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(54) **TRANSFLECTIVE LIQUID CRYSTAL DISPLAY**

(52) **U.S. Cl. 345/92**

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(57) **ABSTRACT**

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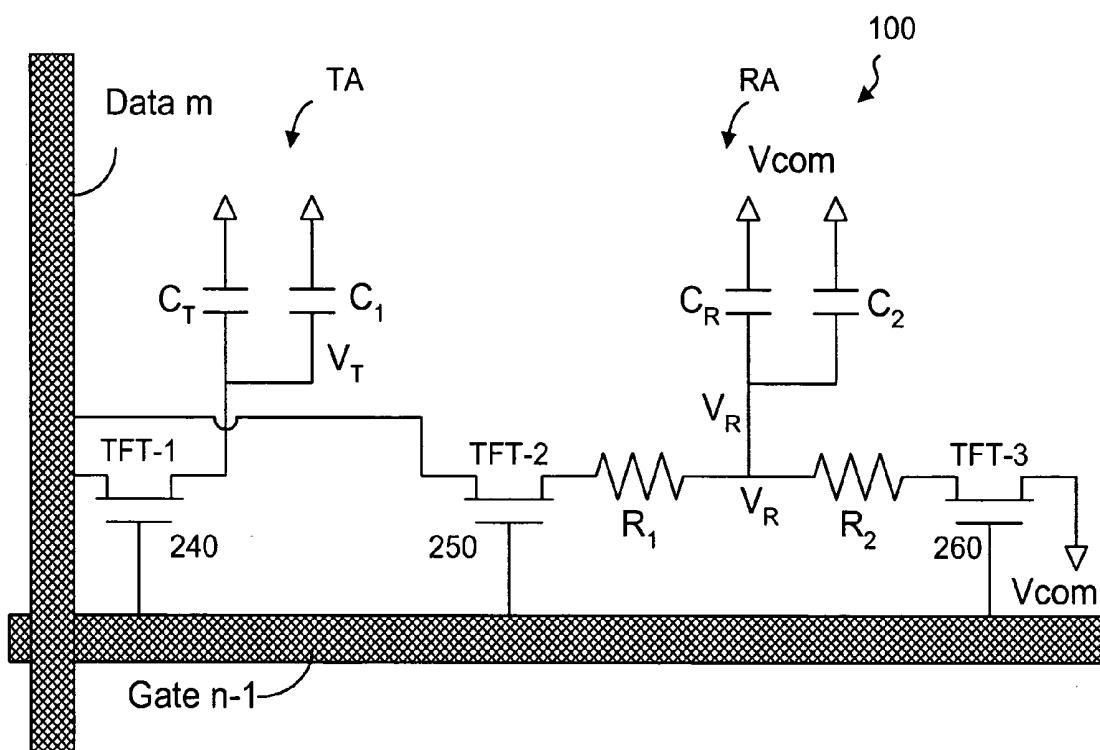
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G09G 3/36 (2006.01)

A single-gap transflective LCD panel having a voltage divider in each sub-pixel for reducing the voltage potential across part of the liquid crystal layer in the sub-pixel. In a normally-black LCD panel, the voltage divider is used to reduce the voltage potential across the liquid crystal layer in the reflection area. In a normally-white LCD panel, the voltage divider is used to reduce the voltage potential across the liquid crystal layer in the transmission area. The voltage divider comprises two poly-silicon resistor segments connected in series between a data line and a common line via one or more switching elements controlled by a gate line signal. With poly-silicon resistor segments being disposed in the reflection area below the reflective electrode, the optical quality of the upper electrode and the transmissive electrode is not affected by the voltage divider.



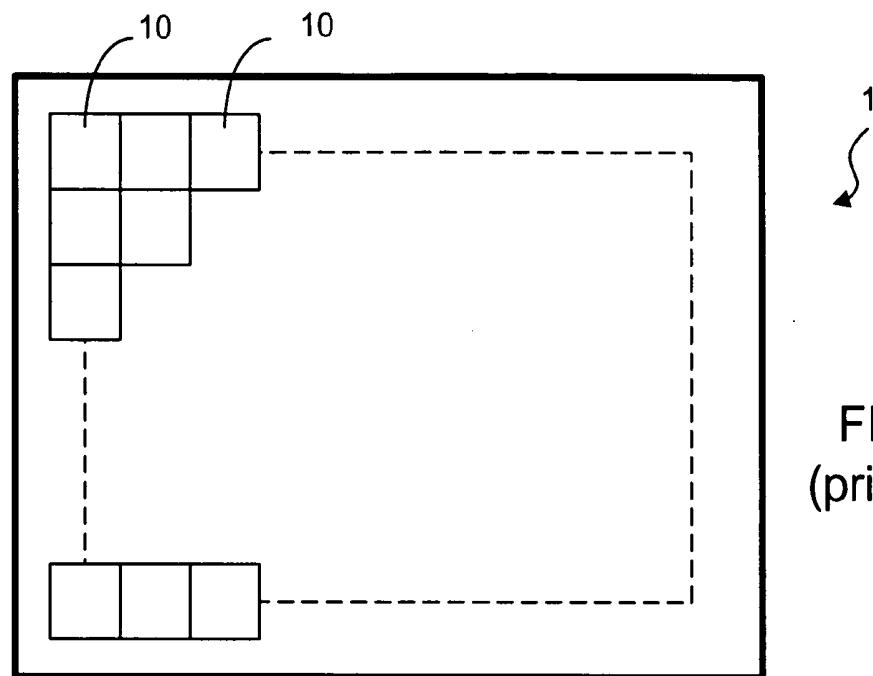


FIG. 1
(prior art)

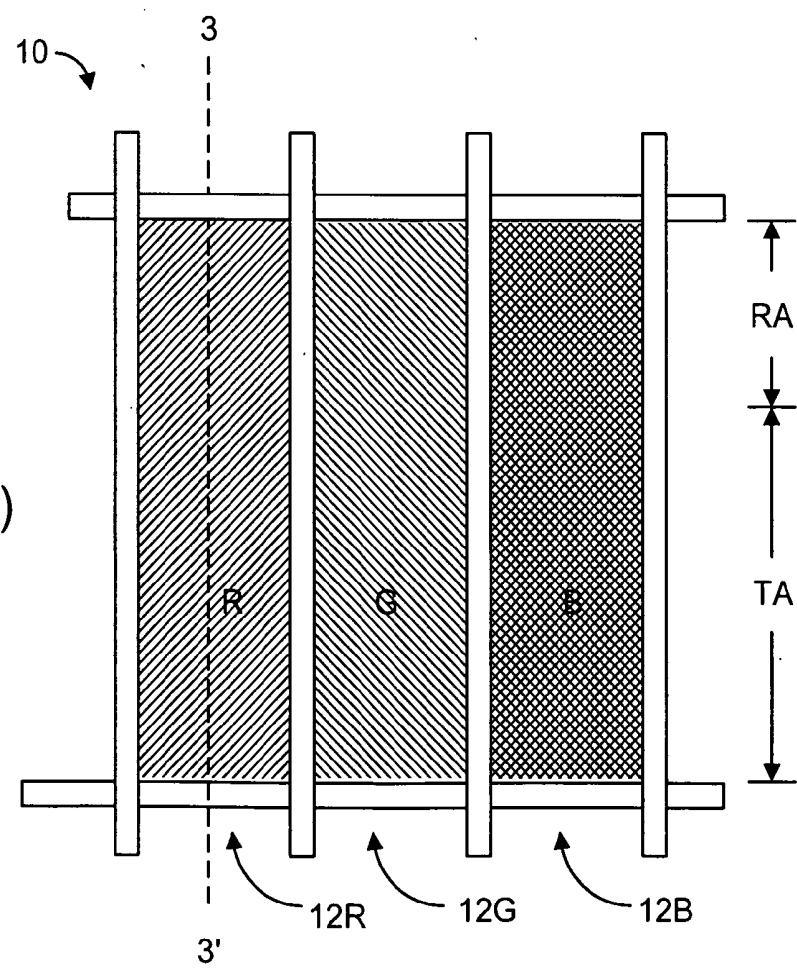


FIG. 2
(prior art)

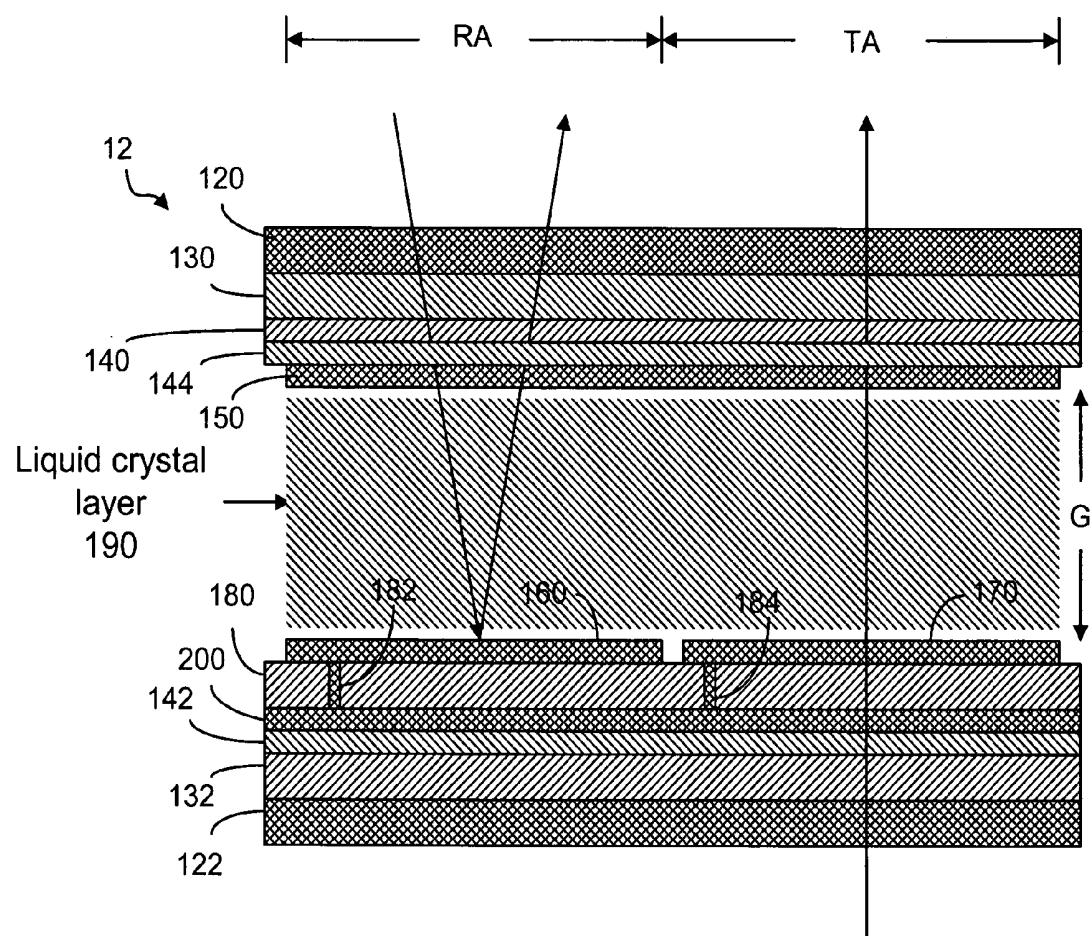


FIG. 3
(prior art)

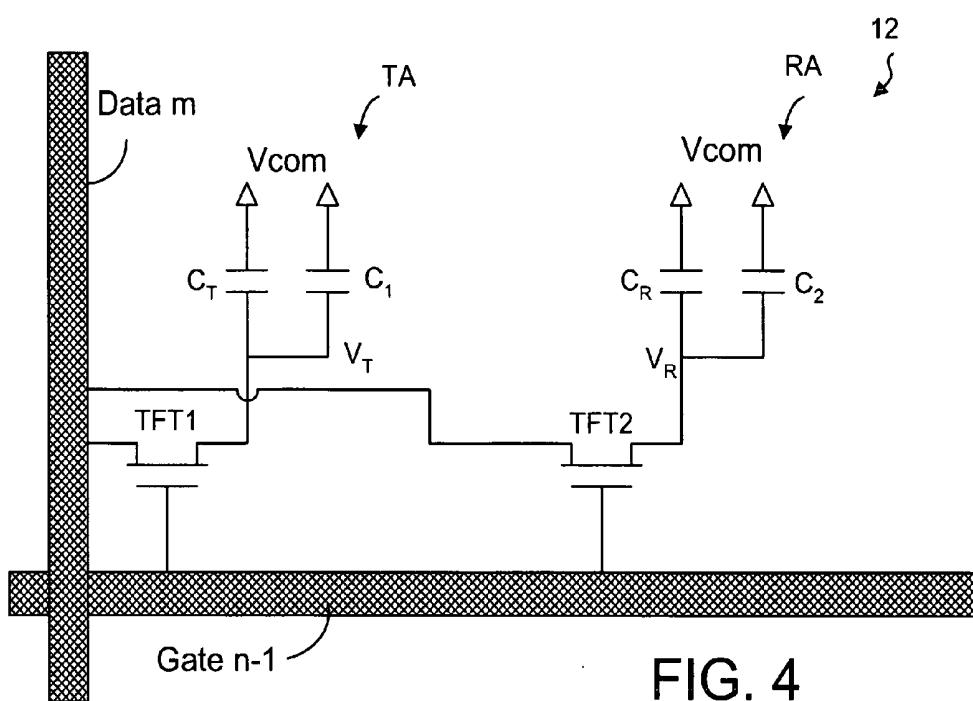


FIG. 4
(prior art)

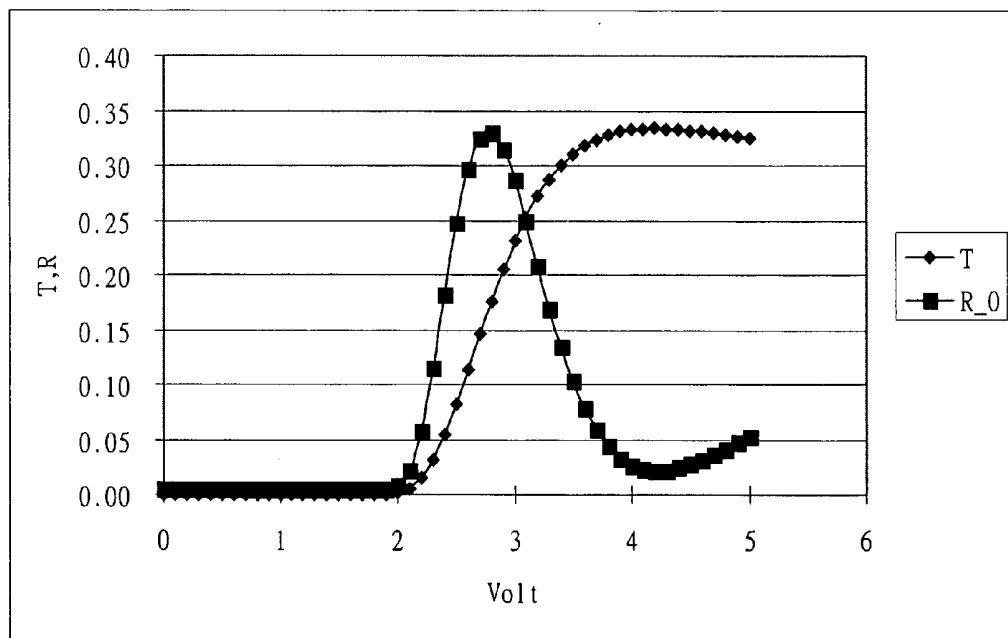


FIG. 5

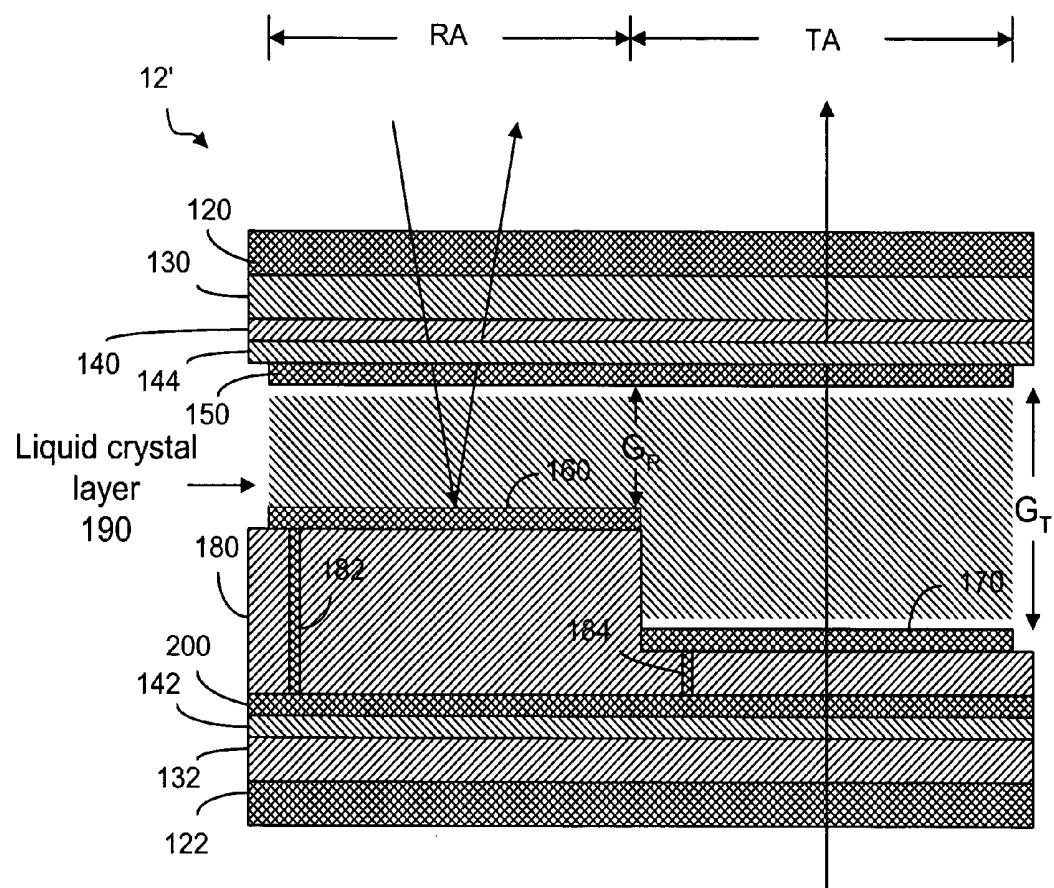


FIG. 6
(prior art)

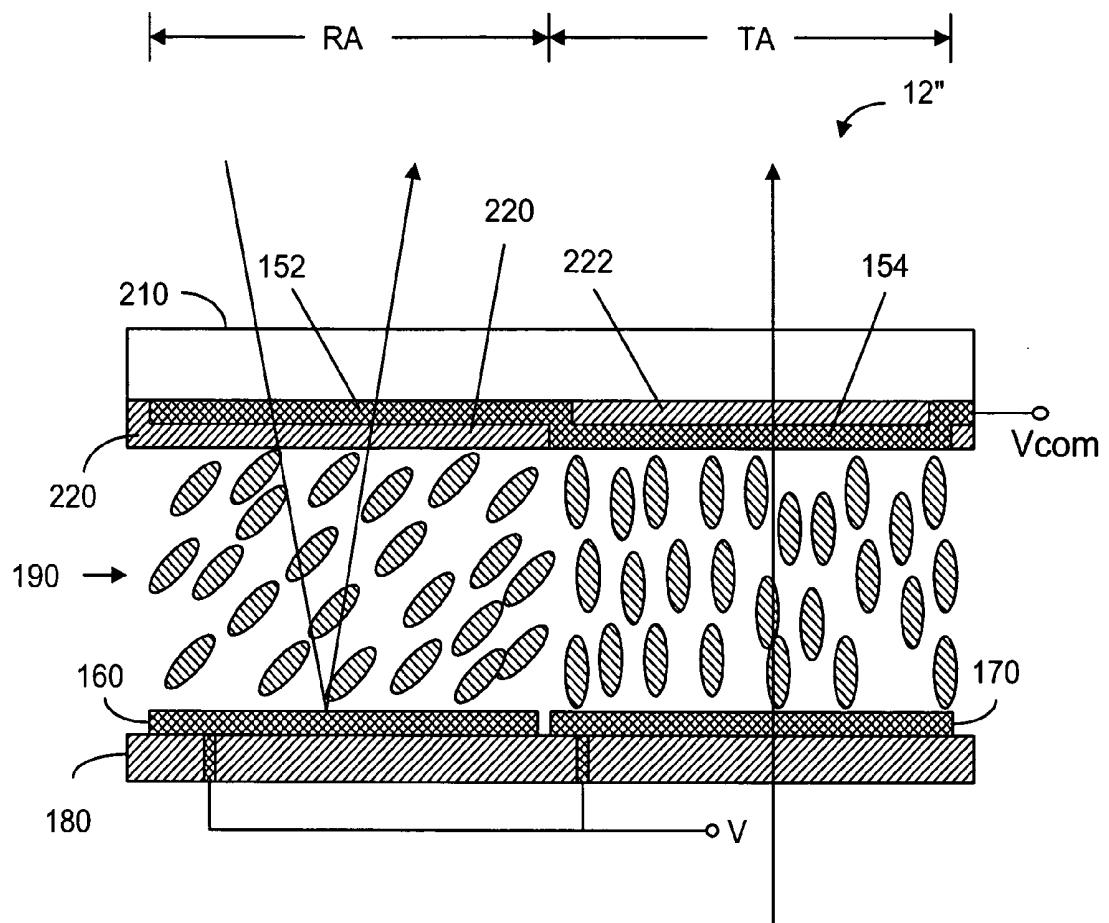


FIG. 7
(prior art)

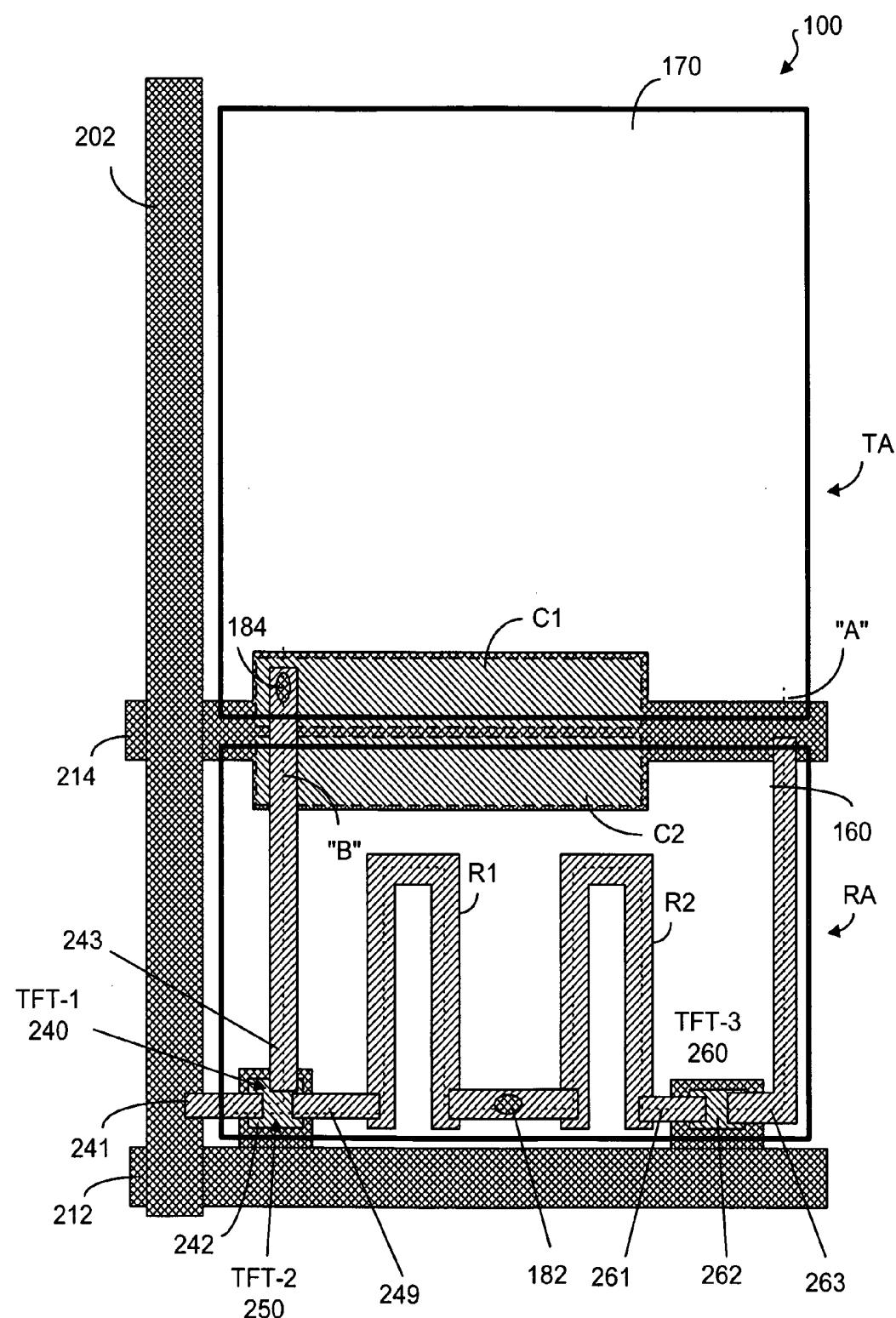


FIG. 8

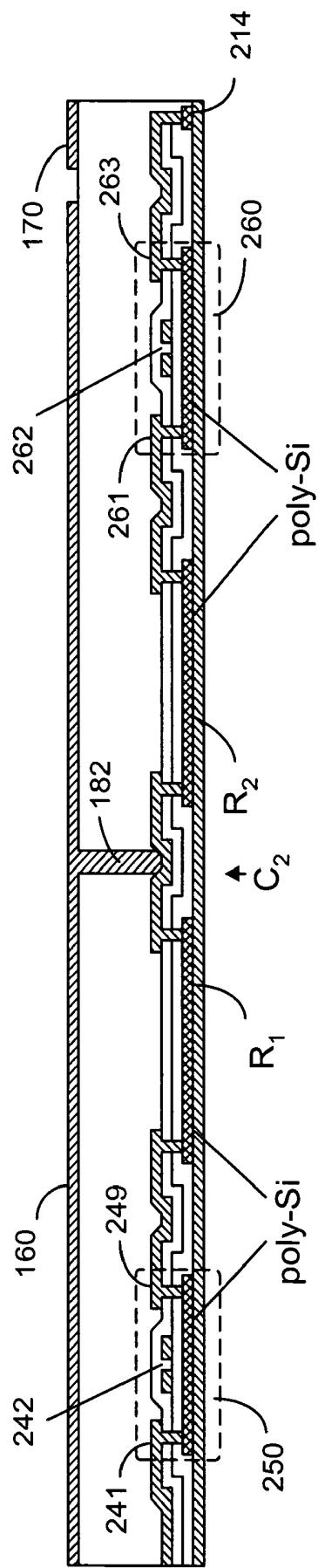


FIG. 9A

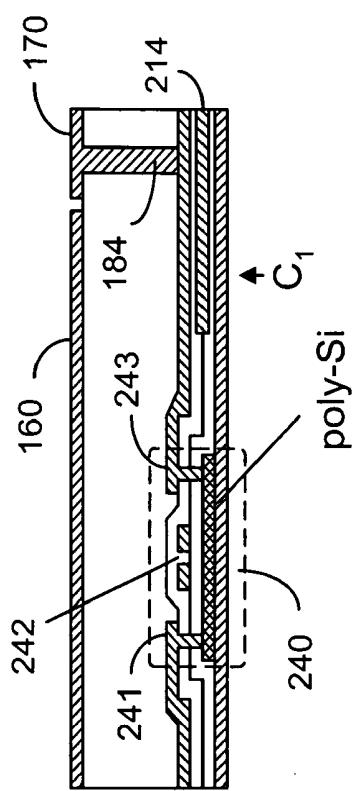


FIG. 9B

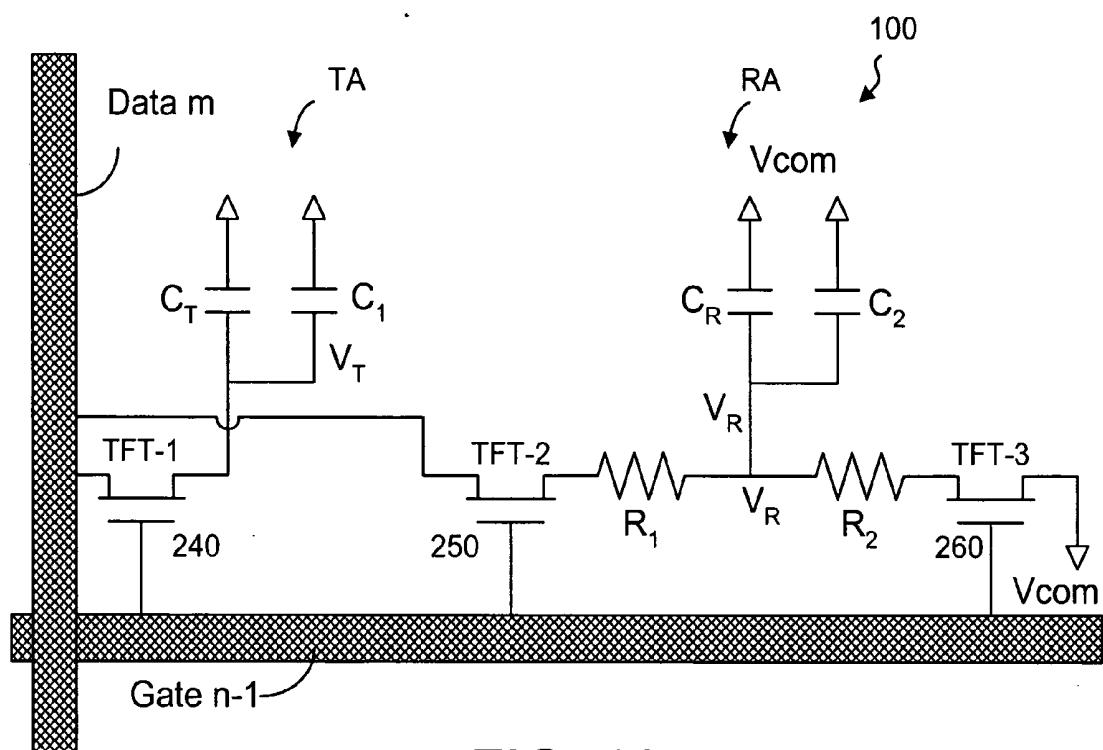


FIG. 10

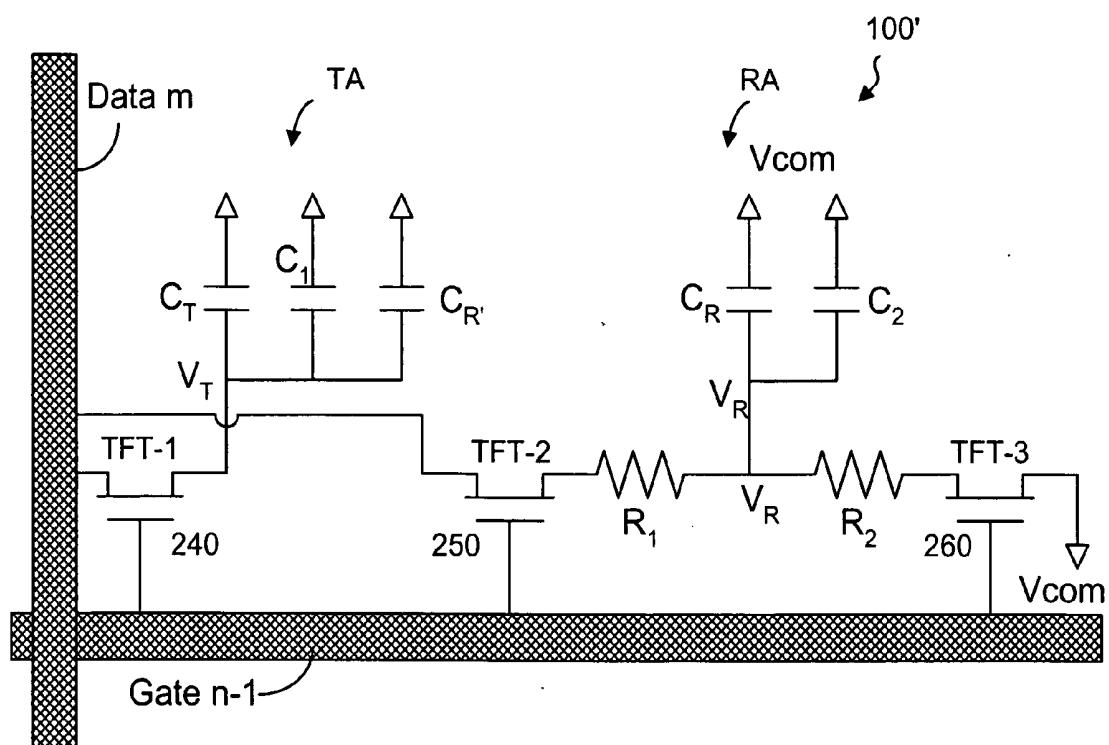


FIG. 14

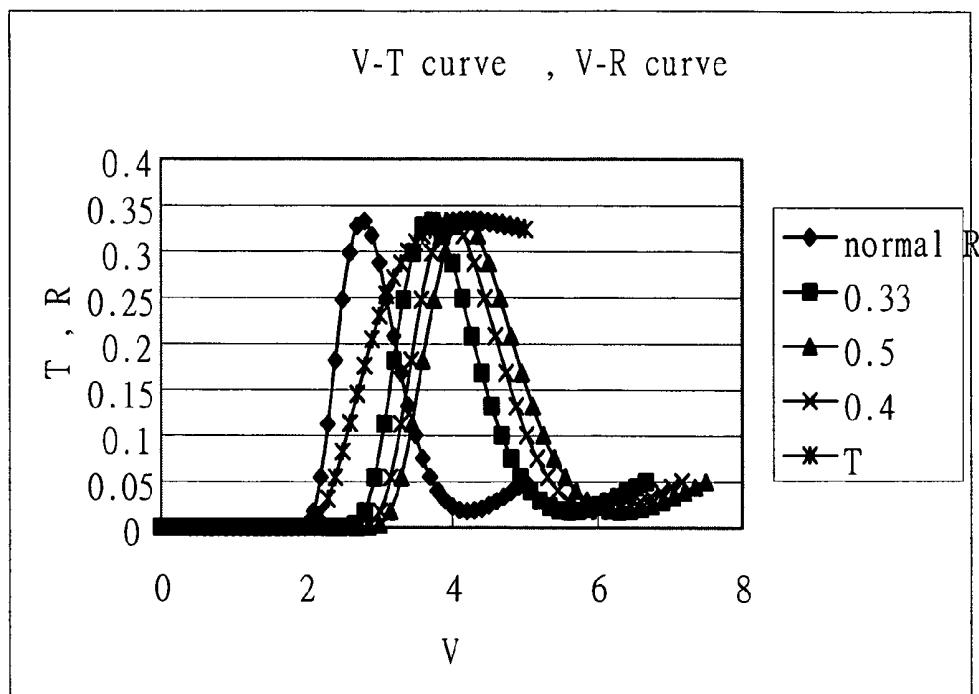


FIG. 11

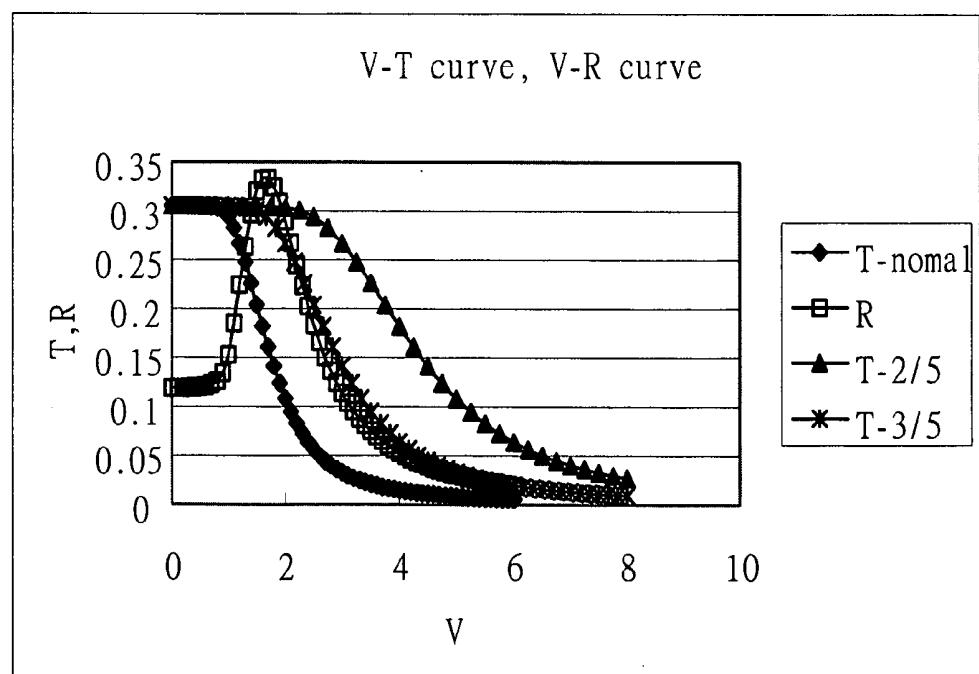


FIG. 17

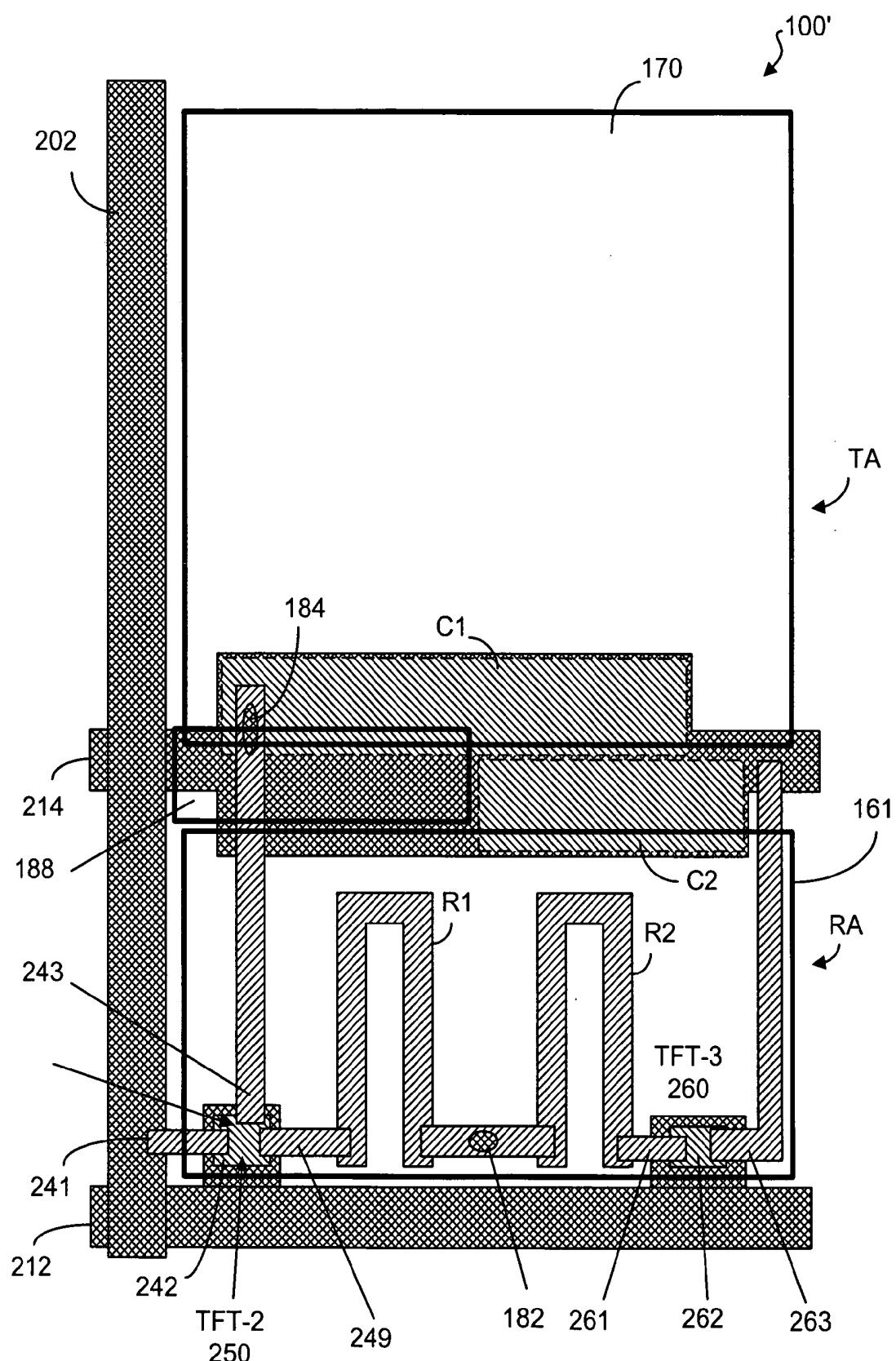


FIG. 12

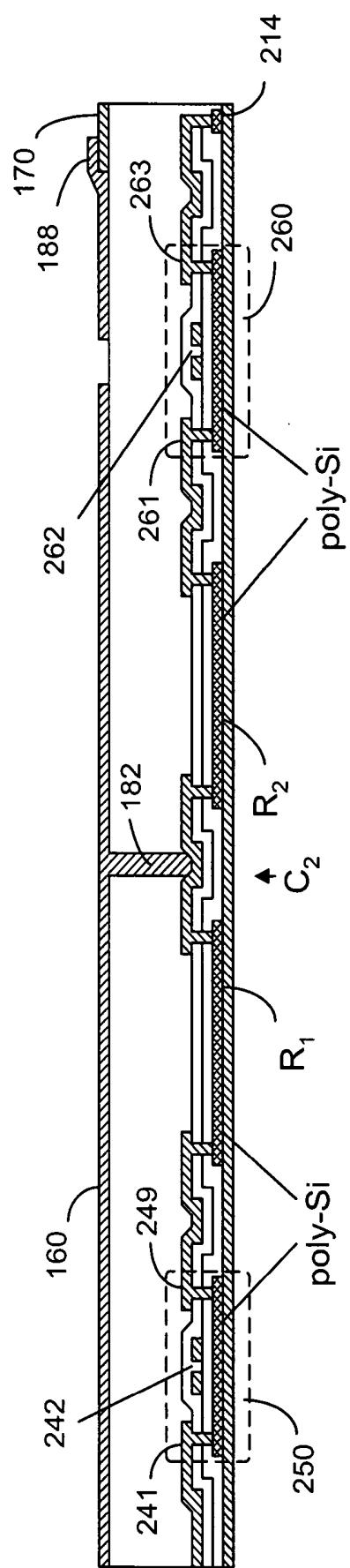


FIG. 13A

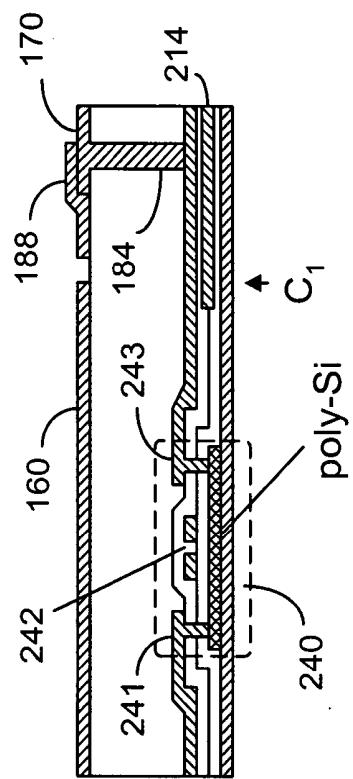


FIG. 13B

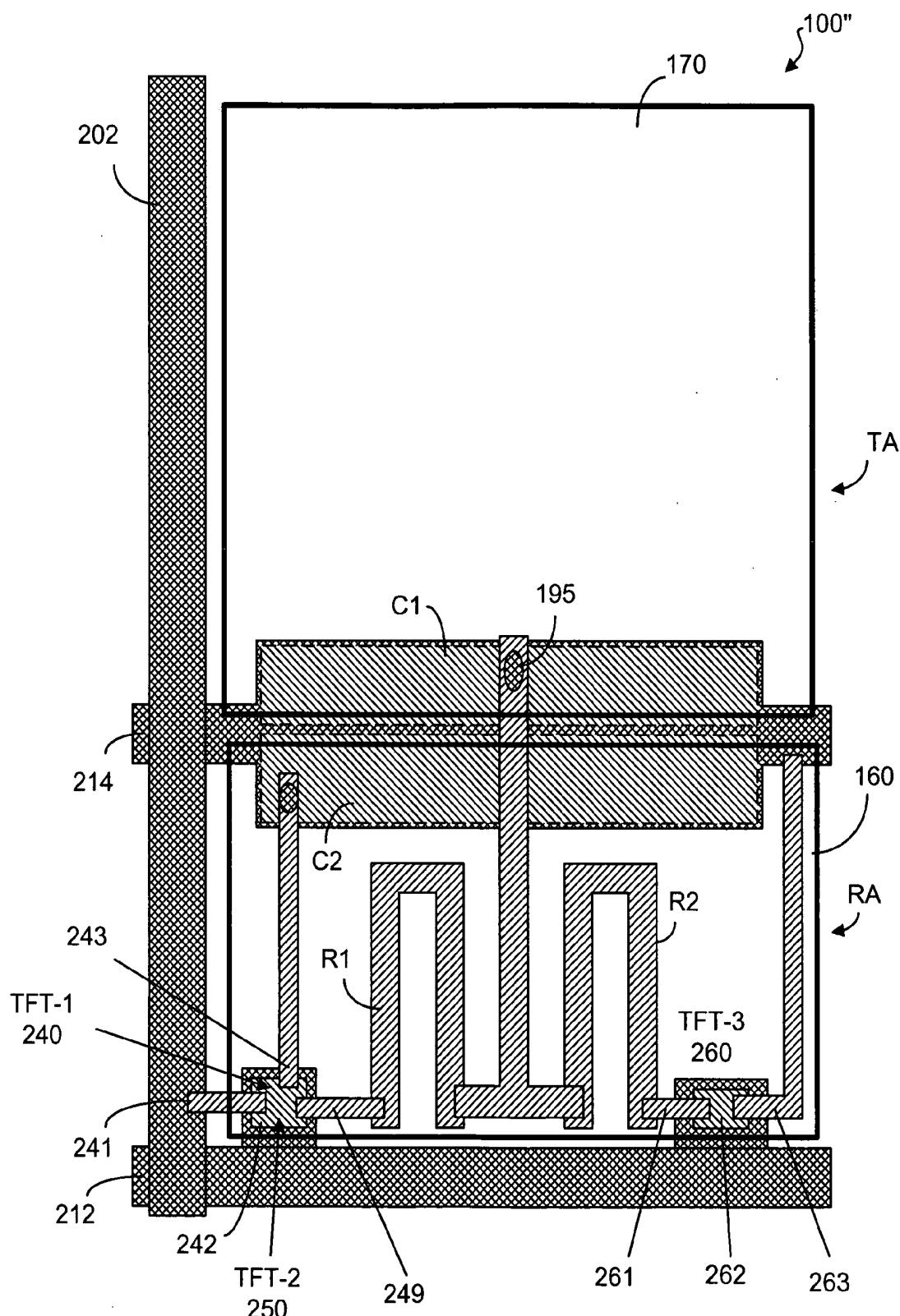


FIG. 15

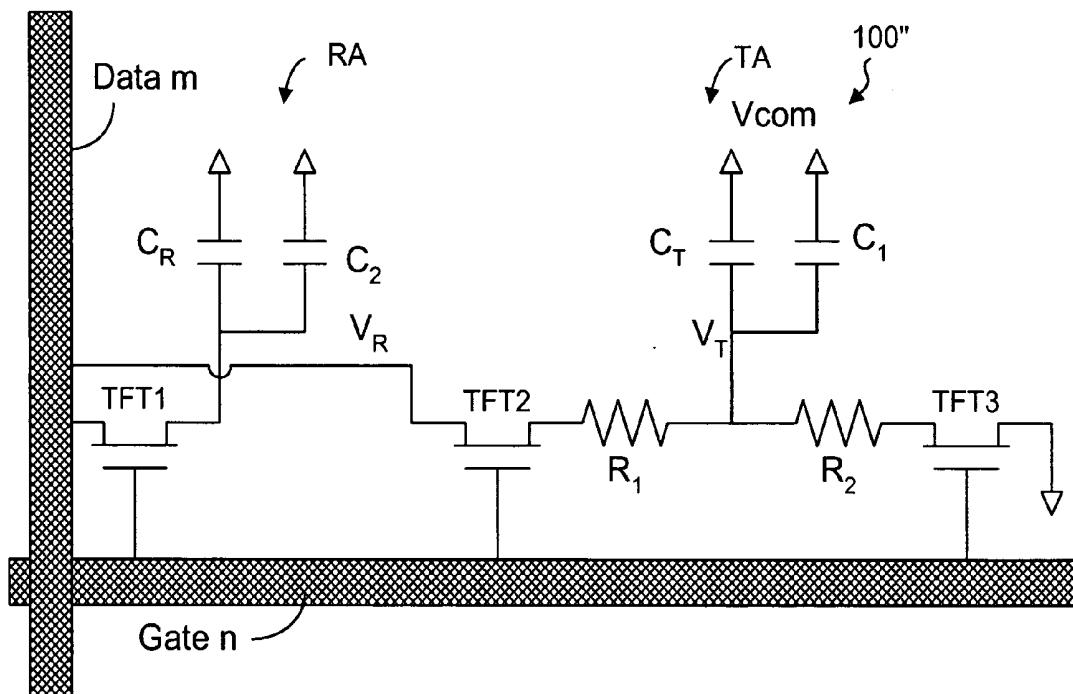


FIG. 16

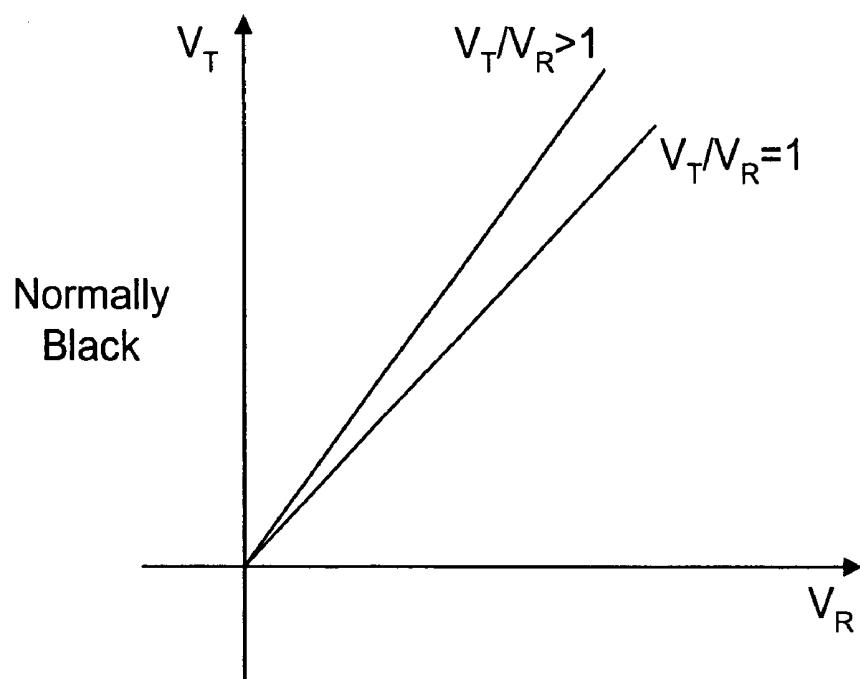


FIG. 18

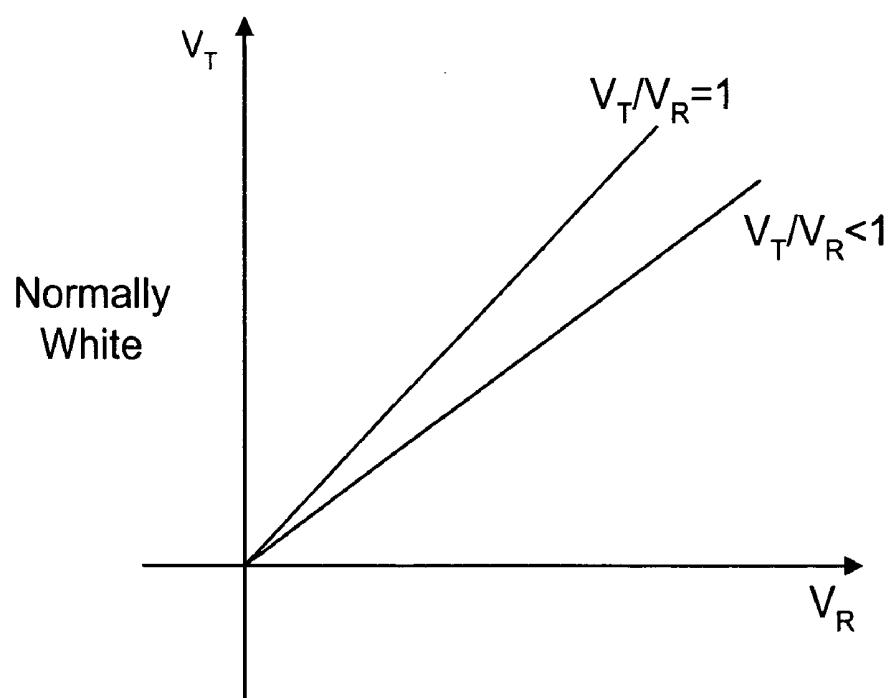


FIG. 20

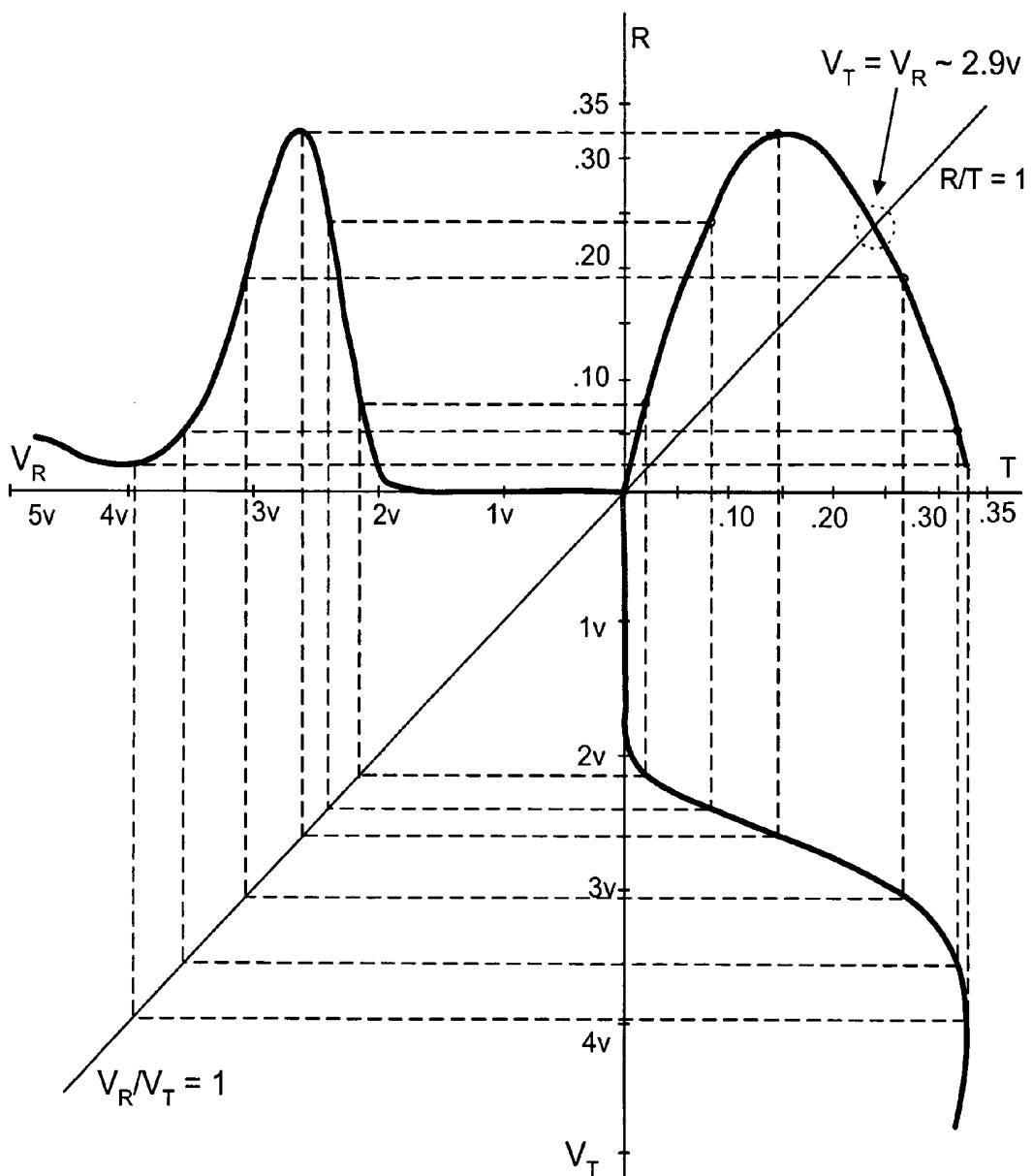


FIG. 19a

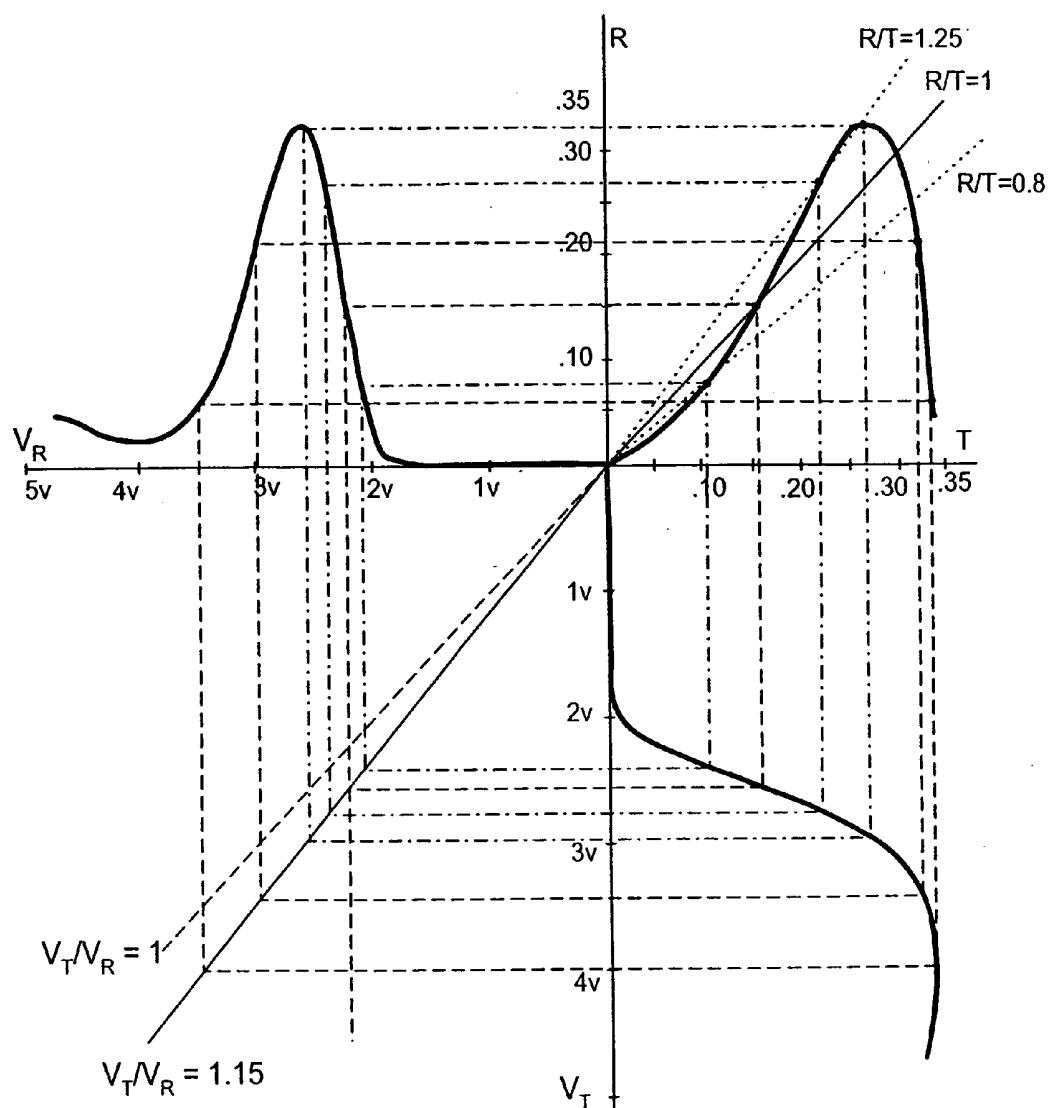


FIG. 19b

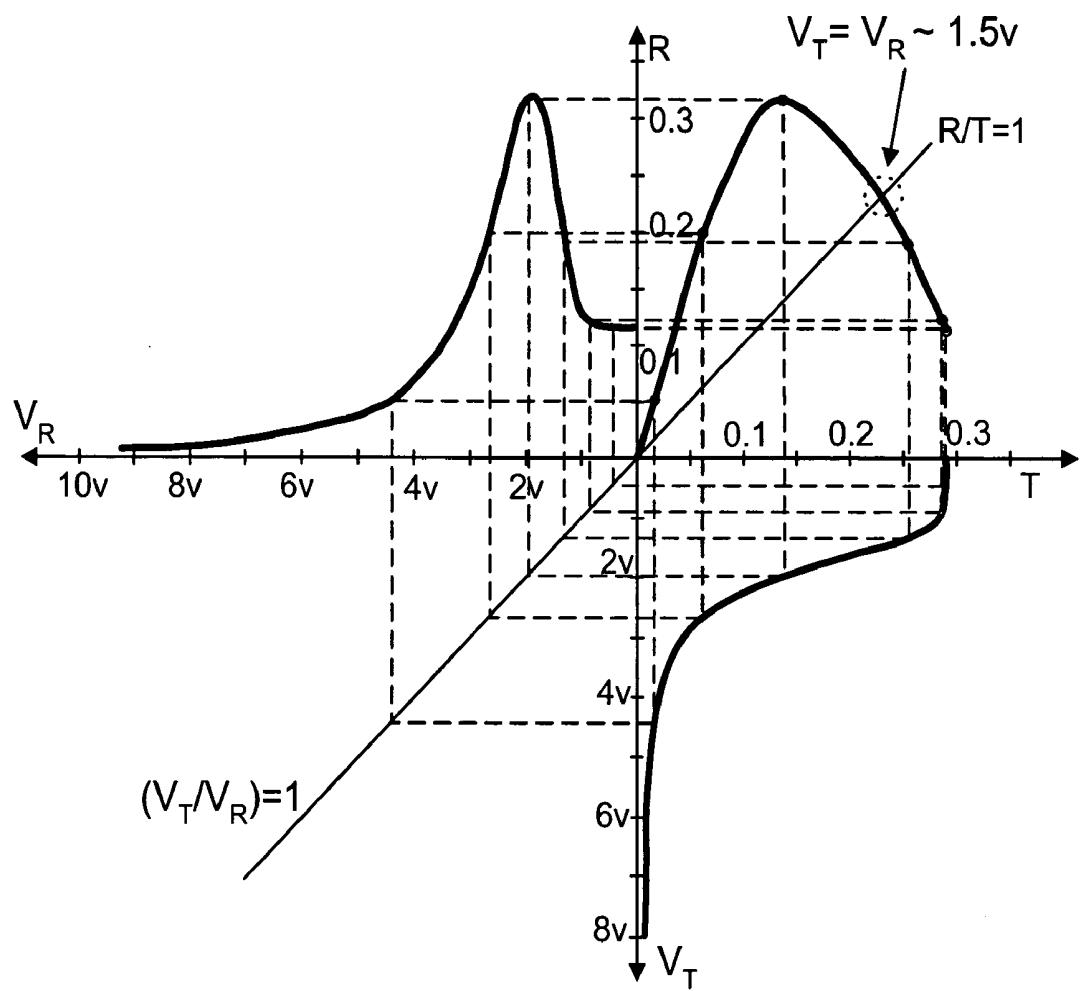


FIG. 21a

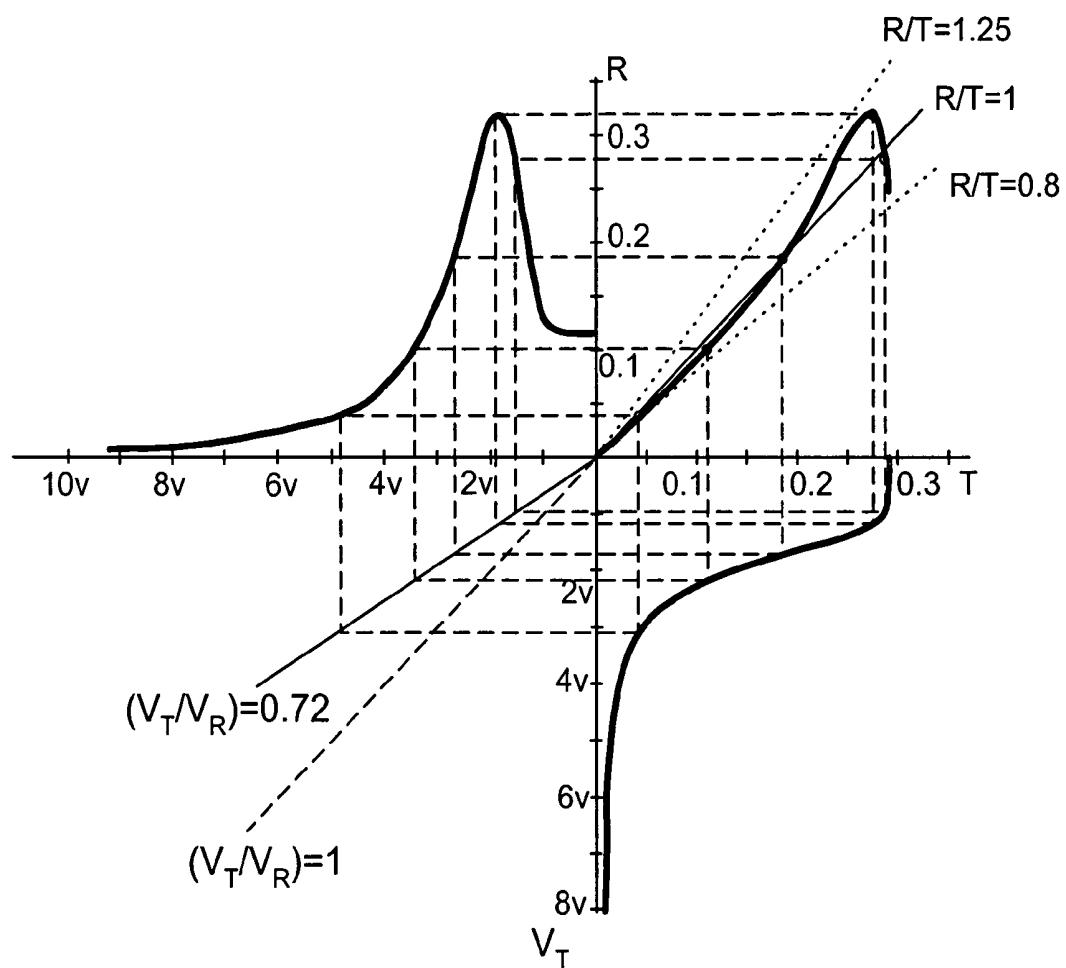


FIG. 21b

TRANSFLECTIVE LIQUID CRYSTAL DISPLAY

FIELD OF THE INVENTION

[0001] The present invention relates generally to a liquid crystal display panel and, more particularly, to a transflective-type liquid crystal display panel.

BACKGROUND OF THE INVENTION

[0002] Due to the characteristics of thin profile and low power consumption, liquid crystal displays (LCDs) are widely used in electronic products, such as portable personal computers, digital cameras, projectors, and the like. Generally, LCD panels are classified into transmissive, reflective, and transflective types. A transmissive LCD panel uses a back-light module as its light source. A reflective LCD panel uses ambient light as its light source. A transflective LCD panel makes use of both the back-light source and ambient light.

[0003] As known in the art, a color LCD panel 1 has a two-dimensional array of pixels 10, as shown in FIG. 1. Each of the pixels comprises a plurality of sub-pixels, usually in three primary colors of red (R), green (G) and blue (B). These RGB color components can be achieved by using respective color filters. FIG. 2 illustrates a plan view of the pixel structure in a conventional transflective LCD panel. As shown in FIG. 2, a pixel 10 is divided into three sub-pixels 12R, 12G and 12B, and each sub-pixel is divided into a transmission area (TA) and a reflection area (RA).

[0004] A typical sub-pixel 12 is shown in FIG. 3. As shown, the sub-pixel 12 has an upper layer structure, a lower layer structure and a liquid crystal layer 190 disposed between the upper layer structure and the lower layer structure. The upper layer comprises a polarizer 120, a half-wave plate 130, a quarter-wave plate 140, a color filter 144 and an upper electrode 150. The upper electrode 150 is made from a substantially transparent material such as ITO (Indium-tin oxide). The lower layer structure comprises an electrode layer having a transmissive electrode 170 and a reflective electrode 160. The transmissive electrode 170 is made from a transparent material such as ITO. The reflective electrode 160 also serves as a reflector and is made from one or more highly reflective metals such as Al, Ag, Cr, Mo, Ti, and AlNd. The lower layer structure further comprises a passivation layer (PL) 180, a device layer 200, a quarter-wave plate 142, a half-wave plate 132 and a polarizer 122. In addition, the transmissive electrode 170 is electrically connected to the device layer 200 through a via 184, and the reflective electrode 160 is electrically connected to the device layer 200 through a via 182.

[0005] In the transmission area as shown in FIG. 3, light (indicated by the arrow) from a back-light source (not shown) enters the pixel area through the lower layer structure, and goes through the liquid crystal layer 190 and the upper layer structure. In the reflection area, light encountering the reflection area goes through the upper layer structure and the liquid crystal layer before it is reflected by the reflective electrode 160.

[0006] In a typical LCD panel, the upper electrode 150 is connected to a common line. The lower electrodes are connected to a data line via a switching element, such as a thin film transistor, which can be switched on by a gate line

signal. The equivalent circuit for a typical LCD sub-pixel is shown in FIG. 4. In FIG. 4, the common line voltage is denoted by V_{com} , V_T is the voltage level on the transmissive electrode 170 and V_R is the voltage level on the reflective electrode 160 (see FIG. 3). C_T represents the capacitance in the liquid crystal layer between the upper electrode 150 and the transmissive electrode 170, and C_R represents the capacitance in the liquid crystal layer between the upper electrode 150 and the reflective electrode 160. The transmissive electrode 170 is connected to the data line Data m through a switching element TFT-1 and the reflective electrode 160 is connected to Data m through a switching element TFT-2. TFT-1 and TFT-2 are switched on by a gate line signal from the gate line Gate n-1. Typically, one or more charge storage capacitors are fabricated in the device layer 200 and the passivation layer 180 in a sub-pixel 12 so as to maintain the pixel voltage V_T in the transmission area and the pixel voltage V_R in the reflection area. As shown in FIG. 4, a charge storage capacitor C_1 is connected in parallel to C_T and a charge storage capacitor C_2 is connected parallel to C_R .

[0007] The sub-pixel structure as shown in FIG. 4 is known as a single-gap structure. In a single-gap transflective LCD, one of the major disadvantages is that transmittance of the transmission area (the V-T curve) and reflectance in the reflection area (the V-R curve) do not reach their peak values in the same voltage range, as shown in FIG. 5. As a result, the reflectance experiences an inversion while the transmittance is approaching its higher value. As shown in FIG. 5, the transmittance starts to peak around 4V but the reflectance is already in decline at about 2.7V.

[0008] In order to overcome this inversion problem, a dual-gap design is used in a transflective LCD. In a dual-gap transflective LCD, as shown in FIG. 6, the gap G_R in the reflection area RA in the sub-pixel 12' is about half the gap G_T in the transmission area TA. Thus, the thickness of the liquid crystal layer 190 in the reflection area RA is one half the thickness of the liquid layer 190 in the transmission area TA. As such, the transmittance and the reflectance of the LCD are more consistent with each other.

[0009] While the optical characteristics of a dual-gap transflective LCD are superior to those of a single-gap transflective LCD, the manufacturing process for controlling the gap in the reflection area in relation to the gap in the transmission area is complex. The production yield for dual-gap transflective LCDs is generally lower than that of single-gap transflective LCDs.

[0010] In order to make the transmittance and the reflectance of a single-gap LCD more consistent with each other, it is possible to reduce the voltage potential V_R by applying an insulating film over part of the upper electrode. As shown in FIG. 7, the upper electrode of the sub-pixel 12" comprises two sections: a first electrode section 152 in the reflection area RA and a second electrode section 154 in the transmission area TA. An insulating film 220 is disposed between the first electrode section 152 and the liquid crystal layer 190. The first electrode section 152 can be directly disposed on the substrate 210, but the second electrode section 154 is disposed on top of an intermediate layer 222 in order to make the gap in the transmission area TA substantially equal to the gap in the reflection area RA. A drawback for this type of single-gap transflective LCD is that the manufacturing

process for controlling the thickness of the insulating film over the first electrode section 152 is also complex. Furthermore, the insulating film 220 and the intermediate layer 222 must be sufficiently transparent and uniform so as not to affect the optical quality of the display panel.

[0011] It is thus advantageous and desirable to provide a method and device to improve the optical characteristics of a single-gap transflective LCD without significantly increasing the complexity in the manufacturing process.

SUMMARY OF THE INVENTION

[0012] The present invention uses a voltage divider within a sub-pixel of a LCD panel to reduce the voltage potential across part of the liquid crystal layer in the sub-pixel. In a normally-black transflective LCD panel, the voltage divider is used to reduce the voltage potential across the liquid crystal layer in the reflection area. In a normally-white transflective LCD panel, the voltage divider is used to reduce the voltage potential across the liquid crystal layer in the transmission area. The voltage divider comprises two resistor segments connected in series between a data line and a common line via one or more switching elements controlled by a gate line signal. In particular, the resistor segments are made of poly-silicon disposed on a lower substrate of the LCD panel. With poly-silicon resistor segments being disposed in the reflection area below the reflective electrode, the optical quality of the upper electrode and the transmissive electrode is not affected by the voltage divider.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a schematic representation of a typical LCD panel.

[0014] FIG. 2 is a schematic representation showing a plan view of the pixel structure of a conventional transflective color LCD panel.

[0015] FIG. 3 is schematic representation showing a cross sectional view of a sub-pixel of the conventional transflective color LCD panel and the reflection and transmission of light beams in the sub-pixel.

[0016] FIG. 4 shows an equivalent circuit of a sub-pixel in the conventional transflective LCD panel.

[0017] FIG. 5 shows the transmittance and reflectance of a sub-pixel in a conventional normally black LCD panel.

[0018] FIG. 6 is a schematic representation of a sub-pixel in a prior art double-gap transflective LCD panel.

[0019] FIG. 7 is a schematic representation of a sub-pixel in a prior art single-gap transflective LCD panel wherein the voltage potential in the reflection area is reduced.

[0020] FIG. 8 is a schematic representation of a sub-pixel in a single-gap transflective LCD panel, according to the present invention.

[0021] FIG. 9A is a schematic representation showing a cross sectional view of the sub-pixel of FIG. 8.

[0022] FIG. 9B is a schematic representation showing another cross sectional view of the sub-pixel of FIG. 8.

[0023] FIG. 10 shows an equivalent circuit of the sub-pixel of FIG. 8.

[0024] FIG. 11 shows the transmittance and reflectance of a sub-pixel in a normally black LCD panel, according to the present invention.

[0025] FIG. 12 is a schematic representation showing a sub-pixel in a single-gap transflective LCD panel, according to another embodiment of the present invention.

[0026] FIG. 13A is a schematic representation showing a cross sectional view of the sub-pixel of FIG. 12.

[0027] FIG. 13B is a schematic representation showing another cross sectional view of the sub-pixel of FIG. 12.

[0028] FIG. 14 shows an equivalent circuit of the sub-pixel of FIG. 12.

[0029] FIG. 15 is a schematic representation of a sub-pixel in another single-gap transflective LCD panel, according to the present invention.

[0030] FIG. 16 shows an equivalent circuit of the sub-pixel of FIG. 15.

[0031] FIG. 17 shows the transmittance and reflectance of a sub-pixel in a normally white LCD panel, according to the present invention.

[0032] FIG. 18 shows the relationship between the voltage level on the transmissive electrode and that on the reflective electrode in a normally black LCD panel.

[0033] FIG. 19a shows the relationship between the transmittance and reflectance when the voltage level of the transmissive electrode is equal to that on the reflective electrode in a normally black LCD panel.

[0034] FIG. 19b shows the relationship between the transmittance and reflectance when the voltage level of the transmissive electrode is lower than that on the reflective electrode in a normally black LCD panel.

[0035] FIG. 20 shows the relationship between the voltage level on the transmissive electrode and that on the reflective electrode in a normally white LCD panel.

[0036] FIG. 21a shows the relationship between the transmittance and reflectance when the voltage level of the transmissive electrode is equal to that on the reflective electrode in a normally white LCD panel.

[0037] FIG. 21b shows the relationship between the transmittance and reflectance when the voltage level of the transmissive electrode is higher than that on the reflective electrode in a normally white LCD panel.

DETAILED DESCRIPTION OF THE INVENTION

[0038] The present invention uses a voltage divider to reduce the voltage level on the reflective electrode in color sub-pixel. In particular, poly-silicon is used to fabricate the resistors in the voltage divider under the reflective electrode in the reflection area.

[0039] A sub-pixel in a normally-black (NB) transflective LCD panel, according to the present invention, is shown in FIG. 8. As shown, the sub-pixel 100 has a data line 202 for providing a data line signal to the sub-pixel 100, a gate line 212 for providing a gate line signal to a switching element that controls the liquid crystal layer within the sub-pixel, and a common line 214 for providing a common line voltage

level V_{com} to the upper electrode (not shown). The sub-pixel **100** is divided into a transmission area **TA** and a reflection area **RA**. The transmission area **TA** has a transmissive electrode **170** operatively connected to the data line **202** via a switching element **240** (TFT-1) in order to receive the data line signal. The switching element **240** has a switch end **241** electrically connected to the data line **202** and another switch end **243** connected to the transmissive electrode **170** through a via **184**. A charge storage capacitor C_1 is also electrically connected to the switch end **243**. The switching element **240** also has a control end **242** electrically connected to the gate line **212**. The reflection area **RA** has a reflective electrode **160** operatively connected to the data line **202** via a switching element **250** (TFT-2) in order to receive the data line signal. The switching element **250** shares the switch end **241** and the control end **242** with the switching element **240**. The switching element **250** has another switch end **249** connected to a voltage divider (R_1+R_2) .

[0040] In order to reduce the voltage potential across the liquid crystal layer in the reflection area **RA**, a voltage divider (R_1+R_2) consisting of a resistor R_1 and a resistor R_2 is disposed in the reflection area **RA** to establish a voltage potential between the switching element **250** and the common line **214** via another switching element **260** (TFT-3). As shown in FIG. 8, one end of the resistor R_1 is connected to the switch end **249** of the switching element **250** and the other end is connected to the reflective electrode **160** through a via **182**. A charge storage capacitor C_2 is also electrically connected to the reflective electrode **160**. One end of the resistor R_2 is electrically connected to the reflective electrode **160** and the other end of the resistor R_2 is connected to a switch end **261** of the switching element **260**. The other switch end **263** of the switching element **260** is connected to the common line **214** and the control end **262** is connected to the gate line **212**.

[0041] The voltage divider (R_1+R_2) is achievable due to the availability of the low-temperature poly-silicon (LTPS) process. LTPS can also be used to fabricate part of the switching elements **240**, **250**, **260**. FIG. 9A is a schematic representation of a cross sectional view along a line "A" as shown in FIG. 8. FIG. 9A shows how poly-silicon is used to fabricate the resistors R_1 , R_2 and part of the switching elements **250**, **260**. As shown in FIGS. 8 and 9A, the resistors R_1 and R_2 are disposed below the reflective electrode **160**. As such, the voltage divider can be fabricated within the sub-pixel **100** without effecting the reflectivity in the reflection area **RA** or the transmissivity in the transmission area **TA**. FIG. 9B is a schematic representation of a cross sectional view along a line "B" as shown in FIG. 8. FIG. 9B shows how poly-silicon can be used to fabricate part of the switching elements **240**.

[0042] FIG. 10 shows an equivalent circuit of the sub-pixel **100** as shown in FIG. 8. In FIG. 10, C_T is the capacitance of the liquid crystal layer between the transmissive electrode **170** and the upper electrode (see electrode **150** in FIG. 3) and C_R is the capacitance of the liquid crystal layer between the reflective electrode **160** and the upper electrode. As shown, the charge storage capacitor C_1 is connected in parallel to C_T , and the charge capacitor C_2 is connected in parallel to C_R . When the switching element TFT-1 is switched "on" by a gate line signal in Gate $n-1$ and the capacitors C_2 , C_R are substantially charged, the voltage

level on the transmissive electrode is $V_T=V_{data}$, where V_{data} is the voltage level at Data m . The voltage potential across the liquid crystal layer in the transmission area **TA** is $(V_{data}-V_{com})$. When the switching elements TFT-2, TFT-3 are switched "on" by the gate line signal in Gate $n-1$ and the capacitors C_1 , C_T are substantially charged, the voltage level on the reflective electrode is $V_R=(V_{data}-V_{com}) (R_1/(R_1+R_2))$. Thus, the voltage potential across the liquid crystal layer in the reflection area **RA** is V_R-V_{com} . If V_{com} is small as compared to V_{data} , then the voltage potential across the liquid crystal layer in the reflection area **RA** is approximately reduced by $R_1/(R_1+R_2)$. As a result, the reflectance is shifted toward the higher voltage end of the V-R curve, as shown in FIG. 11. The shifting is dependant upon the ratio $R_1/(R_1+R_2)$. FIG. 11 shows the shifting according to the ratios 0.33, 0.4 and 0.5. As such, the reflectance inversion problem of the reflectance can be avoided by choosing a suitable voltage range for controlling the liquid crystal layer.

[0043] According to another embodiment of the present invention, the reflection area **RA** in the sub-pixel **100'** has two reflective electrodes **161** and **188**, as shown in FIG. 12. The reflective electrode **188** is electrically connected to the transmissive electrode **170**. As with the embodiment as shown in FIG. 8, the voltage level on the reflective electrode **161** is reduced by the voltage divider (R_1+R_2) in order to avoid the reflectance inversion problem. A cross sectional view of this embodiment is shown in FIGS. 13A and 13B, similar to the cross sectional views along the line "A" and the line "B", respectively, as shown in FIGS. 9A and 9B.

[0044] The equivalent circuit of the sub-pixel **100'** is shown in FIG. 14. In FIG. 14, C_R' is the capacitance of the liquid crystal layer between the reflective electrode **188** and the upper electrode (not shown), and C_R is the capacitance of the liquid crystal layer between the reflective electrode **161** and the upper electrode. As such, part of the reflectance in the reflection area is not shifted. This unshifted portion of the reflectance improves the matching between transmittance and reflectance at the starting end of the V-T, V-R curves.

[0045] A sub-pixel in a normally-white (NW) transreflective LCD panel, according to the present invention, is shown in FIG. 15. As shown, the sub-pixel **100''** has a data line **202** for providing a data line signal to the sub-pixel **100''**, a gate line **212** for providing a gate line signal to a switching element that controls the liquid crystal layer within the sub-pixel, and a common line **214** for providing a common line voltage level V_{com} to the upper electrode (not shown). The sub-pixel **100''** is divided into a transmission area **TA** and a reflection area **RA**. The reflection area **RA** has a reflective electrode **160** operatively connected to the data line **202** via a switching element **240** (TFT-1) in order to receive the data line signal. The switching element **240** has a switch end **241** electrically connected to the data line **202** and another switch end **243** connected to the reflective electrode **160** through a via **193**. A charge storage capacitor C_2 is also electrically connected to the switch end **243**. The switching element **240** also has a control end **242** electrically connected to the gate line **212**. The transmission area **TA** has a transmissive electrode **170** operatively connected to the data line **202** via a switching element **250** (TFT-2) in order to receive the data line signal. The switching element **250** shares the switch end **241** and the control end **242** with the

switching element 240. The switching element 250 has another switch end 249 connected to a voltage divider.

[0046] In order to reduce the voltage potential across the liquid crystal layer in the transmission area TA, a voltage divider consisting of a resistor R_1 and a resistor R_2 is disposed in the transmission area TA to establish a voltage potential between the switching element 250 and the common line 214 via another switching element 260 (TFT-3). As shown in FIG. 15, one end of the resistor R_1 is connected to the switch end 249 of the switching element 250 and the other end is connected to the transmissive electrode 170 through a via 195. A charge storage capacitor C_1 is also electrically connected to the transmissive electrode 170. One end of the resistor R_2 is electrically connected to the transmissive electrode 170 and the other end of the resistor R_2 is connected to a switch end 261 of the switching element 260. The other switch end 263 of the switching element 260 is connected to the common line 214 and the control end 262 is connected to the gate line 212.

[0047] FIG. 16 shows an equivalent circuit of the sub-pixel 100" as shown in FIG. 15. In FIG. 16, C_T is the capacitance of the liquid crystal layer between the transmissive electrode 170 and the upper electrode (see electrode 150 in FIG. 3), and C_R is the capacitance of the liquid crystal layer between the reflective electrode 160 and the upper electrode. As shown, the charge storage capacitor C_1 is connected in parallel to C_T and the charge capacitor C_2 is connected in parallel to C_R . When the switching element TFT-1 is switched "on" by a gate line signal in Gate n-1 and the capacitors C_2 , C_R are substantially charged, the voltage level on the reflective electrode is $V_R = V_{data}$, where V_{data} is the voltage level at Data m. The voltage potential across the liquid crystal layer in the reflection area is $(V_{data} - V_{com})$. When the switching elements TFT-2, TFT-3 are switched "on" by the gate line signal in Gate n-1 and the capacitors C_1 , C_T are substantially charged, the voltage level on the transmissive electrode is $V_T = (V_{data} - V_{com})(R_1 / (R_1 + R_2))$. Thus, the voltage potential across the liquid crystal layer in the transmission area is $V_T - V_{com}$. If V_{com} is small as compared to V_{data} , then the voltage potential across the liquid crystal layer in the transmission area is approximately reduced by $R_1 / (R_1 + R_2)$. As a result, the transmission is shifted toward the higher voltage end of the V-T curve, as shown in FIG. 17. The shifting is dependant upon the ratio $R_1 / (R_1 + R_2)$. FIG. 17 shows the shifting according to the ratios 0.4 and 0.6. As such, the reflectance inversion problem of the reflectance can be avoided by choosing a suitable voltage range for controlling the liquid crystal layer.

[0048] As shown in FIGS. 5 and 11, when V_T is equal to V_R in a single-gap, normally-black LCD panel, the reflectance peaks at a much lower voltage level than the transmittance. Thus, it is desirable to reduce the voltage level on the reflective electrode such that $V_T / V_R > 1$, as shown in FIG. 18, so as to match reflectance to transmittance within a certain range. To further illustrate the problem associated with $V_T = V_R$ in a single-gap, normally-black LCD panel, a plot of reflectance against transmittance is shown in FIG. 19a.

[0049] As shown in FIG. 19a, the reflectance peaks approximately at $V_R = 2.7V$ and the transmittance peaks approximately at $V_T = 4V$. In a quality LCD display, the ratio

between transmittance and reflectance should be within a certain range in order to achieve a plurality of gray-scale levels. Thus, the R-T curve should approximately follow the $R/T = 1$ slope. However, as shown in FIG. 19a, the transmittance is approximately equal to the reflectance only around $V_T = V_R = 2.9V$. At other voltage levels, the discrepancy between transmittance and reflectance is too great to be useful. Thus, a useful range of gray-scale levels is not achievable.

[0050] As shown in FIG. 11, when $(V_R / V_T) < 1$, the peak of the V-R curve shifts toward the peak of the V-T curve. FIG. 19b shows the relationship between transmittance and reflectance when the voltage divider is designed such that $R_1 / (R_1 + R_2) \sim (V_R / V_T) = 0.87$. As shown in FIG. 19b, when V_T is approximately in the range of 2.4V to 3.3V (V_R in the range of 2.1V to 2.9V), the ratio R/T is approximately in the range of 0.8 to 1.25. Thus, with $R_1 / (R_1 + R_2) \sim (V_R / V_T) = 0.87$, the reasonable operational V_T voltage range of the LCD panel is 2.4V to 3.3V.

[0051] As shown in FIG. 17, when V_T is equal to V_R in a single-gap, normally-white LCD panel, the reflectance peaks at a much higher voltage level than the transmittance. Thus, it is desirable to increase the voltage level on the reflective electrode such that $V_T / V_R < 1$, as shown in FIG. 20, so that the ratio of transmittance to reflectance falls within a certain range. To further illustrate the problem associated with $V_T = V_R$ in a single-gap, normally-white LCD panel, a plot of reflectance against transmittance is shown in FIG. 21a.

[0052] As shown in FIG. 21a, before the reflectance peaks approximately at $V_R = 2.0V$, the transmittance already decreases from about 0.29 to 0.14. The transmittance is approximately equal to the reflectance only around $V_T = V_R = 1.5V$. At other voltage levels, the discrepancy between the transmittance and reflectance is too great to be useful.

[0053] As shown in FIG. 17, when $(V_R / V_T) > 1$, the downward slope of the V-T curve shifts toward the downward slope of the V-R curve. FIG. 21b shows the relationship between transmittance and reflectance when the voltage divider is designed such that $R_1 / (R_1 + R_2) \sim (V_T / V_R) = 0.72$. As shown in FIG. 21b, when V_T is approximately in the range of 1.1V to 4.3V (V_R in the range of 1.5V to 6V), the ratio R/T is approximately in the range of 0.8 to 1.25. Thus, with $R_1 / (R_1 + R_2) \sim (V_T / V_R) = 0.72$, the reasonable operational V_R voltage range of the LCD panel is 1.5V to 6V.

[0054] In sum, the present invention uses a voltage divider in a single-gap, normally-black transreflective LCD panel to reduce the V_R / V_T ratio so as to reduce the discrepancy between transmittance and reflectance. In one embodiment, only one reflective electrode is provided in the reflection area to effect the reflection, and the voltage divider is operatively connected to the reflective electrode for reducing the V_R / V_T ratio. In another embodiment, two reflective electrodes are used to effect the reflection, one reflective electrode is operatively connected to the transmissive electrode and the other reflective electrode is operatively connected to the voltage divider for reducing the V_R / V_T ratio. The present invention also uses a voltage divider in a single-gap, normally-white LCD panel to reduce the V_T / V_R ratio so as to reduce the discrepancy between transmittance and reflectance. In particular, poly-silicon is used to fabri-

cate the resistors in the voltage divider. These resistors can be located beneath the reflective electrode in the reflection area, for example.

[0055] Thus, although the invention has been described with respect to one or more embodiments thereof, it will be understood by those skilled in the art that the foregoing and various other changes, omissions and deviations in the form and detail thereof may be made without departing from the scope of this invention.

What is claimed is:

1. A method for improving optical characteristics of a single-gap transreflective liquid crystal display panel having a plurality of pixels, at least some of the pixels having a transmission area and a reflection area, wherein the transmission area comprises a transmissive electrode and the reflection area comprises a reflective electrode, said method comprising the steps of:

providing a first voltage level to the transmissive electrode to achieve a transmittance in the transmission area;

providing a second voltage level to the reflective electrode to achieve a reflectance in the reflection area, the second voltage level having a voltage ratio in relation to the first voltage level; and

adjusting the voltage ratio so that a ratio of the reflectance to the transmittance is achievable within a predetermined range.

2. The method of claim 1, wherein the step of adjusting the voltage ratio comprising disposing a voltage divider in each of said pixels for adjusting the voltage ratio.

3. The method of claim 2, wherein the liquid crystal display panel is a normally-black display panel, and wherein the voltage divider is operatively connected to the reflective electrode for adjusting the second voltage level so that the voltage ratio is smaller than 1.

4. The method of claim 2, wherein the liquid crystal display panel is a normally-white display panel, and wherein the voltage divider is operatively connected to the transmissive electrode for adjusting the first voltage level so that the voltage ratio is greater than 1.

5. The method of claim 2, wherein the voltage divider is made of poly-silicon disposed in the reflection area.

6. A single-gap transreflective liquid crystal display panel having a plurality of pixels, at least some of the pixels having a transmission area and a reflection area, said display panel comprising:

a transmissive electrode disposed in the transmission area in each of said pixels, the transmissive electrode operatively connected to a first voltage level to achieve a transmittance in the transmission area;

a reflective electrode disposed in the reflection area in each of said pixels, the reflective electrode operatively connected to a second voltage level to achieve a reflectance in the reflection area, the second voltage level having a voltage ratio in relation to the first voltage level; and

a voltage divider disposed in each of said pixels for adjusting the voltage ratio such that a ratio of the reflectance to the transmittance is achievable within a predetermined range.

7. The display panel of claim 6, wherein the liquid crystal display panel is a normally-black display panel, and wherein the voltage divider is operatively connected to the reflective electrode for adjusting the second voltage level so that the voltage ratio is smaller than 1.

8. The display panel of claim 6, wherein the liquid crystal display panel is a normally-white display panel, and wherein the voltage divider is operatively connected to the transmissive electrode for adjusting the first voltage level so that the voltage ratio is greater than 1.

9. The display panel of claim 6, wherein the voltage divider comprises at least two resistor segments.

10. The display panel of claim 6, wherein the resistor segments are made of poly-silicon disposed substantially in the reflection area.

11. The display panel of claim 7, wherein the voltage divider comprises at least two resistor segments made of poly-silicon, and the reflective electrode is operatively connected to the voltage divider between the resistor segments, said display panel further comprising

a storage capacitor in each of said pixels, operatively connected to the voltage divider between the resistor segments.

12. The display panel of claim 11, further comprising

a further reflective electrode in each of said pixels electrically separated from the reflective electrode, wherein the further reflective electrode is operatively connected to the transmissive electrode.

13. The display panel of claim 11, further comprising

a further storage capacitor operatively connected to the transmissive electrode.

14. The display panel of claim 11, wherein each of said pixels is associated with a data line and a gate line, and wherein the resistor segments comprise a first resistor segment and a second resistor segment, said display panel further comprising:

a first switching element controllable by the gate line, the first switching element operatively connected between the data line and the transmissive electrode;

a second switching element controllable by the gate line, the second switching element operatively connected between the data line and first resistor segment; and

a third switching element controllable by the gate line, the third switching element operatively connected between the second resistor segment and a common line of the display panel.

15. The display panel of claim 8, wherein the voltage divider comprises at least two resistor segments made of poly-silicon, and the transmissive electrode is operatively connected to the voltage divider between the resistor segments, said display panel further comprising

a storage capacitor in each of said pixels, operatively connected to the voltage divider between the resistor segments.

16. The display panel of claim 15, further comprising

a further storage capacitor operatively connected to the reflective electrode.

17. The display panel of claim 15, wherein each of said pixels is associated with a data line and a gate line, and wherein the resistor segments comprise a first resistor segment and a second resistor segment, said display panel further comprising:

a first switching element controllable by the gate line, the first switching element operatively connected between the data line and the reflective electrode;

a second switching element controllable by the gate line, the second switching element operatively connected between the data line and first resistor segment; and a third switching element controllable by the gate line, the third switching element operatively connected between the second resistor segment and a common line of the display panel.

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专利名称(译)	透反液晶显示器		
公开(公告)号	US20070120797A1	公开(公告)日	2007-05-31
申请号	US11/291239	申请日	2005-11-30
[标]申请(专利权)人(译)	友达光电股份有限公司		
申请(专利权)人(译)	友达光电股份有限公司		
当前申请(专利权)人(译)	友达光电股份有限公司		
[标]发明人	LIN YUNG LUN LIN CHING HUAN		
发明人	LIN, YUNG-LUN LIN, CHING-HUAN		
IPC分类号	G09G3/36		
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摘要(译)

一种单间隙透射反射型LCD面板，在每个子像素中具有分压器，用于降低子像素中部分液晶层的电压电位。在常黑型LCD面板中，分压器用于降低反射区域中液晶层上的电压电位。在常白LCD面板中，分压器用于降低透射区域中液晶层上的电压电位。分压器包括两个多晶硅电阻器段，它们通过由栅极线信号控制的一个或多个开关元件串联连接在数据线和公共线之间。由于多晶硅电阻器段设置在反射电极下方的反射区域中，上电极和透射电极的光学质量不受分压器的影响。

