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Method and Device for Driving Liquid Crystal Displays

The invention relates to a method of driving liquid crystal cells of
10 the so-called DHF (distorted helix ferroelectric) type, and to a circuit
suitable for the purpose.

In the case of DHF cells it is known to reduce the switching times
using special driving pulse shapes (see EP-A-356 730). This results in
15 switching times in the region of about 40 ms.

This mode of operation permits not only the grey scale values
typical of DHF cells, but also multiplexing in combination with an active
matrix. The relatively short switching time of the DHF cell is of
20 advantage in the industrial use of liquid crystal cells, e.g. in switchable
filters, light valves (so-called spatial light modulators, SLMs) or 3D-
spectacles. Accordingly, in liquid crystal cells there is in principle still
a need for even shorter switching times.

25 It has now been unexpectedly found that the switching times can
be reduced by a factor of 10 by a novel driving circuit.

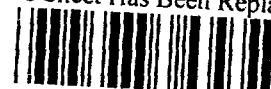
According to the invention, the aim of a high switching speed
with simultaneous availability of grey scale values is obtained by driving
30 the cell via a capacitance connected thereto in series.

In a suitable circuit the cell, during operation, is connected in
series with a capacitance which is small compared with the capacitance
of the helix.

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In a particularly preferred embodiment of the invention, the
additional capacitance takes the form of a transparent insulating layer
between the driving electrodes and the liquid crystal.

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The times thus achievable are shorter than for comparable DHF cells which are directly driven by square-wave pulses. The driving voltage is preferably higher than previous conventional driving voltages. In this mode of operation it can also be higher without damaging, i.e. unwinding, the helical structure of the liquid crystal.

The driving according to the invention still allows grey scales, as with driving using a special pulse shape and in contrast to the Lagerwall cell. Consequently, any desired deformation (= alteration of transmission) of the cell can be achieved by suitable choice of amplitude and/or pulse time.

Electrochemically-induced degradation of the liquid crystal is avoided, since, owing to the insulating layer, no direct current is flowing in the cell.

The cell can be used in display cells, including television sets and so-called terminals, in printers (replacement for laser printers) and generally in all cases where high-speed light modulators or modulators with grey scales can be used.

A preferred embodiment of the invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a schematic representation of a DHF cell in section.

Fig. 2 is an alternative circuit diagram of the cell according to the invention.

The liquid crystal cell shown schematically in section in Fig. 1 is a so-called DHF (distorted helix ferroelectric) cell as described in Swiss Patent Application No. 1555/88 dated 26 April 1988. It has two parallel substrates, e.g. glass plates 1, 2, spaced apart by about 2 mm and provided on facing surfaces with electrode layers 3, 4. The plates 1, 2 also have on facing surfaces PVA coatings 5, 6 which are treated in a preferred direction, e.g. by rubbing, so as to orient the liquid crystal molecules in known manner. A liquid crystal layer 7 is disposed between the plates.

In the present embodiment the liquid crystal is a mixture of:



- 13.1 wt.% of 5-nonyl-2-[p-(nonyloxy)phenyl]pyrimidine,
 21.9 wt.% of 2-[p-(hexyloxy)phenyl]-5-nonylpyrimidine,
 4.4 wt.% of 2-[p-[(E)-2-octenyloxy]phenyl]-5-octylpyridine,
 5 8.8 wt.% of 2-(p-heptylphenyl)-5-[(E)-2-octenyloxy]pyrimidine,
 8.8 wt.% of 5-[(E)-2-decenyloxy]-2-(p-heptylphenyl)pyrimidine,
 4.4 wt.% of (E)-5-heptyl-2-(4-oct-2-enyloxy-phenyl)-pyridine,
 9.3 wt.% of 2,2'-(4,4'-biphenylene)bis[(2S,4S,5S)-4-methyl-5-octyl-m-
 dioxan] and
 10 29.3 wt.% of bis[(R)-1-methylheptyl] p-terphenyl-4,4"-
 dicarboxylate.

An insulating layer 8 is disposed on one of the two glass plates
 between the electrode layer 3 and the orienting layer 5 and constitutes
 15 the dielectric of a capacitance which lies in series with the capacitance
 of the liquid crystal layer. In place of the capacitance integrated in the
 liquid crystal layer, driving can, however, also be effected by a
 commercially obtainable capacitor connected in series with the cell.

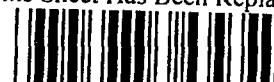
20 In the alternative circuit diagram of the cell according to the
 invention, shown in Fig. 2, the subscript hx denotes the parameter of the
 liquid crystal layer. The electro-optical effect of the DHF cell is brought
 about by a deformation of a ferroelectric helix. This deformation is
 coupled with a charge (polarisation charge) on the helix. The charge
 25 Q_{hx} is therefore a measure of the deformation of the helix and
 consequently of the electro-optical effect. The fact that an applied voltage
 deforms the helix can be described by introducing a capacitance C_{hx}
 which is charged when a voltage is applied. The viscosity of the liquid
 crystal is thus described by a series resistance R_{hx} . The series
 30 resistance of the ITO layer is also present in R_{hx} .

The electro-optical effect $f_{eo}(Q_{hx})$ is therefore only a function of
 Q_{hx} . This model leads to a frequency dependence for Q_{hx} of the following
 form:

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$$Q_{hx}(p) = C_{hx} \frac{U(p)}{pR_{hx}C_{hx} + 1} \quad (1)$$

where $p = j w$, w = frequency, j = imaginary unit.





The frequency behaviour of f_{e0} therefore corresponds to that of an RC element with a characteristic time $t_{hx} = R_{hx} C_{hx}$. The electro-optical effect follows the applied voltage up to the cut-off frequency of the RC element, so that a separation into switching voltage and holding voltage is superfluous.

If an additional capacitance C_{ext} is connected in series with the cell, then C_{hx} in formula (1) must be replaced by C , the capacitance of the series connection of C_{hx} and C_{ext} :

$$C = C_{hx} C_{ext} / (C_{hx} + C_{ext}) \quad (2)$$

The new characteristic time is therefore $t = R_{hx} C$. Since C is always smaller than C_{ext} , this time can be made very short for small values of C_{ext} . Since the extent of the electro-optical effect is also proportional to C (equation 1), the lower time is limited ultimately by the highest voltage which can be applied without damaging the cell.

No direct current voltage component can be applied to capacitively-coupled liquid crystal cells. On the one hand this is very desirable, since then no space charges are separated in the liquid crystal cell, which would have an adverse effect on the orientation, stability or working point (ghost images). Two modes of operating a DHF cell can be distinguished, depending upon the chosen position of the crossed polarisers relative to the helix. In both modes, dc-free driving is possible within limitations:

If a polariser is parallel to the helical axis, then the light transmission is at a minimum when a voltage 0V is applied to the liquid crystal cell, and is greater for both positive and negative voltages. If, therefore, the liquid crystal cell is driven alternately positively and negatively, the average voltage at the liquid crystal cell will be zero. In the case of television images, therefore, a positive and a negative image can be recorded in alternation. One disadvantage of this method is that the useful electro-optical effect is halved.

If a polariser is rotated through a fixed angle (preferably 22.5°) to the helical axis, the light transmission is at a minimum e.g. at a given

negative voltage U_- and at a maximum for a positive voltage U_+ . To guarantee dc-free driving, therefore, U_+t_+ must equal U_-t_- , t_+ , denoting the times during which the positive and, respectively, negative voltage is applied. This mode of operation is therefore particularly suitable for applications with a constant scanning ratio such as e.g. serially connected filters or spectacles for watching stereo images on a screen where the left and right images are presented in alternation.

As already partly mentioned, the advantages of the driving method according to the invention mainly consist in short switching times, in the absence of a dc component across the cell, in substantially simpler driving and in inherent protection by isolation from short circuits. These advantages are in addition to the known advantages of DHF cells regarding the possibility of grey scales, thin cells with little dependence on the angle of viewing, and combination with active addressing.

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Claims

1. A method of driving a liquid crystal cell of the DHF (distorted helix ferroelectric) type, characterized in that driving is capacitive via a
5 capacitance which is small compared with the capacitance of the liquid crystal layer.
2. A circuit for driving a liquid crystal cell of the DHF type,
characterized in that during operation the cell is connected in series
10 with a capacitance which is small compared with the capacitance of the liquid crystal layer.

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