTO-
DETECTOR B
EXTERNAL
LIGHT
VERTICALLY
POLARIZING PLATE
HORIZONTALLY
POLARIZING PLATE
LIQUID CRYSTAL

FIG. 3B

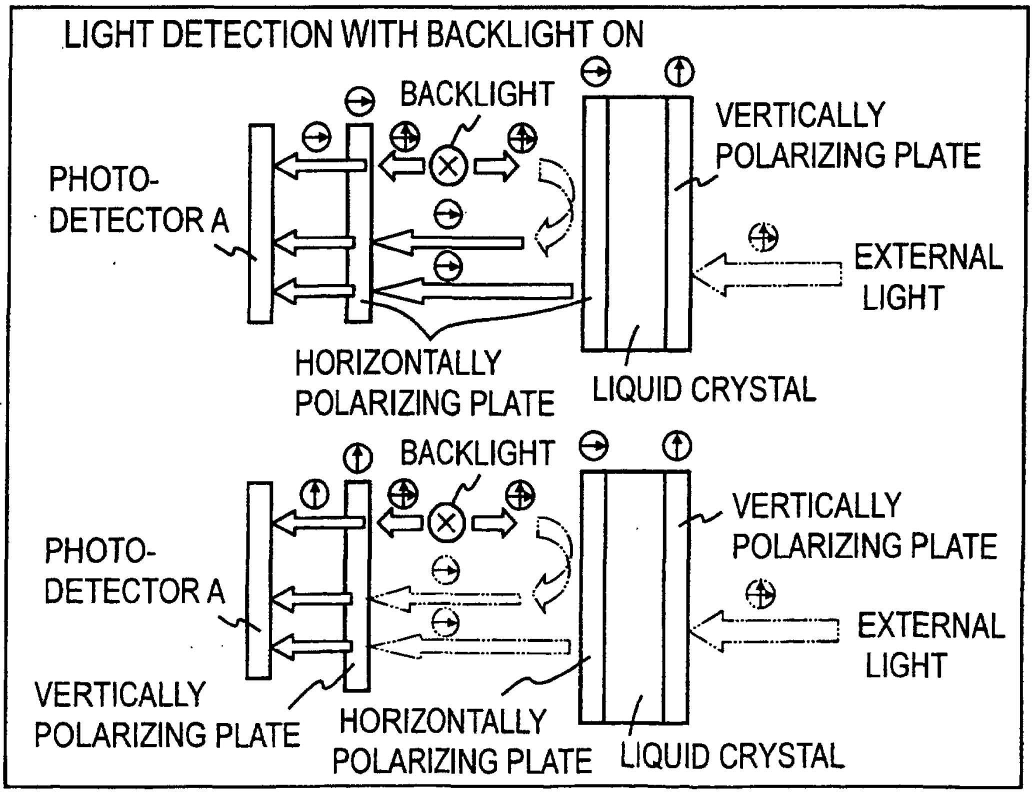

LIGHT DETECTION WITH BACKLIGHT ON
BACKLIGHT
VERTICALLY
POLARIZING PLATE
PHOTO-
DETECTOR A
EXTERNAL
LIGHT
HORIZONTALLY
POLARIZING PLATE
LIQUID CRYSTAL
BACKLIGHT
VERTICALLY
POLARIZING PLATE
PHOTO-
DETECTOR A
EXTERNAL
LIGHT
VERTICALLY
POLARIZING PLATE
HORIZONTALLY
POLARIZING PLATE
LIQUID CRYSTAL

FIG. 4

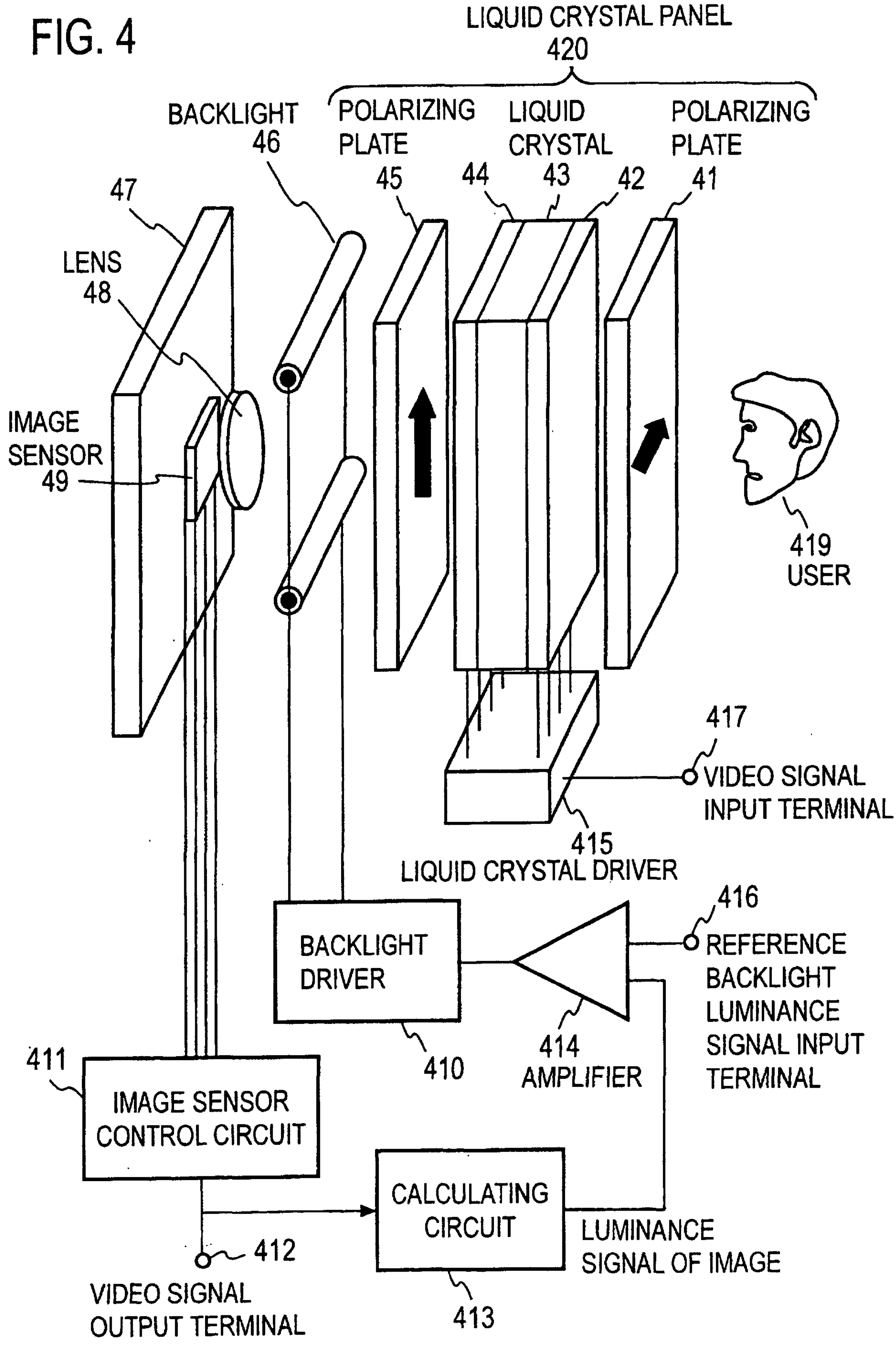

LIQUID CRYSTAL PANEL
420
BACKLIGHT
46
POLARIZING
PLATE
45
LIQUID
CRYSTAL
43
44
42
POLARIZING
PLATE
41
47
LENS
48
IMAGE
SENSOR
49
419
USER
417
VIDEO SIGNAL
INPUT TERMINAL
415
LIQUID CRYSTAL DRIVER
416
REFERENCE
BACKLIGHT
LUMINANCE
SIGNAL INPUT
TERMINAL
BACKLIGHT
DRIVER
410
414
AMPLIFIER
411
IMAGE SENSOR
CONTROL CIRCUIT
CALCULATING
CIRCUIT
LUMINANCE
SIGNAL OF IMAGE
412
VIDEO SIGNAL
OUTPUT TERMINAL
413

FIG. 5

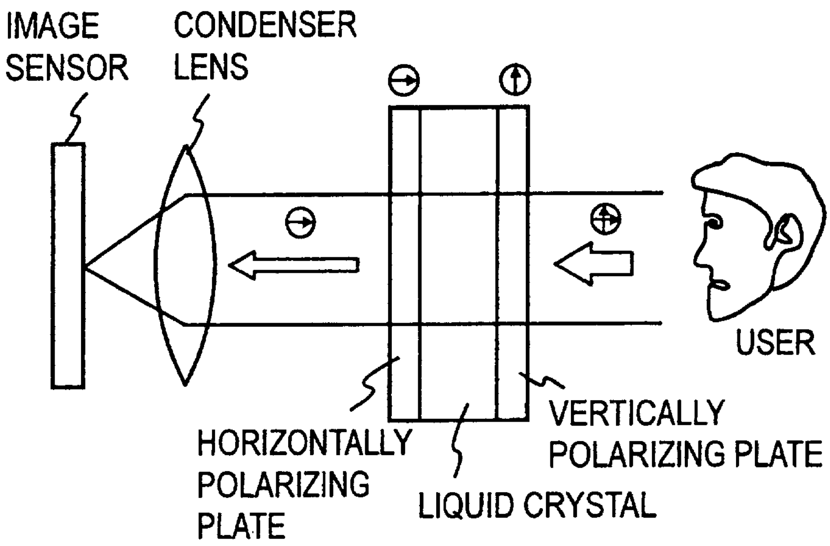
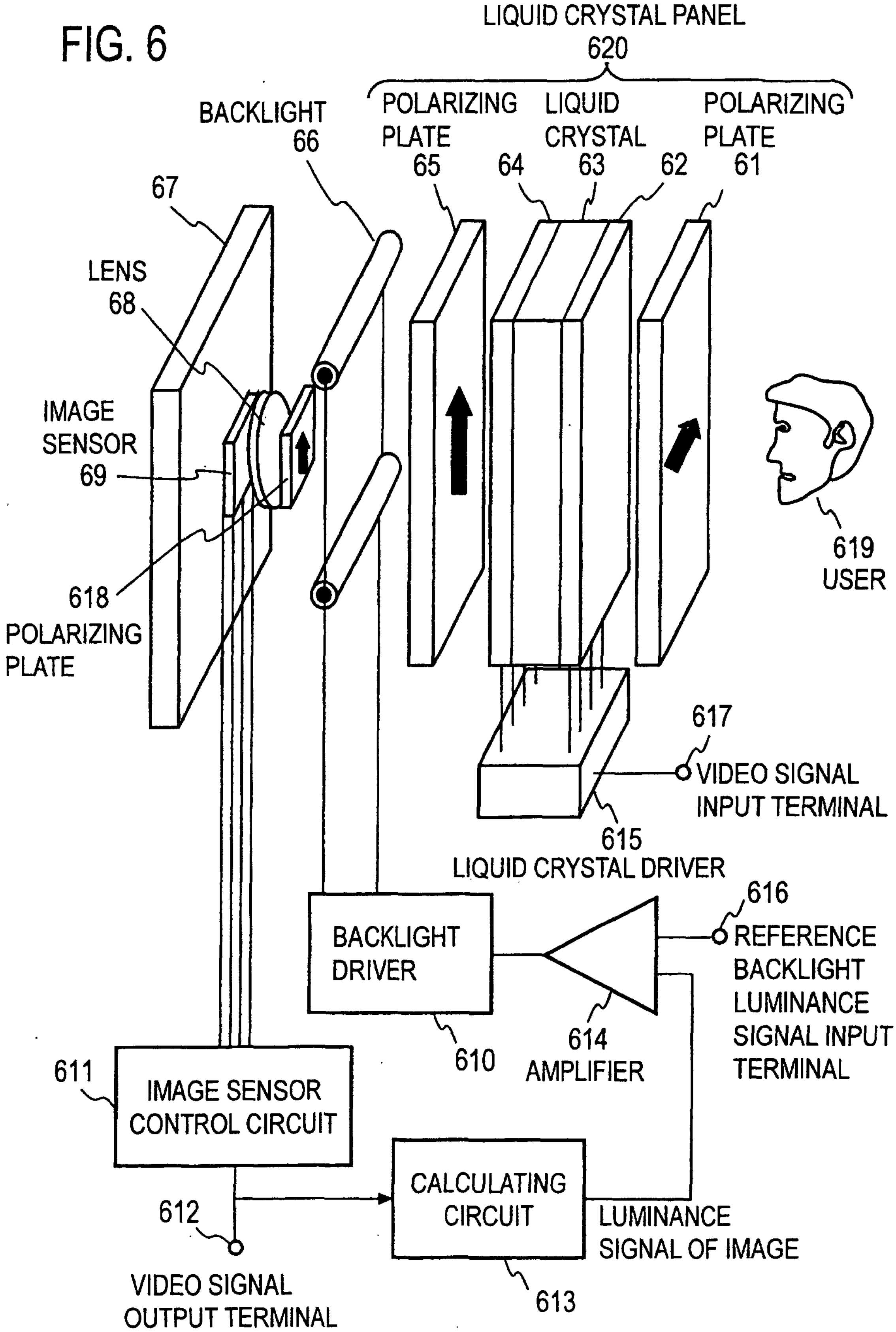


IMAGE
SENSOR
CONDENSER
LENS
USER
HORIZONTALLY
POLARIZING
PLATE
LIQUID CRYSTAL
VERTICALLY
POLARIZING PLATE

FIG. 6



LIQUID CRYSTAL PANEL
620
BACKLIGHT
66
POLARIZING
PLATE
65
64
LIQUID
CRYSTAL
63
62
POLARIZING
PLATE
61
67
LENS
68
IMAGE
SENSOR
69
618
POLARIZING
PLATE
619
USER
617
VIDEO SIGNAL
INPUT TERMINAL
615
LIQUID CRYSTAL DRIVER
616
REFERENCE
BACKLIGHT
LUMINANCE
SIGNAL INPUT
TERMINAL
BACKLIGHT
DRIVER
610
614
AMPLIFIER
611
IMAGE SENSOR
CONTROL CIRCUIT
CALCULATING
CIRCUIT
LUMINANCE
SIGNAL OF IMAGE
612
VIDEO SIGNAL
OUTPUT TERMINAL
613

FIG. 7A

WITH HORIZONTALLY POLARIZING PLATE INSTALLED

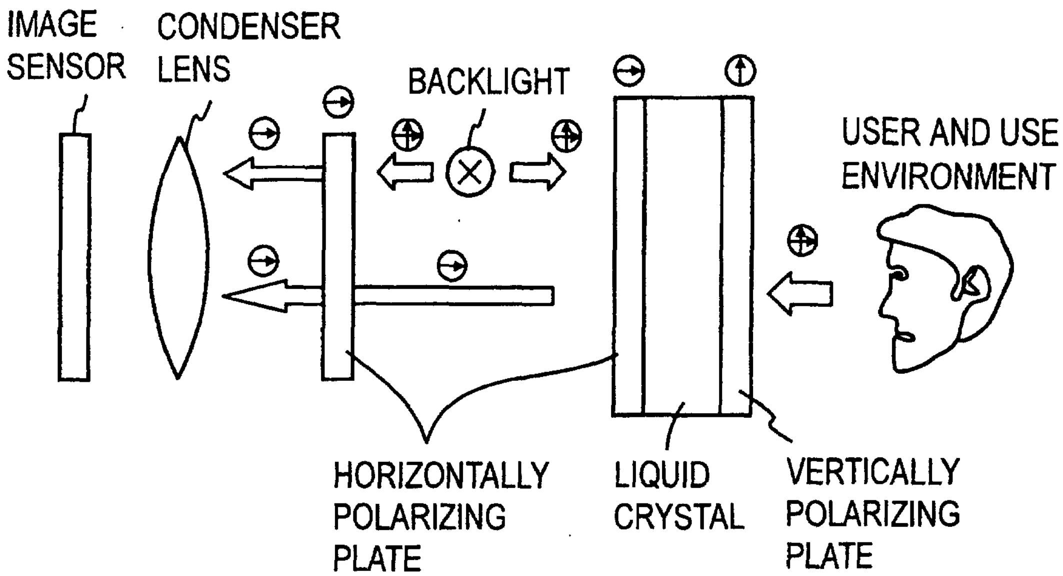


FIG. 7B

WITH VERTICALLY POLARIZING PLATE INSTALLED

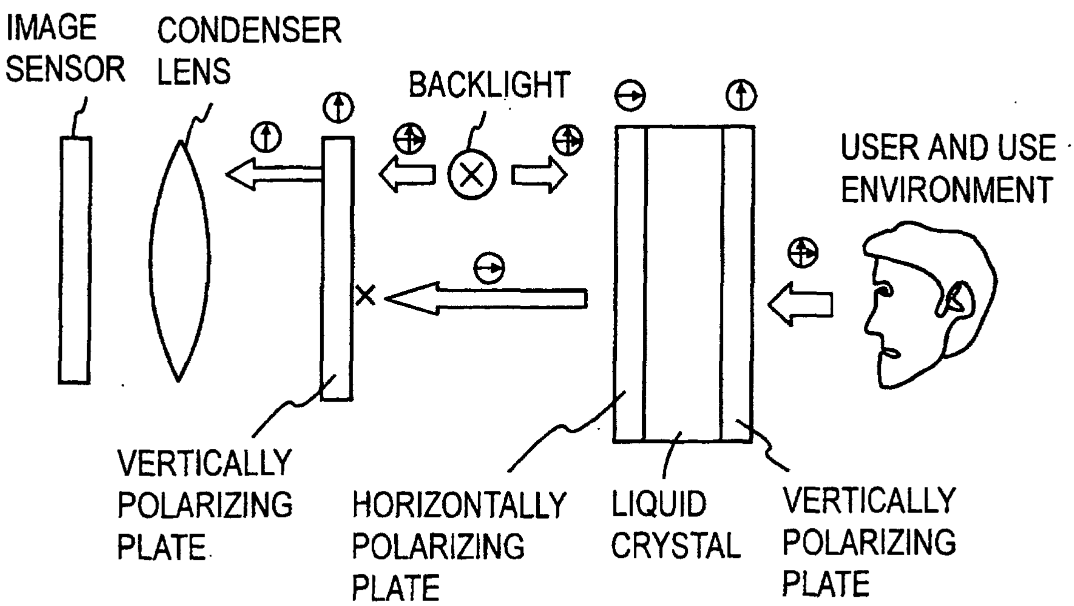
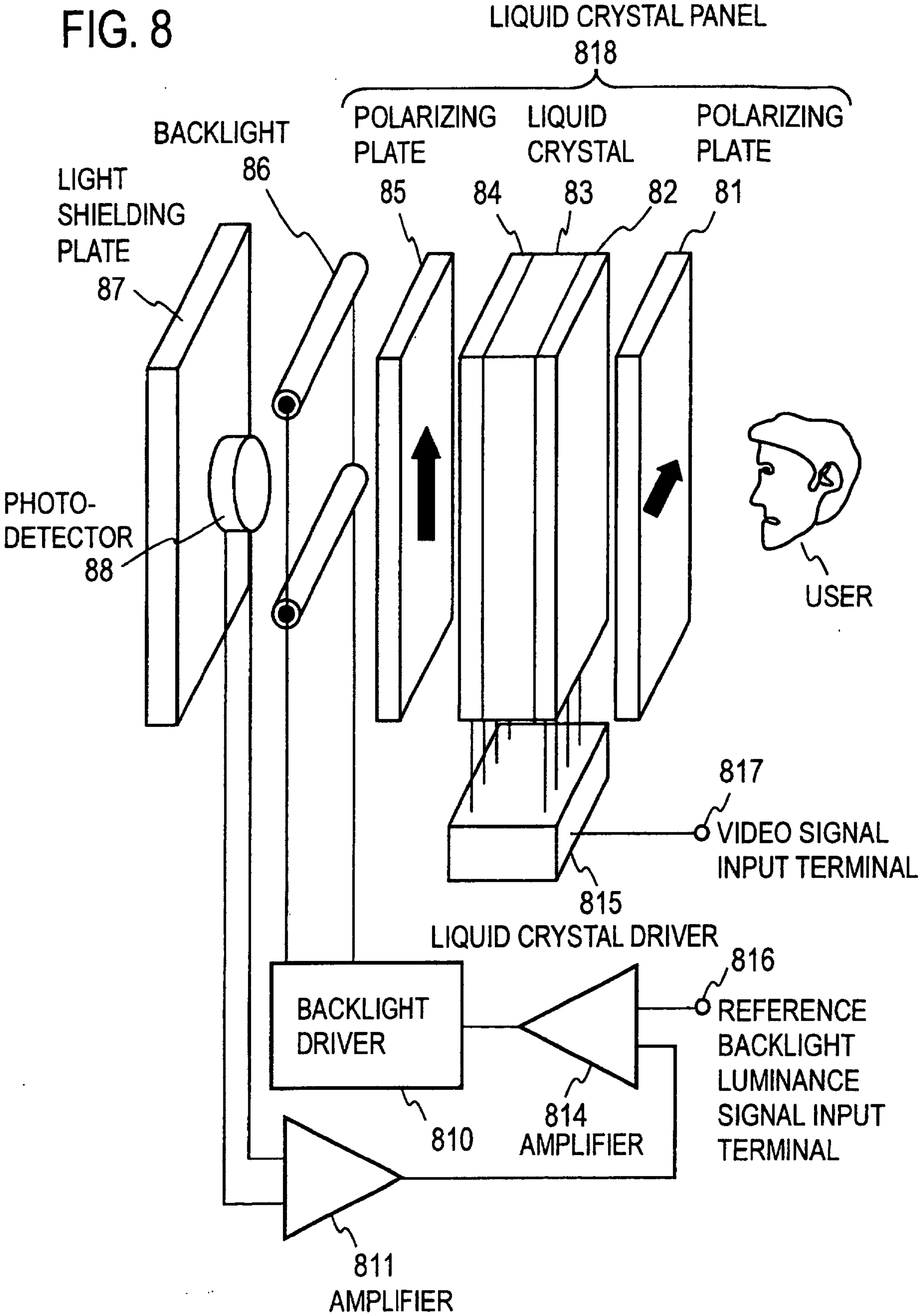


FIG. 8



(CONVENTIONAL BACKLIGHT CONTROL CONFIGURATION)

FIG. 9A

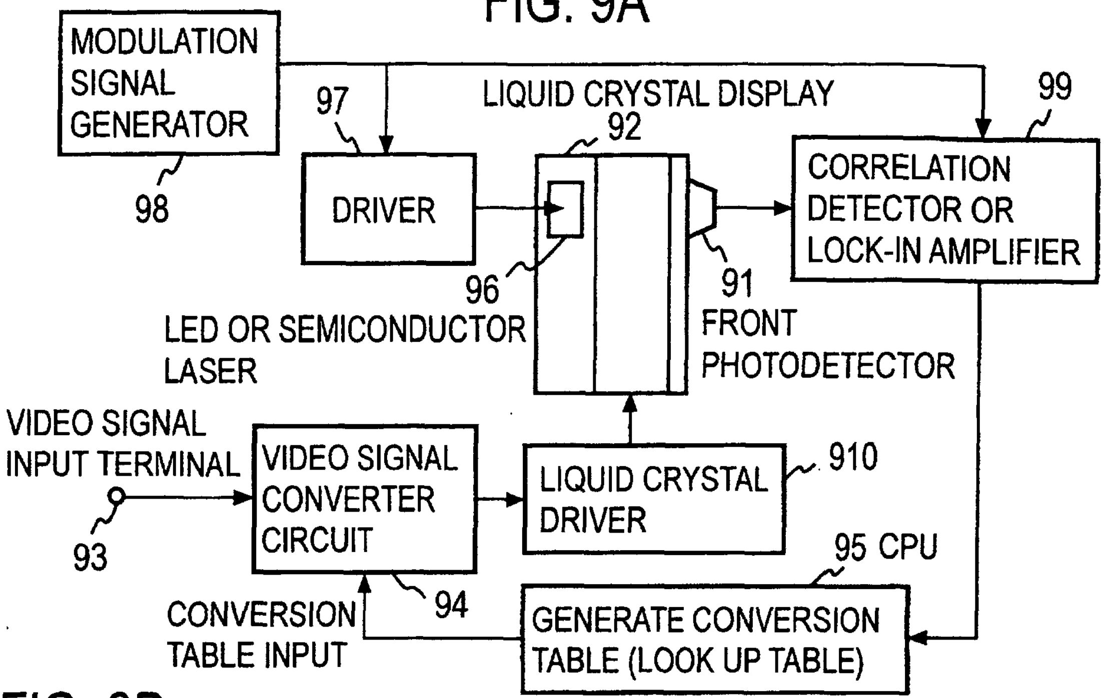


FIG. 9B

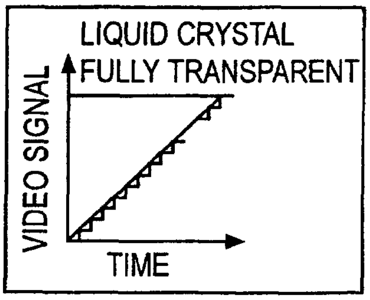


FIG. 9C

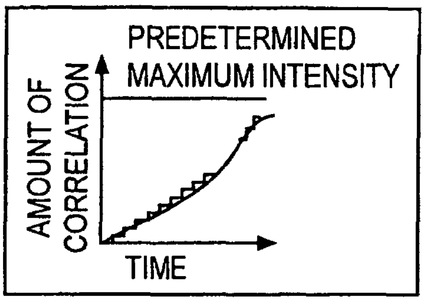


FIG. 9D

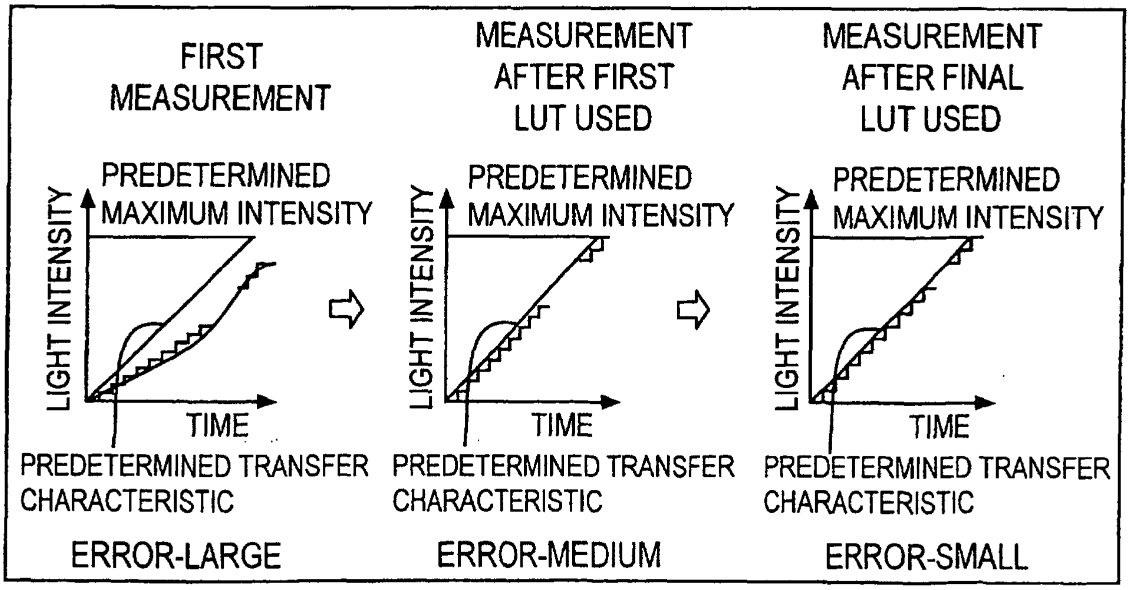


FIG. 10A

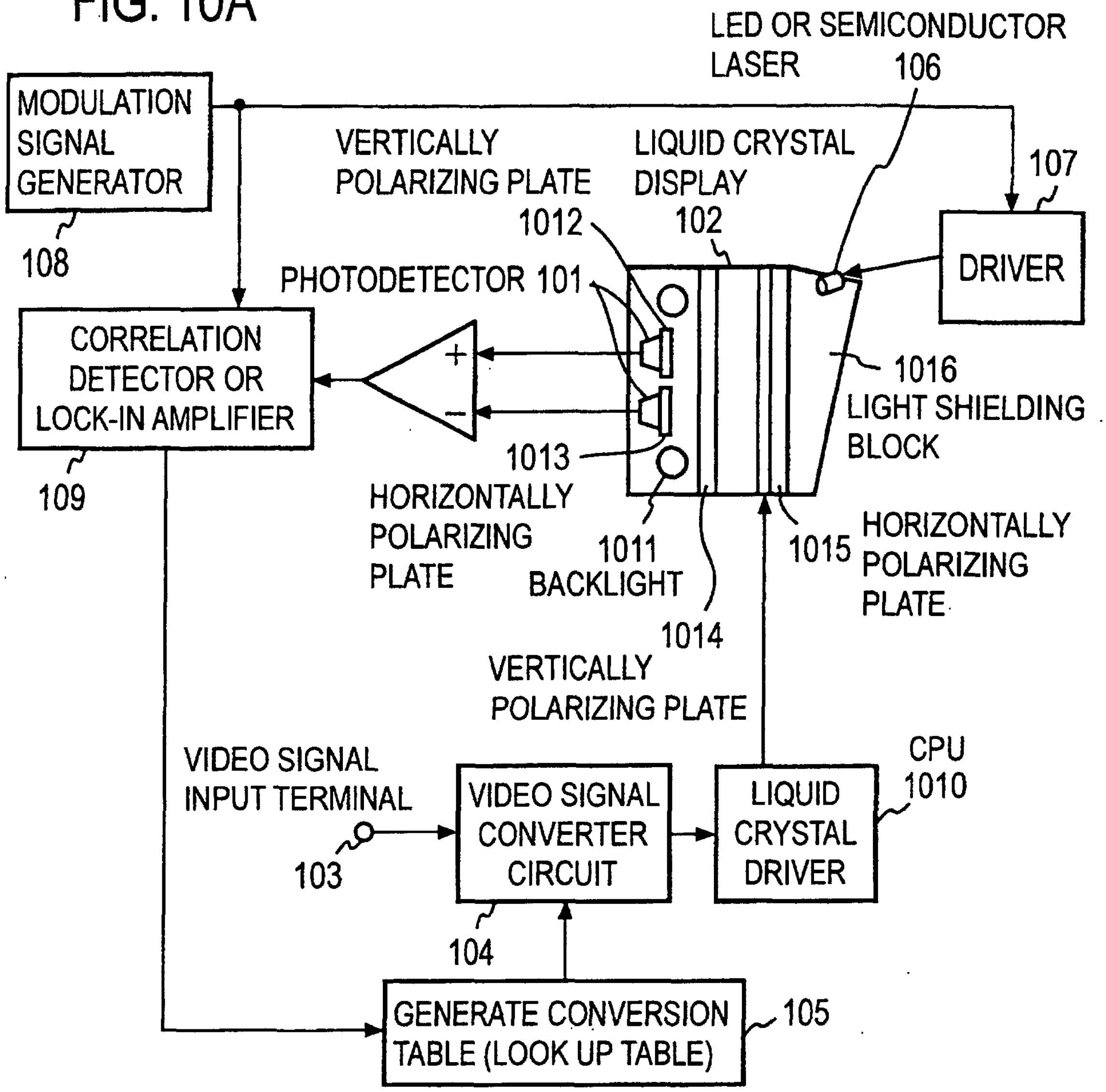


FIG. 10B

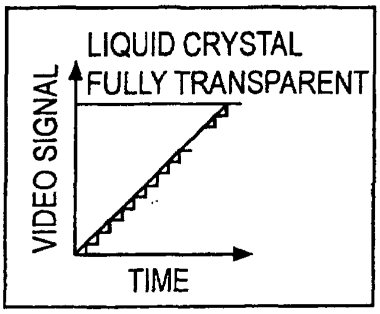
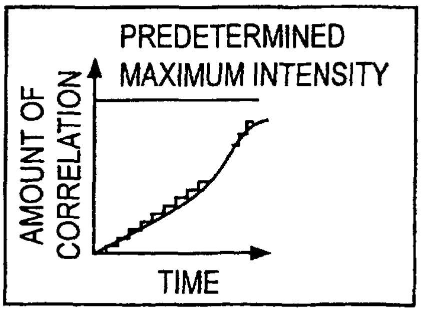


FIG. 10C



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP01/09062

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] G02F1/133, G09G3/36, G09G3/36

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)
Int.Cl[7] G02F1/133, G09G3/36, G09G3/36

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

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2001
Kokai Jitsuyo Shinan Koho	1971-2001	Jitsuyo Shinan Toroku Koho	1996-2001

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 07-064057 A (Matsushita Electric Ind. Co., Ltd.), 10 March, 1995 (10.03.95), Par. No. [0016] (Family: none)	1,6
Y	JP 11-282404 A (Dainippon Printing Co., Ltd.), 15 October, 1999 (15.10.99), Claims; Fig. 1 (Family: none)	1,6
X	JP 02-018520 A (Mitsubishi Electric Corporation), 22 January, 1990 (22.01.90), Claims (Family: none)	3
Y	JP 07-036132 U (Jeco Co., Ltd.), 04 July, 1995 (04.07.95), Claims of Utility Model; Fig. 1 (Family: none)	6
Y	JP 08-054859 A (Casio Computer Co., Ltd.), 27 February, 1996 (27.02.96), Claims (Family: none)	6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* 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 document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or 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
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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
"&" document member of the same patent family

Date of the actual completion of the international search 28 November, 2001 (28.11.01)	Date of mailing of the international search report 11 December, 2001 (11.12.01)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP01/09062

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 05-289056 A (Nikon Corporation), 05 November, 1993 (05.11.93), Claims (Family: none)	6

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP01/09062

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The technical matter that a photodetector (image sensor) is disposed on the back of a liquid crystal device, an image sensor directed toward the display is disposed on the back so as to acquire illuminance information in the direction of display in such a way that the light transmits the liquid crystal makes no contribution over the prior art. Therefore the common technical matter cannot be any special technical matter within the meaning of PCT Rule 13.2, second sentence.

Therefore there is no common technical matter common to all the inventions of claims 1-4. Consequently there is no technical relationship among the different inventions within the meaning of PCT Rule 13 since there are no other technical matters considered to be special technical matters within the meaning of PCT Rule 13.2, second sentence.

As a result, the inventions of claims 1-4 do not comply with the requirement of unity of invention.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.
☒ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (1)) (July 1992)

专利名称(译)	液晶显示器及其校正方法		
公开(公告)号	EP1445643A1	公开(公告)日	2004-08-11
申请号	EP2001974871	申请日	2001-10-16
[标]申请(专利权)人(译)	SPECTRATECH		
申请(专利权)人(译)	SPECTRATECH INC.		
当前申请(专利权)人(译)	EIZO NANAO CORPORATION		
[标]发明人	OHASHI MITSUO UEDA KATSUE		
发明人	OHASHI, MITSUO UEDA, KATSUE		
IPC分类号	G02F1/13 G02F1/133 G09G3/34 G09G3/36		
CPC分类号	G09G3/3406 G02F1/133602 G02F2203/69 G09G2320/0626 G09G2320/0693 G09G2360/144 G09G2360/145		
其他公开文献	EP1445643B1 EP1445643A4		
外部链接	Espacenet		

摘要(译)

来自背光的光量由第一光电探测器监测，并且用户方的环境由设置在液晶面板后部而不是在其前面的第二光电探测器监测。可以排除来自用户侧的外部光对第一光电检测器的影响，该第一光电检测器检测来自背光的光量。

FIG. 1