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(54) **LCD HAVING PARTICULAR DIELECTRIC CONSTANT RELATIONSHIP BETWEEN ORIENTATION FILM AND LC LAYER**

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(51) **Int. Cl.**[7] **C09K 19/02**
(52) **U.S. Cl.** **349/177**; 349/123
(58) **Field of Search** 349/123, 177, 349/171; 399/123, 171, 177

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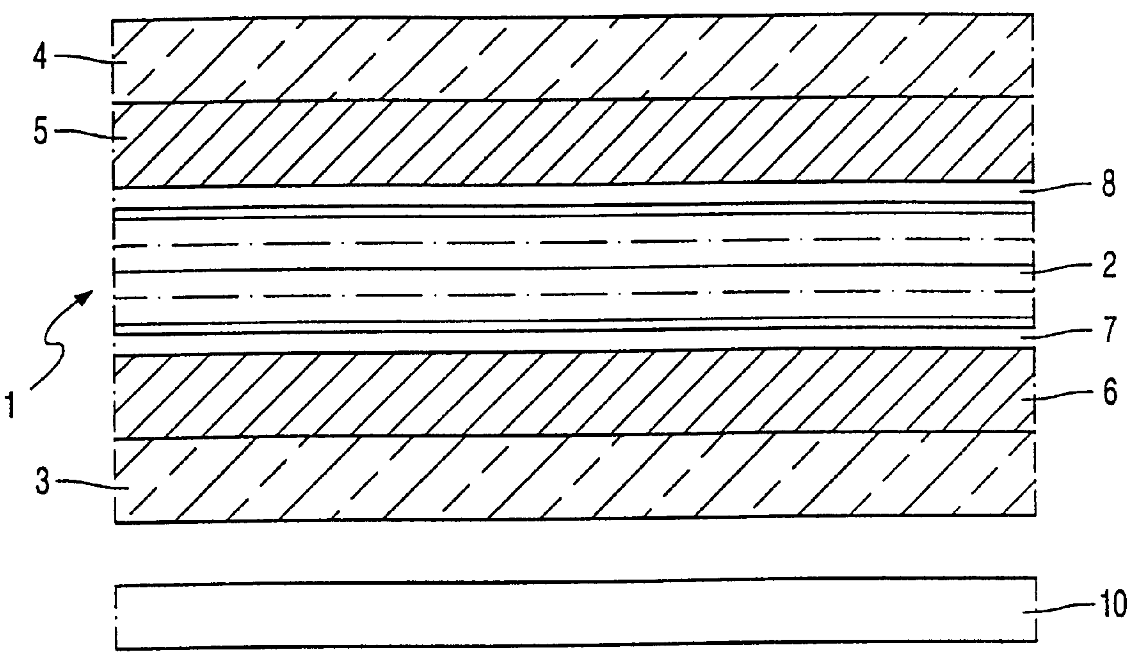
(57) **ABSTRACT**

In a liquid crystal display device, the dielectric constants (∈) and resistivities (ρ) of the liquid crystal material and the layers of orienting material have such values that the liquid crystal display device can be driven by means of a DC voltage.

11 Claims, 3 Drawing Sheets



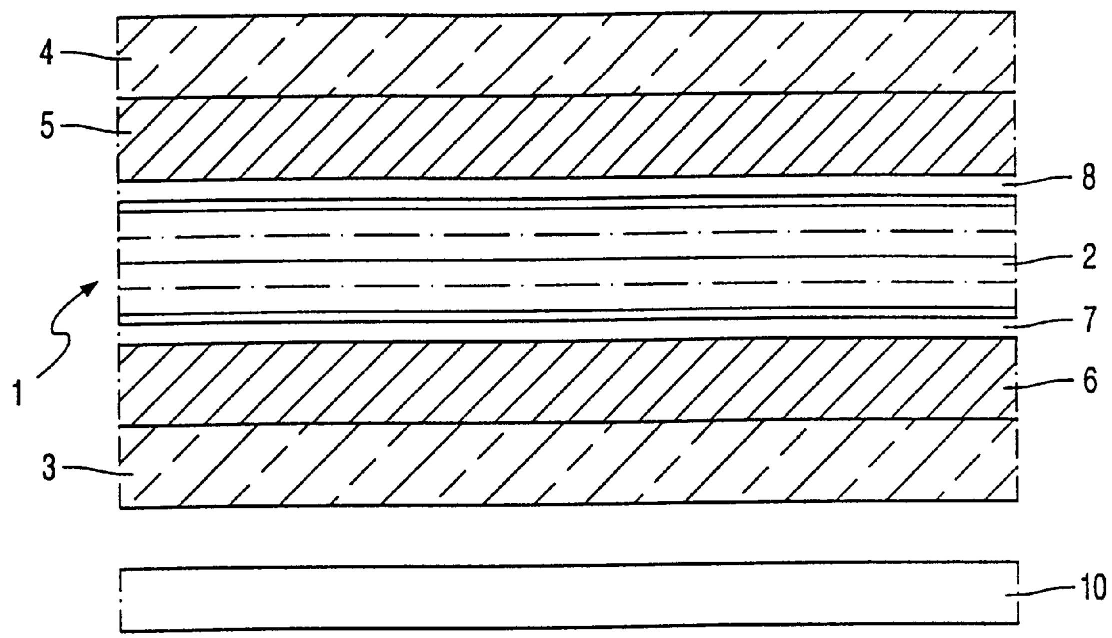


FIG. 1

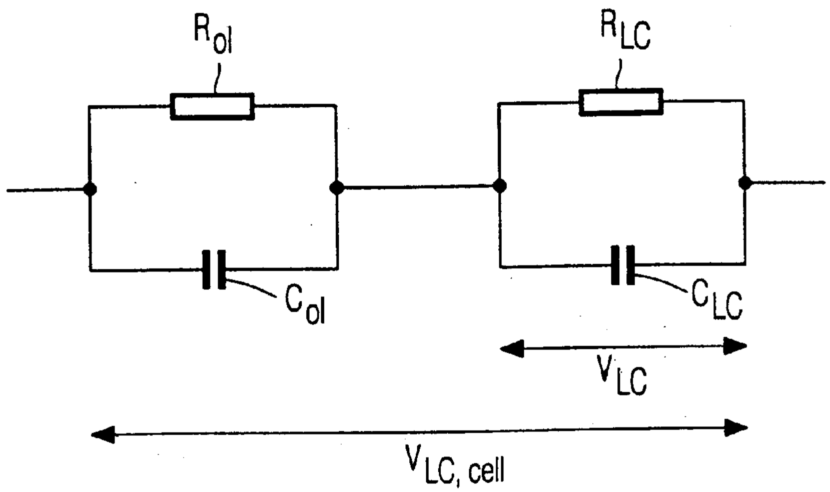


FIG. 2

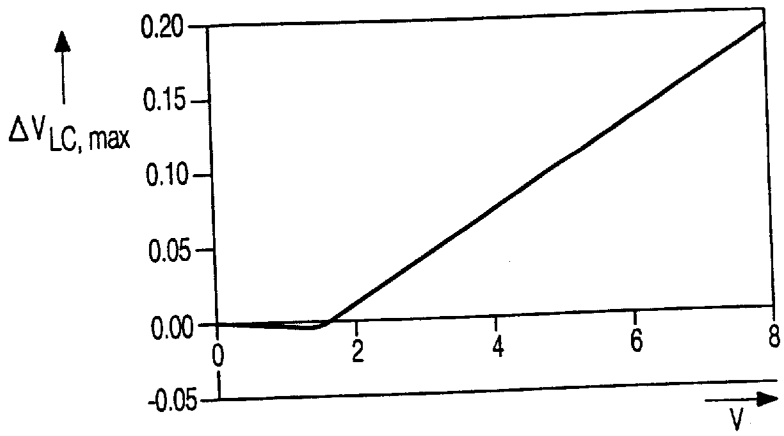


FIG. 3

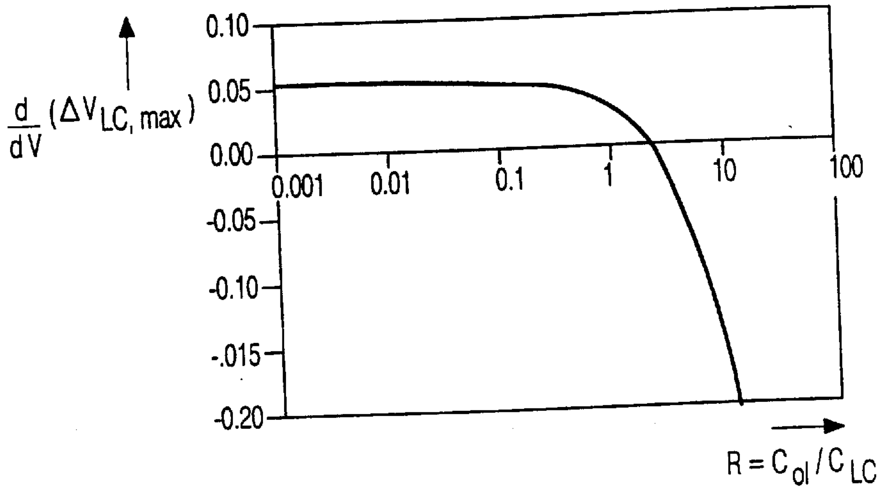


FIG. 4

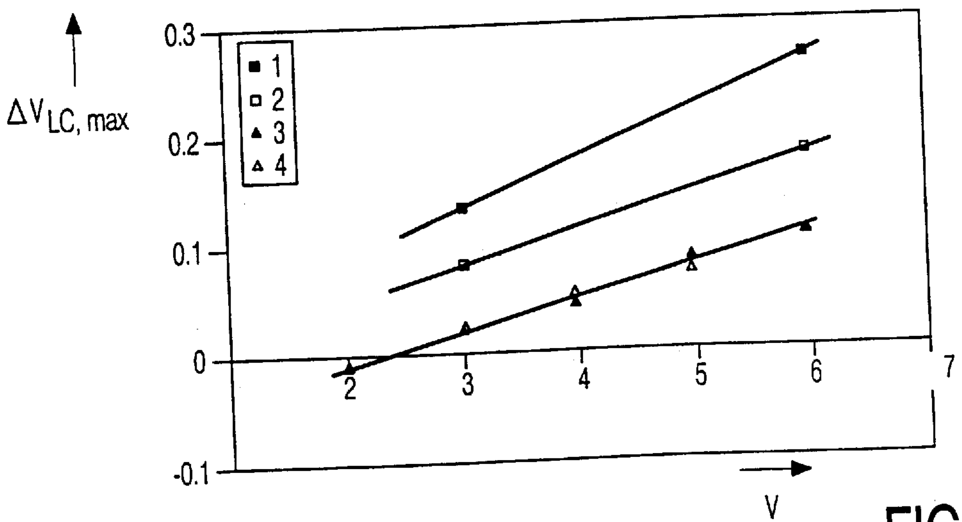


FIG. 5

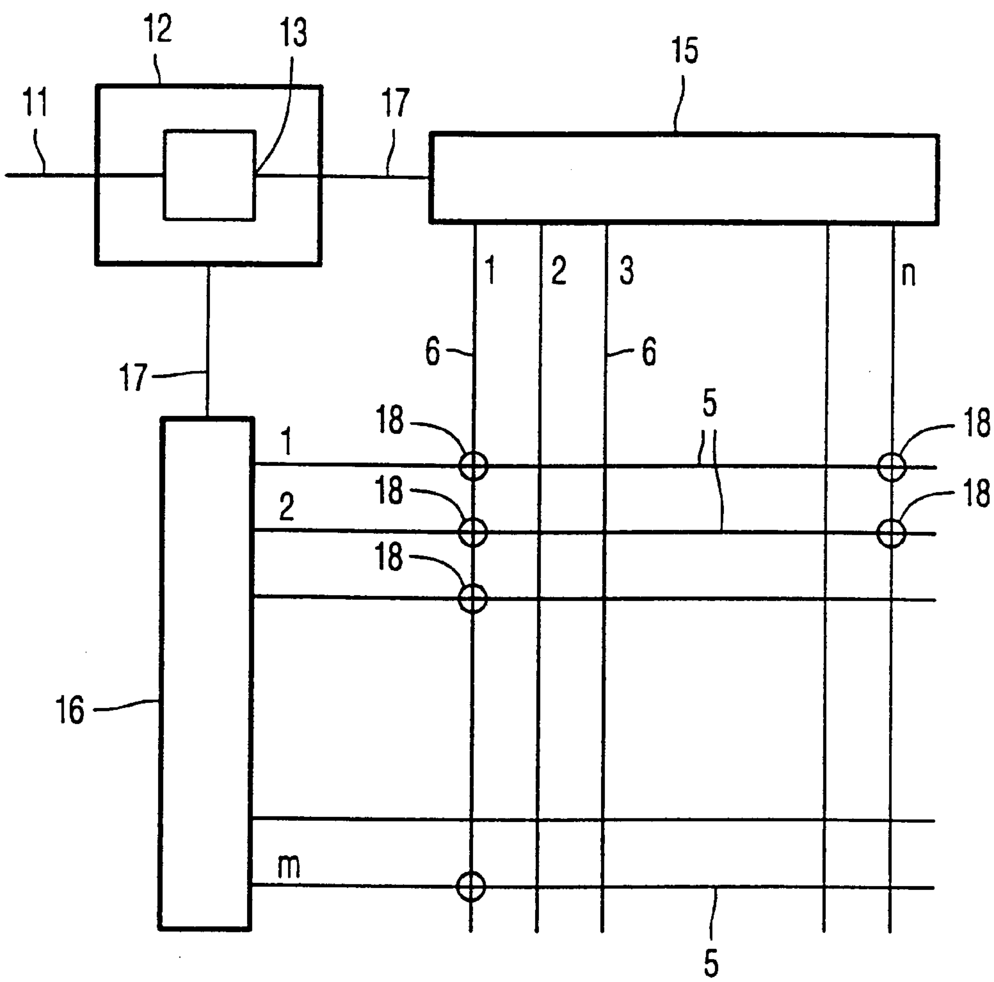


FIG. 6

LCD HAVING PARTICULAR DIELECTRIC CONSTANT RELATIONSHIP BETWEEN ORIENTATION FILM AND LC LAYER

BACKGROUND OF THE INVENTION

The invention relates to a liquid crystal display device comprising pixels and electrodes for driving the pixels, each pixel comprising a display element defined by picture electrodes, which display element comprises layers of orienting material and a layer of liquid crystal material between the picture electrodes.

Such liquid crystal display devices are generally known and used, for example, in monitors, but also in portable applications (organizers, mobile telephones).

OBJECTS AND SUMMARY OF THE INVENTION

A known phenomenon in such liquid crystal display devices is the displacement of ions in the liquid, so that degradation occurs, which becomes manifest as image retention. To prevent this, liquid crystal display devices are driven with an inverting or alternating voltage across the pixels. This is notably detrimental in portable applications because the use of an inverting voltage is accompanied by a high energy consumption and a high battery voltage for the drive electronics. This in turn leads to higher costs.

A liquid crystal display device according to the invention is characterized in that, for the quotient Q of a dielectric constant $\in_{LC}$ of the liquid crystal material and the dielectric constant of the layers of orienting material $\in_{ol}$, it holds that $Q=\in_{LC}/\in_{ol}>0.7\ \rho_{ol}/\rho_{LC}$, in which, for a liquid crystal material having a negative dielectric anisotropy $(\Delta\in<0)\ \in_{LC}$, the dielectric constant perpendicular to the directors of the liquid crystal material is $(\in_{\perp})$, and for a liquid crystal material having a positive dielectric anisotropy $(\Delta\in>0)\ \in_{LC}$, the dielectric constant parallel to the directors of the liquid crystal material is $(\mathbf{531}_{\parallel})$ and ρ_{ol} and ρ_{LC} are the resistivities of the liquid crystal material and the layers of orienting material, respectively.

The orientation layer may comprise sub-layers of different material. In that case, ρ_{ol} is understood to mean the average resistivity of the orientation layer.

The value Q is preferably between 0.4 and 4, while values of between 1.2 and 3 look optimal.

To inhibit image retention even further, a first embodiment is characterized in that $\rho_{ol}/\rho_{LC}<10$ (and preferably<5) at 25° C. To prevent lateral conduction in the orientation layers, ρ_{ol} is chosen to be $>10^7$ ohmmeter (T=25° C.).

A further embodiment is characterized in that the liquid crystal display device comprises means for presenting drive voltages in one polarity across the pixels (DC drive). In this connection, one polarity is understood to mean that no measures have been taken to change the polarity across the pixels during operations over a longer period of time (e.g. 1000 or 2000 frame times), but measures may be taken to drive the pixels with opposite polarity when modes are re-used or changed (for example, switching from or to a standby mode in a display in a portable application or switching between use of modes, Internetpages etc. in computer applications) of the display device.

The inventors have surprisingly found that the display device can be DC-driven without degradation or image retention occurring in said combination of dielectric constants of the orienting material and of the liquid crystal material. By approximation, a theoretical explanation can

also be given for this effect. Since the display device is now DC driven, the electronics for continuously reversing the voltage across a pixel may be dispensed with. (Reversing can be restricted to e.g. once every minute or five minutes). Moreover, there is no flicker.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** shows diagrammatically a part of a liquid crystal display device,

FIG. **2** shows an equivalent circuit diagram of the display cell in FIG. **1**,

FIG. **3** shows the maximum change with respect to time $\Delta V_{lc,max}$ across the liquid crystal layer as function of the applied drive voltage, while

FIG. **4** shows the influence of $R=\rho_{ol}/\rho_{LC}$ on the slope $d(\Delta V_{lc,max})/dV$,

FIG. **5** shows the maximum change with respect to time $\Delta V_{lc,max}$ as a function of the applied drive voltage for different liquids, and

FIG. **6** shows diagrammatically a display device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a diagrammatic cross-section of a part of a liquid crystal display device comprising a liquid crystal cell **1** with a twisted nematic liquid crystal material **2** which is present between two substrates **3**, **4** of, for example, glass, provided with electrodes **5**, **6**. The device further comprises two orientation layers **7**, **8** which orient the liquid crystal material on the inner walls of the substrates, in this example in the direction of the axes of polarization of polarizers (not shown), such that the cell has a twist angle of 90°. In this example, the liquid crystal material has a positive optical anisotropy and a positive dielectric anisotropy. If the electrodes **5**, **6** are energized with an electric voltage, the molecules, and hence the directors, are directed towards the field. The display device further comprises a backlight **10** (in this example). Alternatively, the display device may be reflective.

In a first approximation, both the combined orientation layers **7**, **8** and the layer of liquid crystal material **2** (LC layer) can be described as a parallel circuit of a resistor and a capacitor, as is shown in FIG. **2**. Upon DC drive, the behavior of the voltage across the LC layer ($V_{lc}(t)$, analogous to a step response, will be:

$$V_{lc}(t)=[R^*+((1/C^*)-R^*).\exp.(-t/\tau)].V_{lc,cell} \quad (1)$$

in which

$$R^*=R_{LC}/(R_{ol}+R_{LC}) \text{ and } C^*=(C_{ol}+C_{LC})/C_{ol}$$

(R and C represent the resistance per surface unit and the capacitance per surface unit, respectively, R=ρ.d (ρ: resistivity, d: layer thickness) and $C=(\in_0\cdot\in_r)/d$, while $\tau=R^*C^*.R_{ol}C_{ol}$. ($V_{lc,cell}$: voltage applied across the cell).

The maximum change in $V_{lc}(t)$ then is

$$\Delta V_{lc}=V_{lc}(t=0)-V_{lc}(t=\infty)=[R^*-(1/C^*)].V_{lc,cell} \quad (2)$$

or

$$\Delta V_{lc} = [1/(1+RD)-1/(1+(D/E(V))] \quad (3)$$

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