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Roosendaal (43) **Pub. Date: Dec. 16, 2004**(54) **TRANSFLECTIVE LIQUID CRYSTAL
DISPLAY DEVICE**(30) **Foreign Application Priority Data**

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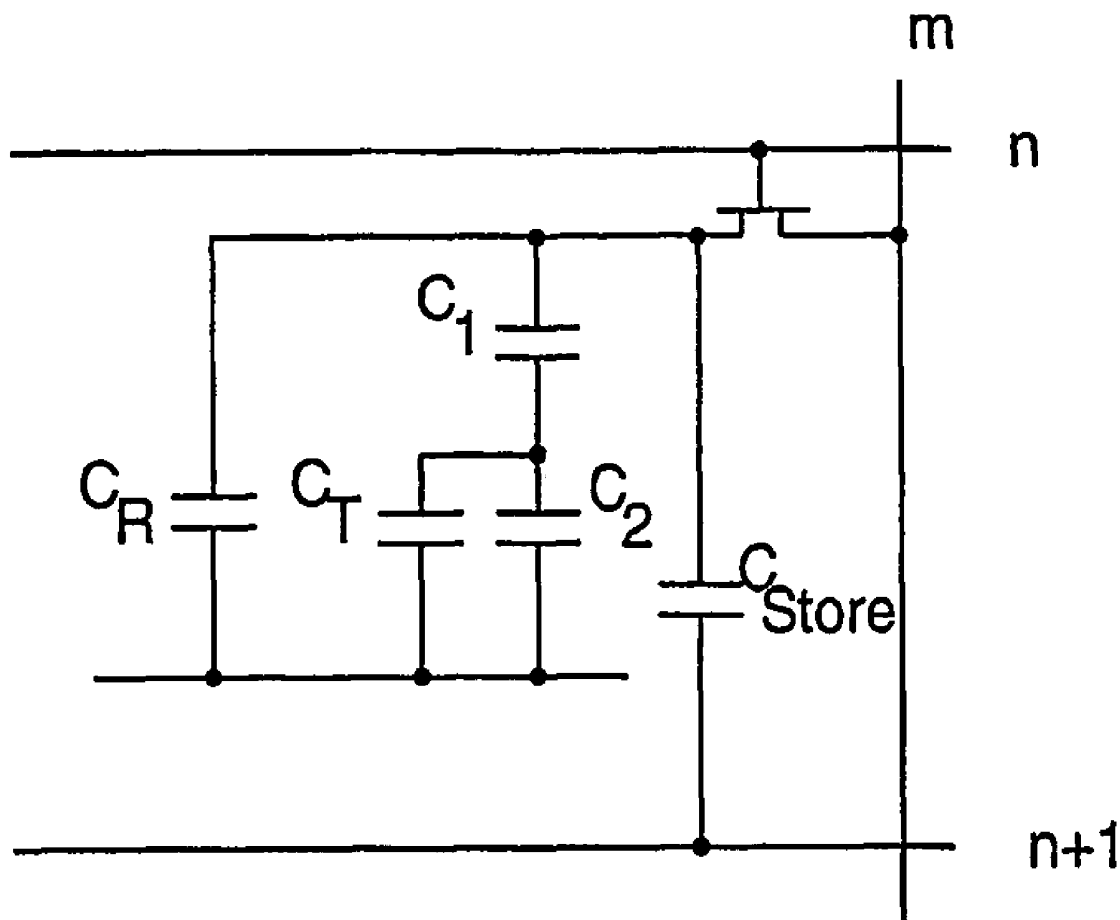
(76) **Inventor: Sander Jurgen Roosendaal, Eindhoven
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Correspondence Address:

**PHILIPS ELECTRONICS NORTH AMERICA
CORPORATION
INTELLECTUAL PROPERTY & STANDARDS
1109 MCKAY DRIVE, M/S-41SJ
SAN JOSE, CA 95131 (US)**(57) **ABSTRACT**

The present invention relates to a transflective liquid crystal display device (11), having at least one pixel, comprising a reflective sub-pixel (11b) including a first liquid crystal cell and a transmissive sub-pixel (11a) including a second liquid crystal cell. The device is characterized in that said first and second liquid crystal cells are arranged to be driven at mutually different driving voltages.

The invention also relates to a method for driving such a transflective display.

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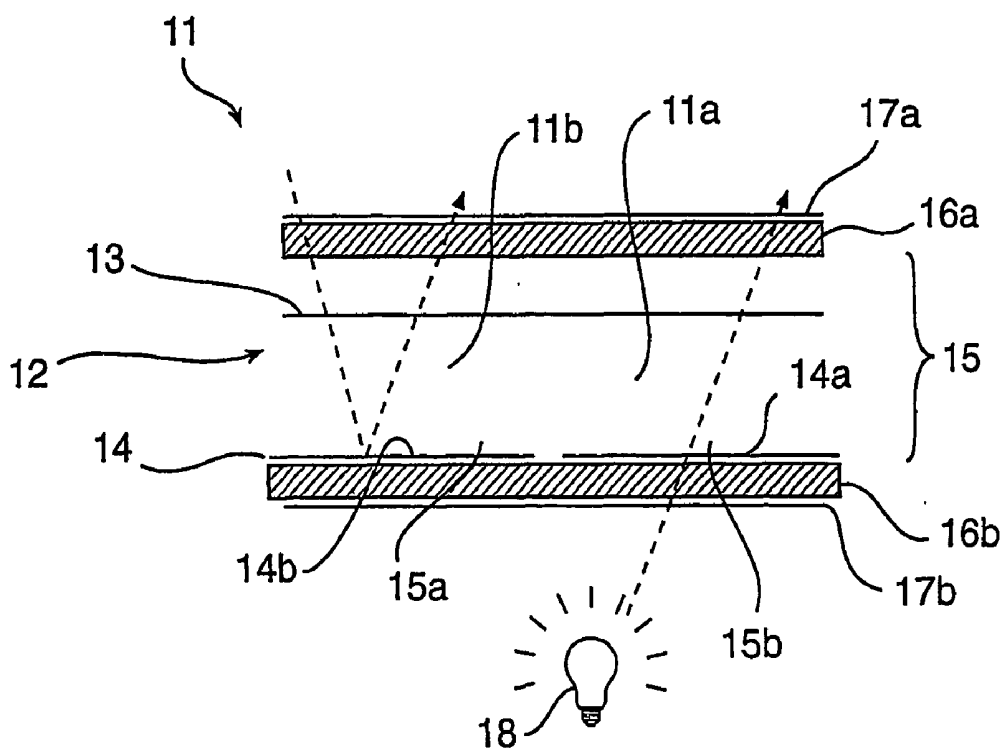


FIG. 1

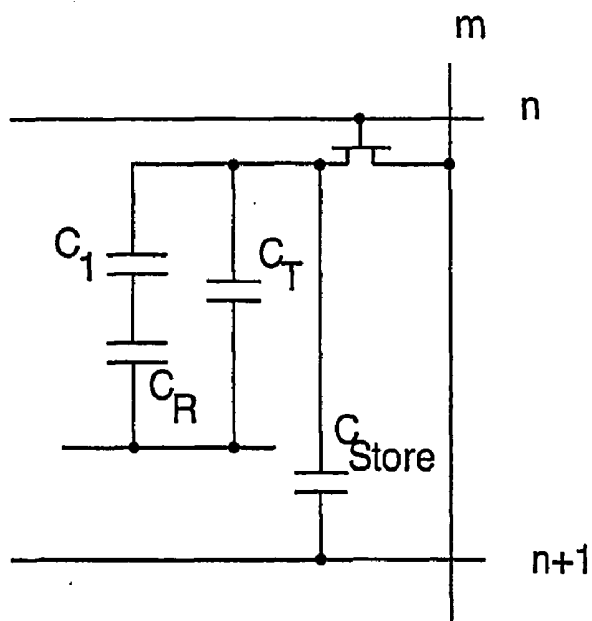


FIG. 2

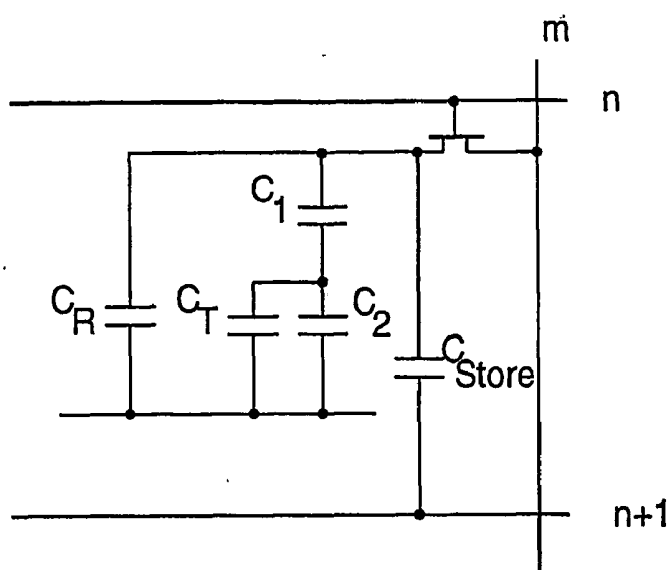


FIG.3

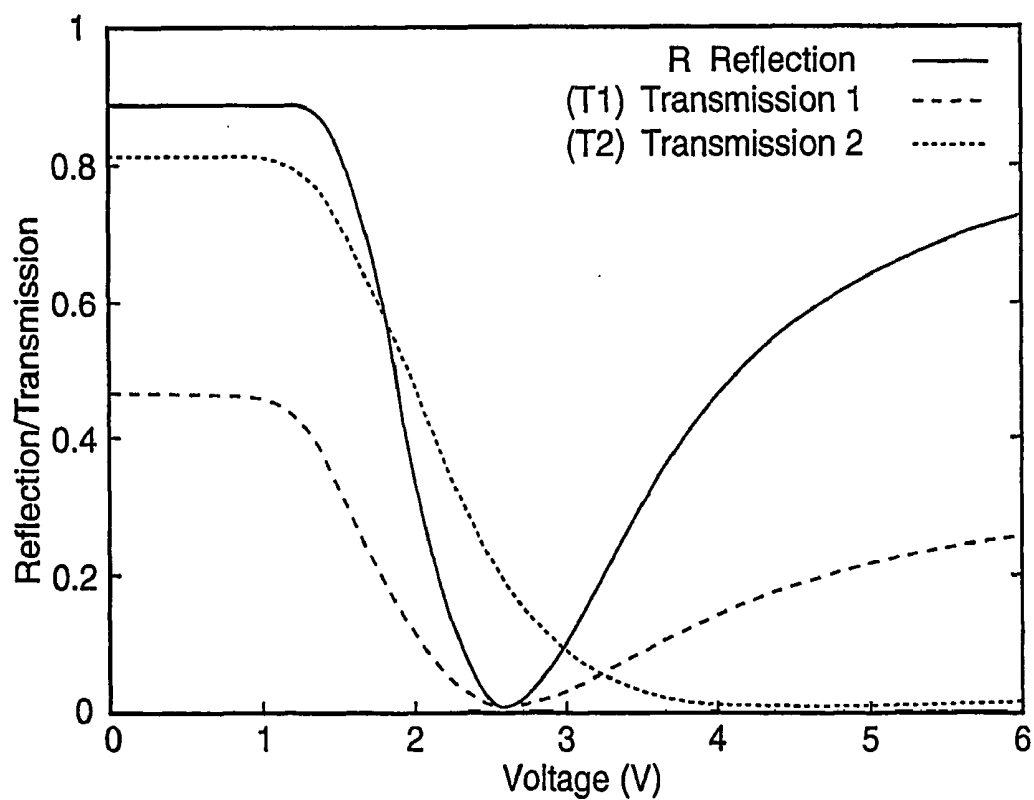


FIG.4

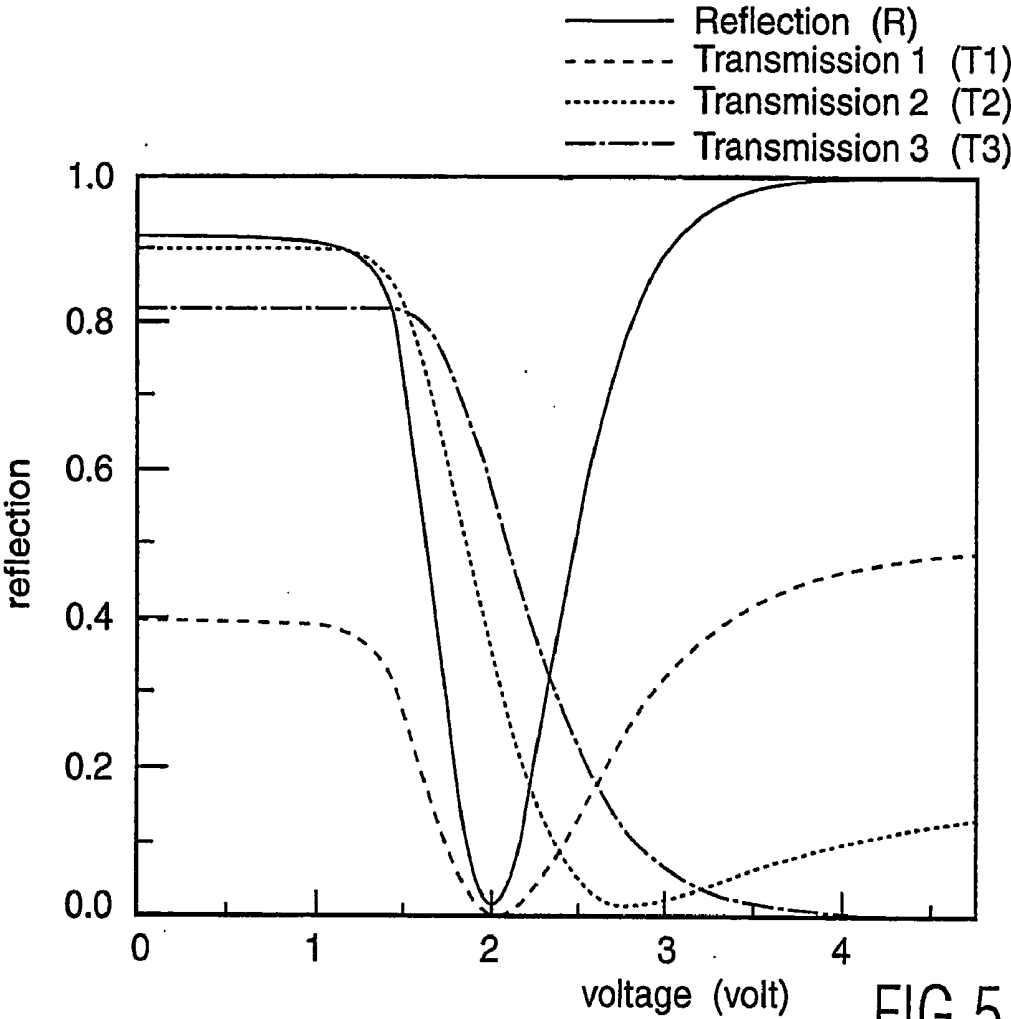


FIG. 5

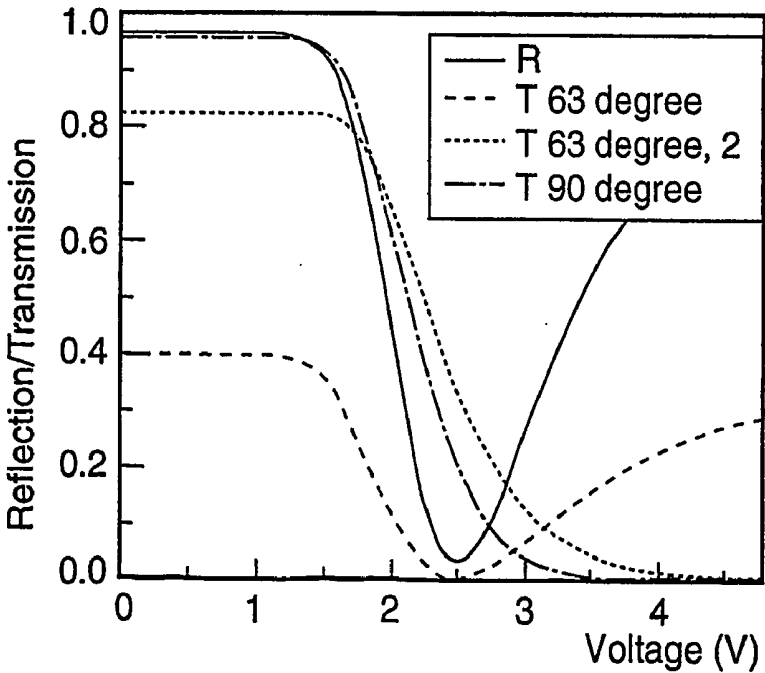
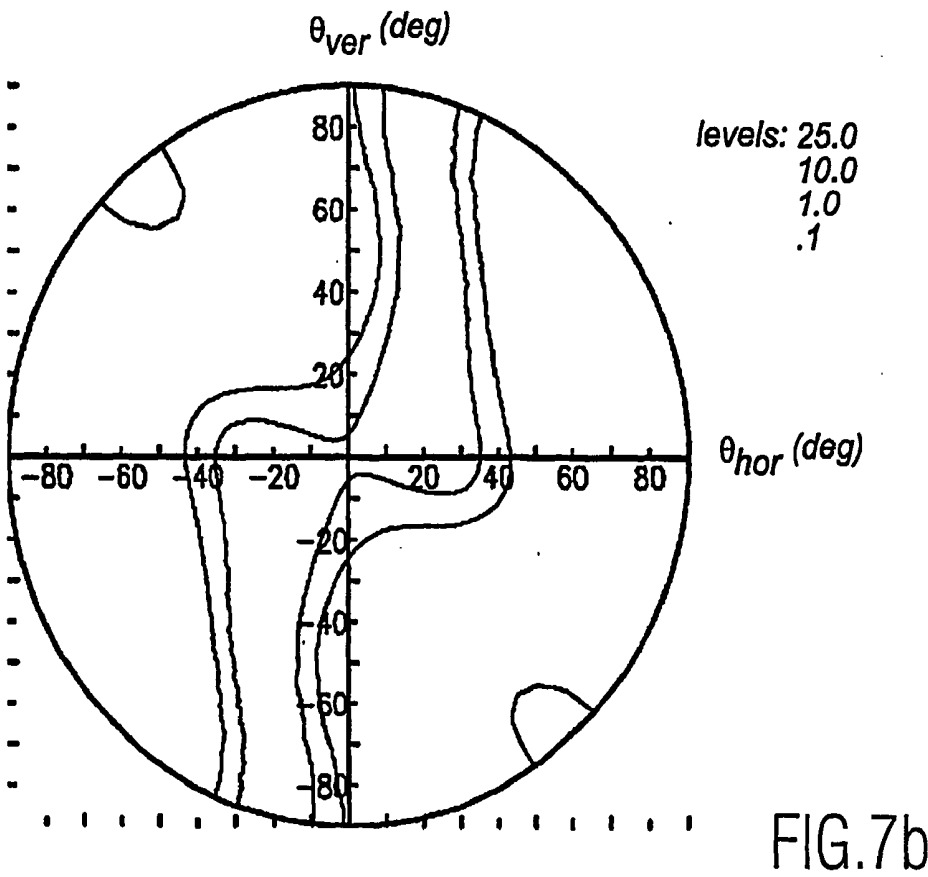
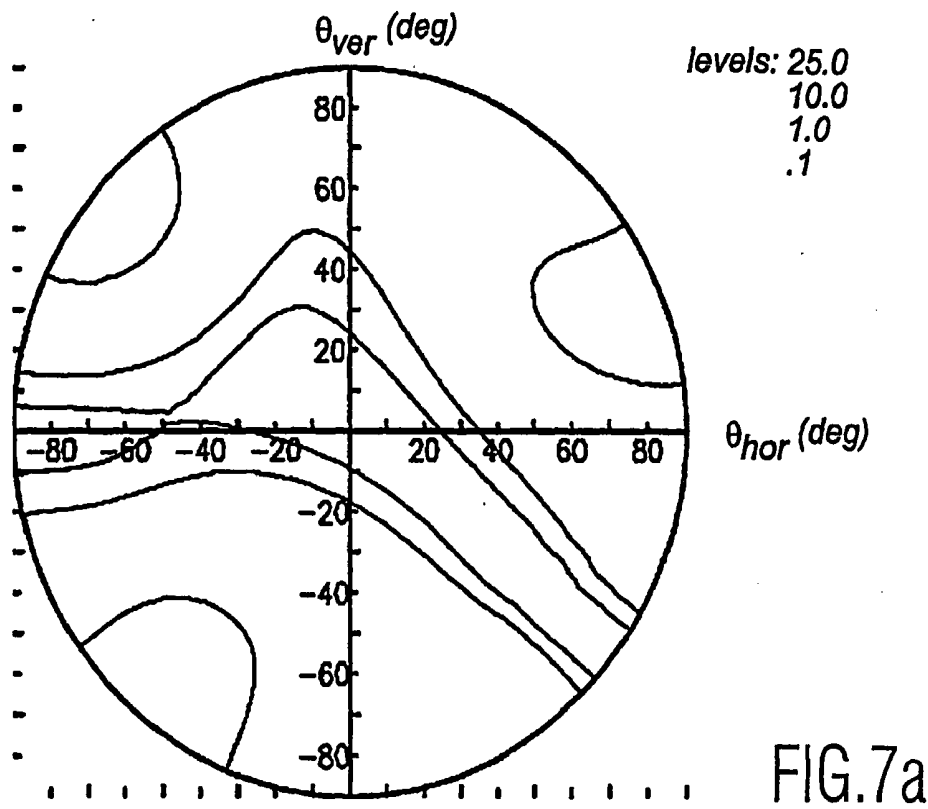


FIG. 6



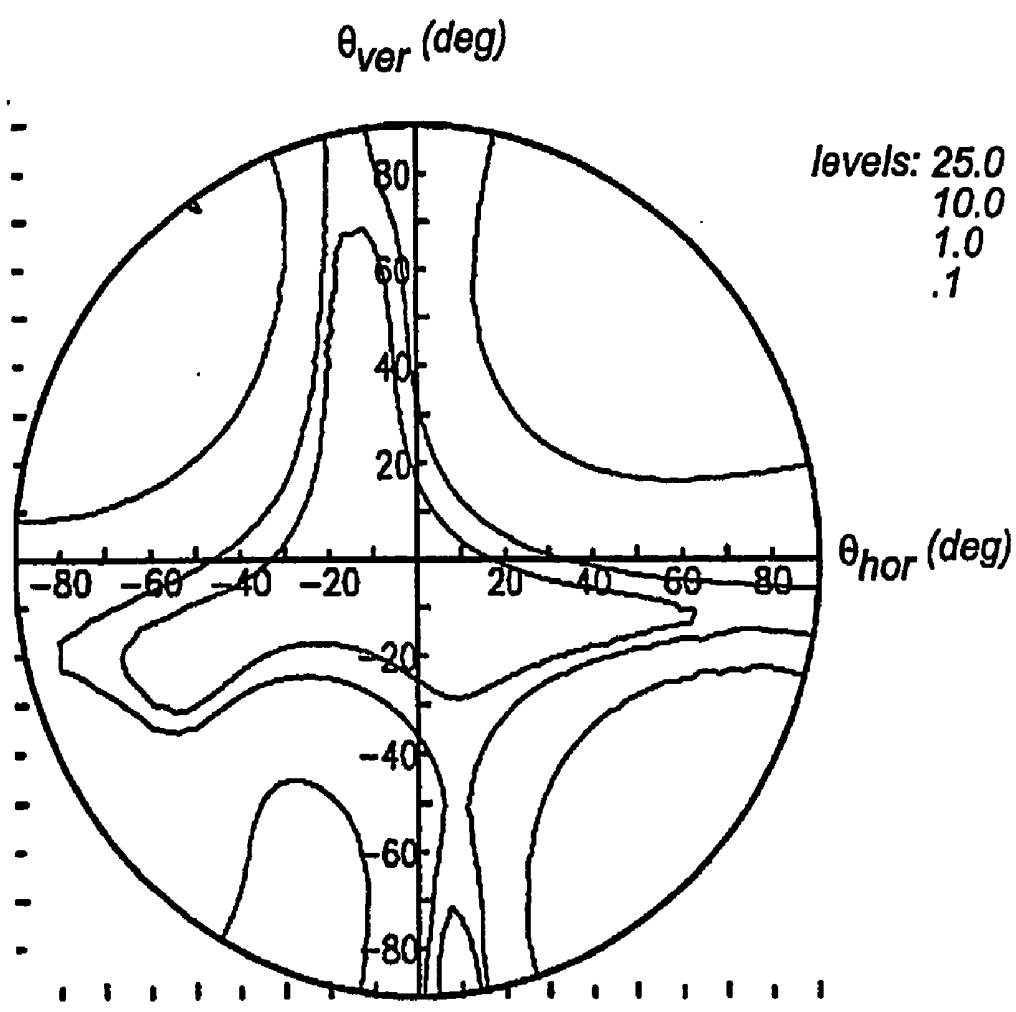


FIG.7c

TRANSFLECTIVE LIQUID CRYSTAL DISPLAY DEVICE

[0001] This invention relates to a transfective liquid crystal display device, having at least one pixel, comprising a reflective sub-pixel including a first liquid crystal cell and a transmissive sub-pixel including a second liquid crystal cell

[0002] The invention also relates to a method for addressing such a transfective liquid crystal display device.

[0003] Due to its low power consumption, reliability and low price, liquid crystal displays, or LCDs have become the standard display choice for mobile applications, such as PDAs, laptops and cellular phones. Different LCD types, such as active matrix reflective and transmissive LCDs are today available on the market. Reflective LCDs are especially suited for outdoor use in direct sunlight. The contrast ratio is relatively low, compared with a transmissive display, and under poor illumination conditions, the brightness of this kind of display is low. On the other hand, transmissive LCDs have a good contrast ratio, but they become practically unreadable in direct sunlight illumination conditions. Furthermore, the transmissive display utilizes a backlight, resulting in an increase of the power consumption.

[0004] Consequently, there is a need for a display having good display properties under all lighting circumstances. One solution is to use a so-called transfective LCD, which may be used in both a transmissive and reflective mode at the same time. The intensity of the backlight can thereby be tuned in order to fit the lighting conditions, either by hand, or automatically, using a photo diode or the like. This invention relates to a transfective liquid crystal display and a method for improving the backlight efficiency of such a display.

[0005] A transfective display as described above is for example described in the patent document U.S. Pat. No. 6,195,140, in which a liquid crystal display device includes a reflection region and a transmission region.

[0006] However, in order to achieve a transfective display having a good contrast, it must be possible to drive both the reflection region and the transmission region, each constituting a sub-pixel of the display, at a state with essentially zero transmission or reflection. This is referred to as a good dark state.

[0007] The transmission or reflection of the different states of the display device are dependant upon the twist angle and the effective optical thickness u of the display, which is given by (for a non-twisted nematic layer):

$$u = \frac{d\Delta n}{\lambda} \quad (1)$$

[0008] where d is the cell gap, Δn is the birefringence of the liquid crystal layer and λ is the wavelength of the incident light. When an electric field (above a threshold value) is applied over the liquid crystal cell, the liquid crystals start to tilt and the light passing the cell experiences less birefringence. Therefore, it is possible to define an effective birefringence (Δn) and an effective optical thickness (u_{eff}) of the cell, in a similar way as defined in (1). Δn_{eff} and u_{eff} are functions of the voltage applied to the cell.

[0009] As implicitly said above, the reflection as well as the transmission of the transfective display is dependant upon the optical thickness u and the twist angle (ϕ). Further, the effective value of u (u_{eff}) may be altered (lowered) by applying an electrical field over the display. Traditionally, both the reflective and transmissive sub-pixels of a transmissive display have had the same optical thickness. Thereby, a display may be generated, having a value of u for which both the transmission and the reflection of the respective sub-pixels have comparatively high values (bright state), and having a value of u_{eff} (when a certain field is applied over the pixel) for which both the transmission and the reflection of the respective sub-pixels have comparatively low values (dark state). Because the dark state of the cell has to be at the same value of u_{eff} for both the reflective and transmissive sub-pixel, the polarization state of the light just after the reflector in the reflective sub-pixel, is the same as the polarization state of the light entering the liquid crystal layer in the transmissive sub-pixel. For the dark state, this polarization state of the light is a circular polarized state. To achieve this in the transmissive sub-pixel, a compensation foil has to be present, which transforms the linear polarization of the entry polarizer to circular polarized light. To obtain maximum reflection in the bright state of the reflective sub-pixel, the light just after the reflector has to be linearly polarized, and the optical thickness of the cell and the twist angle are adjusted to achieve this. For the bright state of the transmissive sub-pixel, however, the light entering the liquid crystal layer is still circularly polarized by the compensation foil. It can be shown that a liquid crystal layer, which transforms a linear polarization state into a linear polarization state, will transform a circular polarization state into a circular polarization state. Thus, at the exit polariser, half of the light will be absorbed and the transmission of the bright state will only be 50%.

[0010] One solution to the above problem, namely the low transmission in bright transmissive sub-pixels, has been proposed by the above document U.S. Pat. No. 6,195,140, namely to provide a display device having different cell gaps for the reflective and transmissive sub-pixels, respectively, thereby optimizing the value of u . However, this solution is disadvantageous in that the active plate has to be provided with lower and higher regions on its surface in order to provide said different cell gaps, and thus the fabrication of this active plate is rather expensive. Other means for solving the above technical problem is therefore desired.

[0011] Consequently, an object of the invention is to accomplish a transfective liquid crystal display device, overcoming the above-mentioned drawbacks.

[0012] A further object of the invention is to provide a transfective liquid crystal display device, having an increased backlight efficiency.

[0013] Yet another object of this invention is to provide a transfective liquid crystal display device, having an increased viewing angle.

[0014] These and other objects are achieved by a display device, as described by way of introduction, being characterized in that said sub-pixels are arranged to be driven at mutually different driving voltages. Thereby, an extra degree of freedom is introduced, which may be used to optimize the transmission of the transmissive and reflective sub-pixels. By using the invention, it is possible to allow the dark state

of the reflective and transmissive sub-pixels to have different values of u_{eff} . Consequently, the dark states of the different sub-pixels may be at different voltages. Suitably, one of said sub-pixels is provided with a sub-pixel voltage altering device. By including said voltage altering device in one of the sub-pixels, it is possible to drive the liquid crystal cells of the reflective and transmissive sub-pixels at mutually different voltages. By including a voltage altering device in the sub-pixel, it is also possible to use simpler driving integrated circuits and to reduce the number of data lines of the display.

[0015] Preferably, said sub-pixel voltage altering device is connected in series with a liquid crystal cell of said one sub-pixel. Thereby, the above-described voltage altering may be achieved by voltage division, being a rather straight-forward method. According to a preferred embodiment of this invention, said sub-pixel voltage altering device is constituted by a first capacitor. Thereby, a simple, stable and cost-efficient device for voltage altering is achieved.

[0016] Furthermore, a second altering circuit is suitably connected in parallel with the liquid crystal cell of said one sub-pixel, being connected in series with said sub-pixel voltage altering device. Thereby, a single voltage in the driving electronics corresponds to a single gray-level of both sub-pixels, resulting in the use of comparatively simple drive electronics for the display. Preferably, said second altering circuit is constituted by a second capacitor. Thereby, a simple, stable and cost-efficient device is achieved.

[0017] According to an alternative embodiment of this invention, said reflective and transmissive sub-pixel comprises a first and a second liquid crystal layer segment, respectively, having mutually different twist angles. Thereby, an extra degree of freedom for the choice of compensation foil(s) and polariser orientation on the backlit side of the transmission sub-pixel is achieved, which may be used to increase the overall efficiency of the backlight.

[0018] Moreover, said sub-pixel voltage altering device is preferably arranged to alter a voltage applied to said one sub-pixel by a data line of said display. Thereby, a common voltage may be applied to all data lines, resulting in the use of comparatively simple drive electronics for the display.

[0019] The objects of the present invention is also achieved by a method, as described by way of introduction, comprising the steps of

[0020] applying a first driving voltage (V1) over said first liquid crystal cell and

[0021] applying a second driving voltage (V2) over said second liquid crystal cell, said first driving voltage being different from said second driving voltage.

[0022] Thereby, an extra degree of freedom is introduced, which may be used to optimize the transmission of the transmissive and reflective sub-pixels. By using the invention, it is possible to allow the dark state of the reflective and transmissive sub-pixels to have different values of u_{eff} . Consequently, the dark states of the different sub-pixels may be at different voltages.

[0023] Preferably, when the liquid crystal display comprises in said first sub-pixel a sub-pixel altering device the method further comprises the steps of:

[0024] applying a common voltage VTOT, equal to the desired second driving voltage (V2), over said first and second sub-pixels, respectively, the voltage over said first liquid crystal cell (15a) due to the sub-pixel voltage altering device being substantially equal to said first driving voltage (V1), when the second driving voltage is applied to the second sub-pixel.

[0025] Thereby, a single driving circuit, providing a single data voltage may be used. Moreover, the method suitably comprises the step of determining said driving voltages individually in order to optimize the reflection in case of a reflective sub-pixel or the transmission in case of a transmissive sub-pixel of said display device.

[0026] According to a preferred embodiment of this invention, the step of arranging in said first sub-pixel, a sub-pixel voltage altering device, comprises the step of arranging said sub-pixel voltage altering device in series with said liquid crystal cell of said one sub-pixel. Thereby, the inventive voltage difference between the liquid crystal cells is readily achieved by means of voltage division. Preferably, said sub-pixel voltage altering device is constituted by a first capacitor, being a cost-efficient and straight-forward way of achieving the inventive result.

[0027] According to an alternative embodiment, the method further comprises the step of connecting a second altering circuit in parallel with the liquid crystal cell of said one sub-pixel, being connected in series with said sub-pixel voltage altering device, resulting in a further degree of freedom when determining the exact relation between the first driving voltage and the second driving voltage. Suitably, said second altering circuit is constituted by a second capacitor.

[0028] According to yet a preferred embodiment of the invention, the method further comprises the steps of:

[0029] determining a desired first twist angle of a liquid crystal layer of said first sub-pixel,

[0030] determining a desired second twist angle of a liquid crystal layer of said second sub-pixel, said first and second twist angles being mutually different,

[0031] applying said first and second twist angles to a respective liquid crystal layer of said first and second sub-pixels. Thereby, an extra degree of freedom for the choice of compensation foil(s) and polariser orientation on the backlit side of the transmission sub-pixel is achieved, which may be used to increase the overall efficiency of the backlight.

[0032] This invention will hereinafter be described in closer detail, with reference to the accompanying drawings.

[0033] FIG. 1 is a schematic drawing showing a cross-section of a transfective display pixel.

[0034] FIG. 2 is a circuit diagram showing a first embodiment of this invention.

[0035] FIG. 3 is a second circuit diagram showing a second embodiment of this invention.

[0036] FIG. 4 is a diagram showing the reflection and transmission vs. the driving voltage for a non-twisted transfective cell.

[0037] FIG. 5 is a diagram showing the reflection and transmission vs. the driving voltage for a 57° twisted transreflective display.

[0038] FIG. 6 is a diagram showing the reflection and transmission vs. the driving voltage for a 63°/90° twisted transreflective cell.

[0039] FIG. 7a is a diagram showing the contrast ratio for the reflective sub-pixel of the 63° twisted nematic display.

[0040] FIG. 7b is a diagram showing the contrast ratio for the transmissive sub-pixel of the 63° twisted nematic display.

[0041] FIG. 7c is a diagram showing the contrast ratio for the transmissive sub-pixel of the 63°/90° twisted nematic display.

[0042] In FIG. 1, a transreflective liquid crystal display arrangement 11 is shown. A transreflective display is a display that might be driven in a reflective mode and/or a transmissive mode. The display according to FIG. 1 comprises a liquid crystal layer 12, in the present embodiment being a twisted nematic liquid crystal layer. This layer 12, is sandwiched between a transparent front electrode 13 and a back electrode 14. Furthermore, orientation layers (not shown) are arranged on said electrodes 13, 14 in order to induce an equilibrium orientation as well as twist and pre-tilt angles of the liquid crystal material layer 12. The display 11 is subdivided into a plurality of pixels, and the pixels are arranged in a plurality of data lines and addressing lines in accordance with prior art. FIG. 1 schematically shows one such pixel.

[0043] As shown in FIG. 1, each pixel is subdivided into a first and a second sub-pixel 11a, 11b, respectively not necessarily having the same area, whereby said first sub-pixel 11a is referred to as a transmissive sub-pixel and said second sub-pixel is referred to as a reflective sub-pixel. Each transmissive sub-pixel 11a contains a first back electrode part 14a, being transparent, e.g. manufactured from ITO, and each reflective sub-pixel comprises a second back electrode part 14b, being combined with a reflector, such as an aluminum layer or the like. Said first electrode part 14a consequently defines a transmitting pixel part, and said second electrode part 14b defines a reflective pixel part. Together, said liquid crystal layer 12 and said electrodes 13, 14 constitute a first and a second liquid crystal cell 15a, 15b. It shall be noted especially that both sub-pixels of the cell have approximately the same cell gap.

[0044] Furthermore, the liquid crystal cells are sandwiched between a front optical foil 16a and a back optical foil 16. Moreover, on the viewer side of the device a front polarizer 17a is arranged, and on the backside, a back polarizer 17b and a backlight panel 18 is arranged, as indicated in FIG. 1.

[0045] A first embodiment of the invention is disclosed in FIG. 2. FIG. 2 shows an electrical equivalent for a single pixel (data line m and addressing line n of the display device), having a transmissive and a reflective sub-pixel as described above. The transmissive sub-pixel is here schematically represented by a capacitance C_T and the reflective sub-pixel is schematically represented by a capacitance C_R . In FIG. 2, no consideration is taken to parasitic capacitances. The values of C_T for the transmissive sub-pixel and

C_R for the reflective sub-pixel are depending upon for example the average orientation of the liquid crystal molecules in the liquid crystal cell of the respective sub-pixel, and are therefore dependant on an applied voltage over each liquid crystal cell. The circuit shown in FIG. 2 also comprises a storage capacitor C_{store} , being connected between addressing line n and the previous or next addressing line of the display on per se known manner, but its function is not essential for this invention and will therefore not be closer described herein.

[0046] However, in accordance with the invention a voltage altering device, here a first capacitance C_1 , is arranged in series with one of the transmissive sub-pixel and the reflective sub-pixel C_R, C_T respectively. In the embodiment shown in FIG. 2, the first capacitor C_1 is connected in series with the reflective sub-pixel C_R , and thereby, a voltage V_R over the reflective sub-pixel C_R is lowered, due to voltage division over C_1 and C_R .

[0047] Given that V_T is the voltage over the transmissive sub-pixel C_T in FIG. 2, then the voltage V_R over the reflective sub-pixel C_R is given by:

$$V_R = \frac{C_1}{C_1 + C_R} V_T = \alpha V_T$$

[0048] Since C_R in the above relationship is depending upon the driving state of the liquid crystal (since C_R is a schematic representation of the reflective sub-pixel, as stated above), so is α . For example, for a liquid crystal material having a positive value of $\Delta\epsilon$ (dielectric anisotropy), the value of α is closer to 1 for a planar, non-switched state, and decreases as the molecular tilt of the liquid crystal material increases (due to switching).

[0049] Correspondingly, if the first capacitance C_1 is connected in series with the transmissive sub-pixel C_T , the voltage over the transmissive sub-pixel may be lowered in a corresponding way as described above.

[0050] Further, a second embodiment of the invention is disclosed in FIG. 3. FIG. 3 discloses an electrical equivalent for a single pixel (data line m and addressing line n of the display device), having a transmissive and a reflective sub-pixel as described above. The transmissive sub-pixel is here also schematically represented by a capacitance C_T and the reflective sub-pixel is schematically represented by a capacitance C_R . In FIG. 3, no consideration is taken to parasitic capacitances. The values of C_T for the transmissive sub-pixel and C_R for the reflective sub-pixel are depending upon the orientation of the liquid crystal molecules in the liquid crystal cell of the respective sub-pixel, and are therefore dependant on an applied voltage over each liquid crystal cell. The circuit shown in FIG. 3 also comprises a storage capacitor C_{store} , as described above, in connection with FIG. 2.

[0051] However, in accordance with the invention, as is also described with reference to FIG. 2, a sub-pixel voltage altering device, a first capacitance C_1 , is arranged in series with one of the transmissive sub-pixel and the reflective sub-pixel C_R, C_T respectively. Furthermore, a second altering device, here a capacitance C_2 , is connected in parallel with the same one of said transmissive sub-pixel or the reflective

sub-pixel C_R, C_T respectively. In the embodiment shown in **FIG. 3**, the first capacitor C_1 is connected in series with the transmissive sub-pixel C_T , and the second capacitor C_2 is connected in parallel with the transmissive sub-pixel C_T . In this case, given that V_R is the voltage over the reflective sub-pixel C_R in **FIG. 3**, then the voltage V_T over the transmissive sub-pixel C_T is given by:

$$V_T = \frac{C_1}{C_1 + C_2 + C_T} \cdot V_R = \beta \cdot V_R$$

[0052] Thereby, by choosing the values of the capacitors C_1 and C_2 in a suitable manner, both the value and the voltage dependence of β may be changed. A parallel capacitor, such as C_2 may be manufactured by the use of lithographic spacers. By choosing the spacer material, as well as the spacer area, a suitable flat plate capacitor is formed by the electrodes, being separated by the spacer. This method does require exact positioning of the spacers, which may be achieved by lithography.

[0053] Examples of the above embodiments of the invention will hereinafter be described.

[0054] **FIG. 4** shows the simulated reflection and transmission curves for a non-twisted transmissive display. The polarisers **17a, 17b**, as shown in **FIG. 1**, were at a 45 degree angle with respect to the LC director of the liquid crystal layer **12** and the cell gap was tuned to match an optical effective thickness of $d\Delta n/\lambda=0.5$, being a reflection maximum. In this case, the liquid crystal material has $\epsilon_{||}=2$ and $\Delta\epsilon=8.3$. Two transmission curves are plotted in **FIG. 4**. The first curve **T1** shows a prior-art solution where u_{eff} is the same for both the transmissive and the reflective sub-pixel. Since circular polarization is needed in the dark state, the transmission in the bright state is limited to 50% or less. In the second case **T2**, the transmissive sub-pixel is switched between 1.5 and 4.5 V, while the value of the first capacitor $C1$ is adjusted so that the reflective sub-pixel is switched between 1.26 V and 2.57 V. The efficiency of the backlight is thereby increased from 45% to 72%.

[0055] **FIG. 5** shows the simulated reflection and transmission curves for a 57° twisted transmissive display. The viewing side polariser **17a**, as shown in **FIG. 1**, were at a 30 degree angle with respect to the LC director at the viewing side and the cell gap was tuned to match an optical thickness of $d\Delta n/\lambda=0.88$. In this case, the liquid crystal material has $\epsilon_{||}=3.6$ and $\Delta\epsilon=6.7$. Here, three alternatives for the transmissive sub-pixel are plotted in **FIG. 5**. If both sub-pixels are switched between 1.3 V and 2 V, the backlight efficiency is only 37%. In the variant where the transmissive sub-pixel is switched between 1.5 V and 2.8 V and the reflective sub-pixel between 1.3 V and 2V, the efficiency of the backlight is increased to 90%. In the third variant where the transmissive sub-pixel is switched between 1.6 V and 2.7 V, the efficiency of the backlight is increased to 82%. In both cases, the backlight efficiency is more than doubled.

[0056] It should be noted that in all of the above-given examples, the voltage dependence of α and β , as described above, is an advantage, because lower values of α and β are needed for the black state.

[0057] It shall also be noted that the above-described are not the only reflective modes that may be used in a trans-

missive liquid crystal display in accordance with the invention, but in principle, all reflective liquid crystal modes may be used.

[0058] According to a third preferred embodiment of this invention, a transmissive display has a transmissive and a reflective sub-pixel, as is shown in **FIG. 1** and is indicated above. The transmissive sub-pixel may, in the same way as above, be schematically represented by a capacitance C_T and the reflective sub-pixel may be schematically represented by a capacitance C_R . In accordance with the invention a sub-pixel voltage altering device, such as a first capacitance C_1 , is arranged in series with one of the transmissive sub-pixel and the reflective sub-pixel C_R, C_T respectively. By connecting one of the sub-pixels in series with a capacitor, both sub-pixels may be driven at different voltages. Furthermore, the liquid crystal material of the reflective and transmissive sub-pixels, respectively, are arranged to have different twist angles. This may be achieved by photo-alignment of said orientation layers as is known in the prior art, as the use of photo-alignment makes it possible to define the orientation of the liquid crystal molecules locally. The advantage of this is that two degrees of freedom (dark state voltage and twist angle) are available when choosing compensation foil(s) and to increase the efficiency of the backlight. By carefully choosing the twist angle of the transmissive sub-pixel, both the grayscale linearity and/or the viewing angle may be improved, while the driving voltages may be lowered as will be described below. This results in a significant power reduction as well as an improvement of the viewing angle.

[0059] An example of the reflection and transmission of a display according to the above-described third embodiment of this invention is shown in **FIG. 6**. **FIG. 6** shows the reflection vs. voltage and transmission vs. voltage curves for a transmissive display in accordance with the invention, having a twist angle of 63° for the reflective sub-pixels. The liquid crystal material and the cell gap are tuned so that $d\Delta n/\lambda=0.75$ and the liquid crystal material has $\epsilon_{||}=3.6$ and $\Delta\epsilon=6.7$. By increasing the voltage on the transmissive sub-pixel (and applying a suitable correction foil on the backlit side of the display), an increase of the backlight efficiency from 40% to 80% is achieved, as seen in **FIG. 6**. **FIG. 2** also shows the corresponding curve for a 90° twisted cell. There are two advantages of increasing the twist angle. First, the dark state is reached at a lower voltage, which saves power, both in the display panel and in the driver integrated circuits. Second, the efficiency of the backlight is even higher. Thereby, by driving the transmissive sub-pixel between 3.8 V and 1.6 V and the reflective sub-pixel between 2.5 V and 1.3 V, a backlight efficiency of 90% is achieved. The differences in grayscale linearity between both sub-pixels are minimal. In order to achieve the same amount of grayscale similarity for the 63° twisted case, one would have to drive the bright state at 1.9 V, which decreases the backlight efficiency to 75%.

[0060] **FIG. 7a** shows the contrast ratio of the reflective sub-pixel. The contrast ratio was calculated as the ratio of the reflectivity of the bright and dark states, respectively, where the dark state was at 2.5 V in this case. **FIG. 7b** shows the contrast ratio of the transmissive sub-pixel, while **FIG. 7c** shows the same for the 90° twisted transmissive sub-pixel. In all three figures, the contrast ratio around the normal viewing direction is much higher than 25. As may be seen from **FIGS. 7b** and **7c**, this central part with contrast

ratio higher than 25, is larger for the 90° twisted solution than for the 63° twisted solution.

[0061] This viewing angle improvement is achieved without the use of an extra compensation foil. By using compensation foils, which do not alter the polarization state of perpendicular incident light, the viewing angle properties of the display may of course be improved even further.

[0062] In summary, a transreflective display has been proposed, which has separate reflective and transmissive sub-pixels. Such a display may be operated in both modes at the same time, thereby greatly increasing the range of applications. Both sub-pixels may be driven at different voltages. This gives an extra degree of freedom for the choice of compensation foil(s) and polariser orientation on the backlit side of the transmission sub-pixel, which may be used to increase the overall efficiency of the backlight. This may be achieved by including a voltage altering device in one of the sub-pixels. One example that is given is the inclusion of a capacitor, being connected in series with the liquid crystal cell of the sub-pixel, thereby utilizing voltage division.

[0063] In this way, the efficiency of the backlight may be more than doubled, which will remarkably increase the battery life of for example a mobile device containing such an inventive display. This solution is also easier to fabricate, in relation to the alternative solution with different cell gaps for different sub-pixels. Furthermore, the transmissive cell gap need not be twice as big as the reflective cell gap (as is the case in prior art devices), which simplifies the manufacturing of the inventive device. Further, the inventive solution provides for a higher transmission than prior art single gap devices and moreover the use of photoalignment is not necessary.

[0064] Alternatively, a transreflective display is proposed, which has separate reflective and transmissive sub-pixels with different twist angles. The different twist angles may be achieved by photo-alignment. Both sub-pixels may be driven at different voltages. This gives an extra degree of freedom for the choice of compensation foil(s) and polariser orientation on the backlit side of the transmission sub-pixel, which may be used to increase the overall efficiency of the backlight. This may be achieved by including a voltage altering device in one of the sub-pixels. One example that is given is the inclusion of a capacitor, being connected in series with the liquid crystal cell of the sub-pixel, thereby utilizing voltage division. In this way the backlight efficiency may be more than doubled, as is shown above. By carefully choosing the twist angle of the transmissive sub-pixel, both the grayscale linearity and viewing angle of the display may be improved, while at the same time the driving voltages are lowered. This results in a significant power reduction and viewing angle improvement.

[0065] It shall be noted that the above-described voltage difference for different sub-pixels may be achieved by letting different driving voltages be generated directly by a driving integrated circuit (i.e. integrating a voltage altering device in the driving IC) or by including the voltage altering device in the sub-pixel, as is described above. The latter method is advantageous in that simpler driving integrated circuits may be used and the number of data lines in the display may also be reduced.

[0066] It shall also be noted that the above-described sub-pixel voltage altering device may be realized as a more

complicated circuit than the above single capacitor. For example, in the case of a LTPS (Low temperature Poly-Si) display, a voltage altering device comprising several transistors, resistors and capacitors is preferred.

1. A transreflective liquid crystal display device, having at least one pixel, comprising a reflective sub-pixel including a first liquid crystal cell and a transmissive sub-pixel including a second liquid crystal cell, characterized in that said first and second liquid crystal cells are arranged to be driven at mutually different driving voltages.

2. A display device as in claim 1, wherein one of said sub-pixels is provided with a sub-pixel voltage altering device.

3. A display device as in claim 2, wherein said sub-pixel voltage altering device is connected in series with a liquid crystal cell of said one sub-pixel.

4. A display device as in claim 2, wherein said sub-pixel voltage altering device is constituted by a first capacitor.

5. A display device as in claims 2-4, wherein a second altering circuit is connected in parallel with the liquid crystal cell of said one sub-pixel, being connected in series with said sub-pixel voltage altering device.

6. A display device as in claim 5, wherein said second altering circuit is constituted by a second capacitors.

7. A display device as in claim 1, wherein the liquid crystal material of said first and a second liquid crystal cells, have mutually different twist angles.

8. A display device as in claims 2, wherein said sub-pixel voltage altering device is arranged to alter a voltage applied to said one sub-pixel by a data line of said display.

9. A method for addressing a transreflective liquid crystal display device, having at least one pixel, comprising a first sub-pixel including a first liquid crystal cell and a second sub-pixel including a second liquid crystal cell comprising the following steps:

applying a first driving voltage over said first liquid crystal cell and

applying a second driving voltage over said second liquid crystal cell, said first driving voltage being different from said second driving voltage.

10. A method according to claim 9, in which the liquid crystal display comprises in said first sub-pixel, a sub-pixel voltage altering device, the method further comprising the steps of:

applying a common voltage, equal to the desired second driving voltages, over said first and second sub-pixels, respectively, the voltage over said first liquid crystal cell due to the sub-pixel voltage altering device being substantially equal to said first driving voltage, when the second driving voltage is applied to the second sub-pixel.

11. The method according to claim 10, said driving voltages having been individually determined in order to optimize the reflection in case of a reflective sub-pixel or the transmission in case of a transmissive sub-pixel of said display device.

12. The method according to claim 10, in which said sub-pixel voltage altering device is arranged in series with said liquid crystal cell of said one sub-pixel.

13. The method according to claim 10, wherein said sub-pixel voltage altering device is constituted by a first capacitors.

14. The method according to claim 10, the device further comprising a second altering circuit in parallel with the liquid crystal cell of said one sub-pixel, being connected in series with said sub-pixel voltage altering device.

15. The method according to claim 14, wherein said second altering circuit is constituted by a second capacitors.

16. The method according to claims 9, the device further comprising a first twist angle of a liquid crystal layer of said first sub-pixel, and a second twist angle of a liquid crystal layer of said second sub-pixel, said first and second twist angles being mutually different.

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申请(专利权)人(译)	罗森达尔SANDER JURGEN		
当前申请(专利权)人(译)	皇家飞利浦电子N.V.		
[标]发明人	ROOSENDAAL SANDER JURGEN		
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摘要(译)

透反液晶显示装置技术领域本发明涉及一种半透半反液晶显示装置(11)，其具有至少一个像素，包括包括第一液晶单元的反射子像素(11b)和包括第二液晶的透射子像素(11a)。细胞。该装置的特征在于，所述第一和第二液晶单元布置成以相互不同的驱动电压驱动。本发明还涉及一种用于驱动这种透反射显示器的方法。

