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EP 0642113 A          WO 95/24715 A

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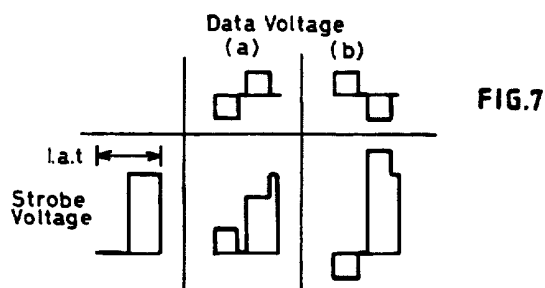UK CL (Edition O ) G5C CHB
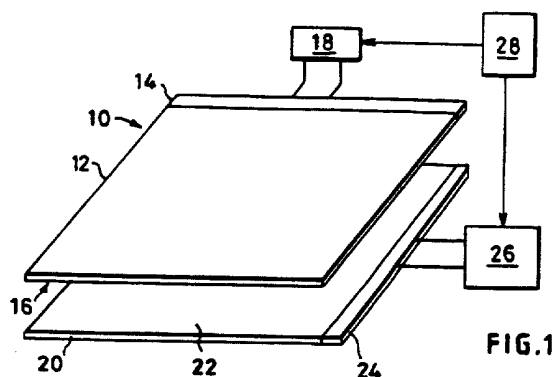INT CL$^6$ G09G 3/36
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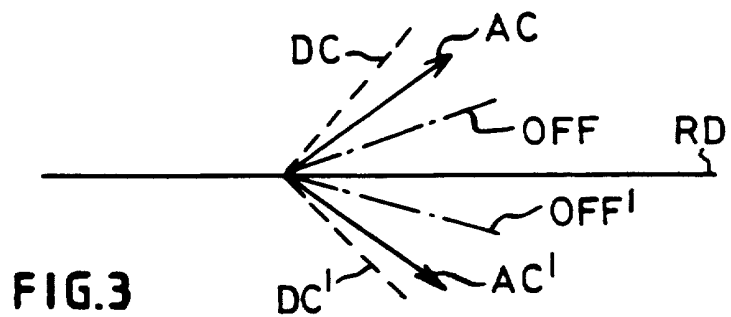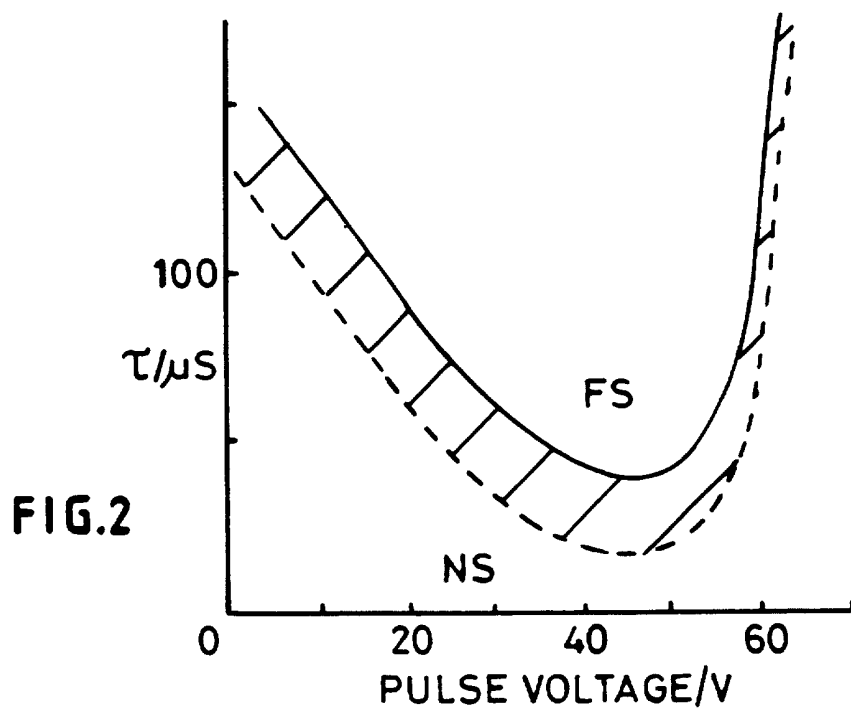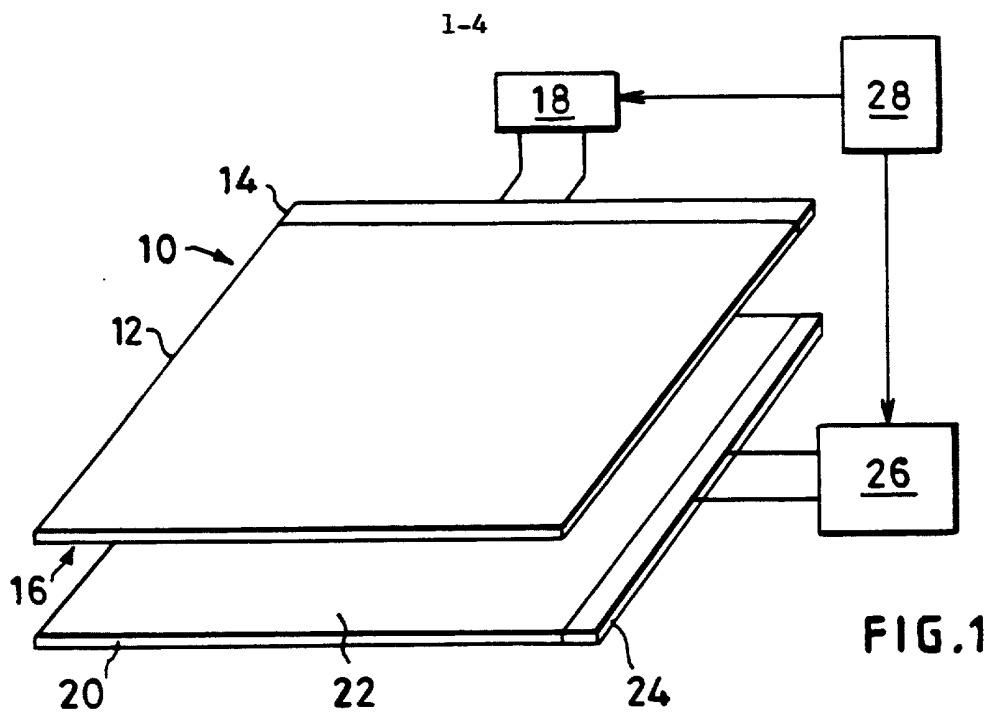(74) Agent and/or Address for Service
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(54) **Liquid crystal array device**

(57) A liquid crystal array device (10) comprises a liquid crystal material contained between two substrates (12, 20), a first and a second plurality of electrodes (16, 22) defining a plurality of pixels and driving circuitry (18, 26, 28) for applying a first signal (Strobe Voltage) in succession to the first plurality of electrodes and for applying a plurality of second signals (Data Voltage) to each of the second plurality of electrodes. Each second signal comprises one of at least a first waveform (a) and a second waveform (b) and the first waveform and the second waveform each comprise first and second signal levels. The first waveform (a) and the second waveform (b) further comprise at least one portion at a third signal level different from the first and second signal levels. This provides a limited difference in heating effect upon the array between a signal comprising a plurality of first waveforms (a, a, a, a etc.) and an alternating succession of first and second waveforms (a, b, a, b, a, b etc.).

FIG.1



Data Voltage
( a )    ( b )

FIG.7

l.a.t

Strobe
Voltage

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**FIG.1**

**FIG.2**

**FIG.3**

2-4
Data Voltage

(a)                    (b)

l.a.t

Strobe
Voltage

**FIG.4**

l.a.t

(a)

**FIG.5**

l.a.t

(b)



**FIG.6**

3-4
Data Voltage
(a)          (b)

**FIG.7**

l.a.t

Strobe
Voltage

l.a.t

(a)

**FIG.8**

l.a.t

(b)



**FIG.9**
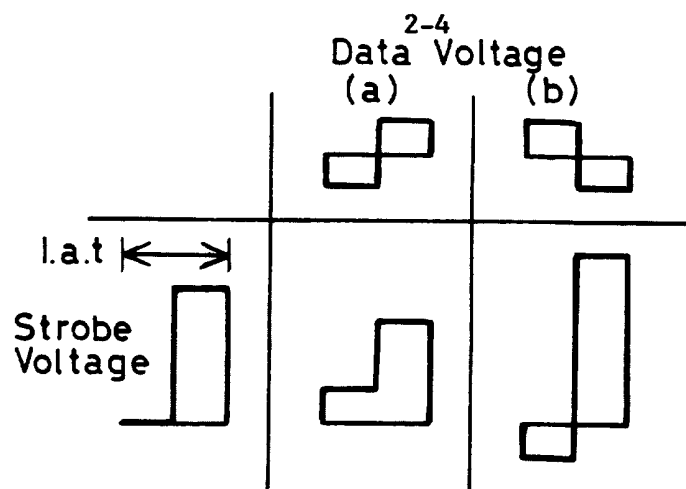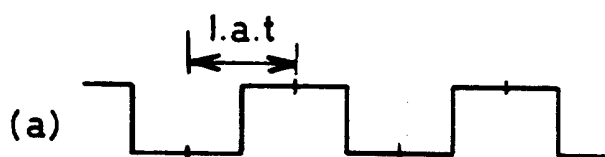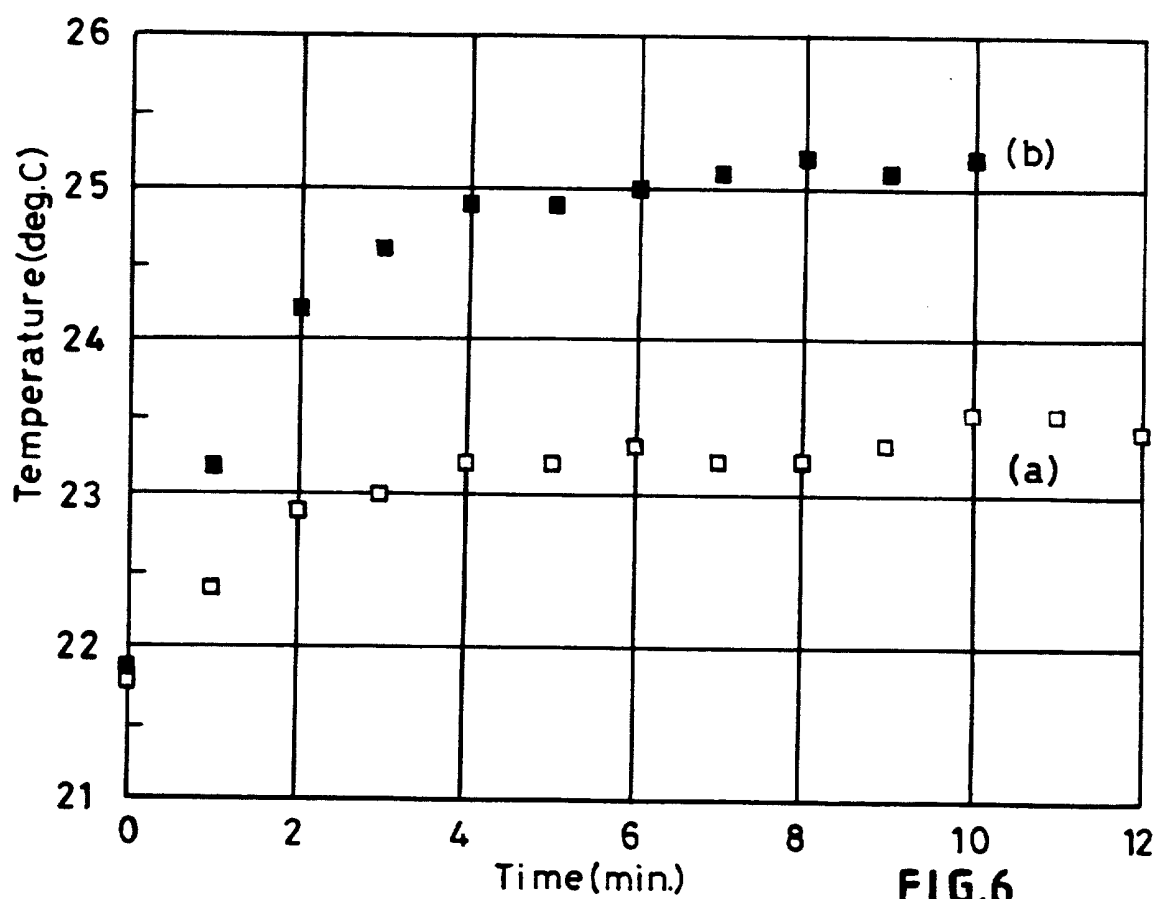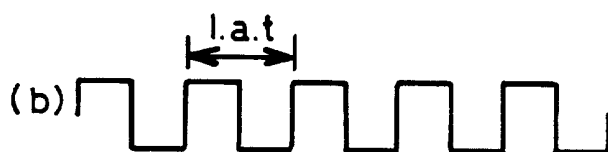
FIG.10

Liquid Crystal Array Device

The present invention relates to a liquid crystal array device having improved resistance to pixel-pattern dependent temperature effects. The invention has particular, but not exclusive, application to a large area liquid crystal array device in which the liquid crystal material is a ferroelectric liquid crystal material. The invention also relates to a driving arrangement for a liquid crystal array device and to a method of driving a liquid crystal array device.

Addressing techniques or multiplexing schemes for liquid crystal array devices are known. Typically, the array will comprise a first plurality of electrodes arranged parallel to each other on a first wall of the device an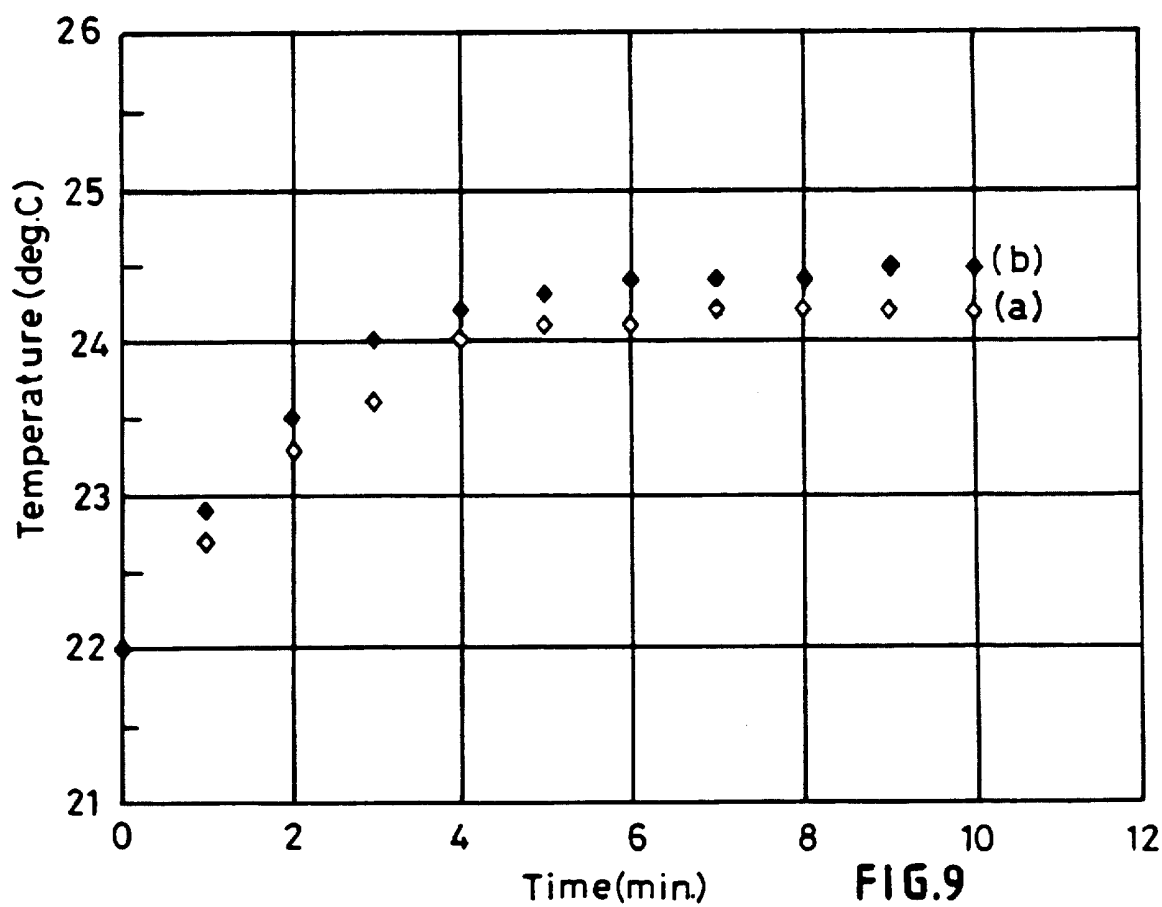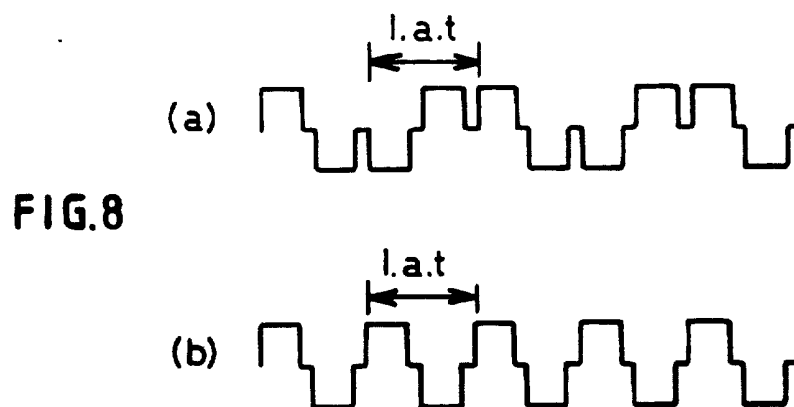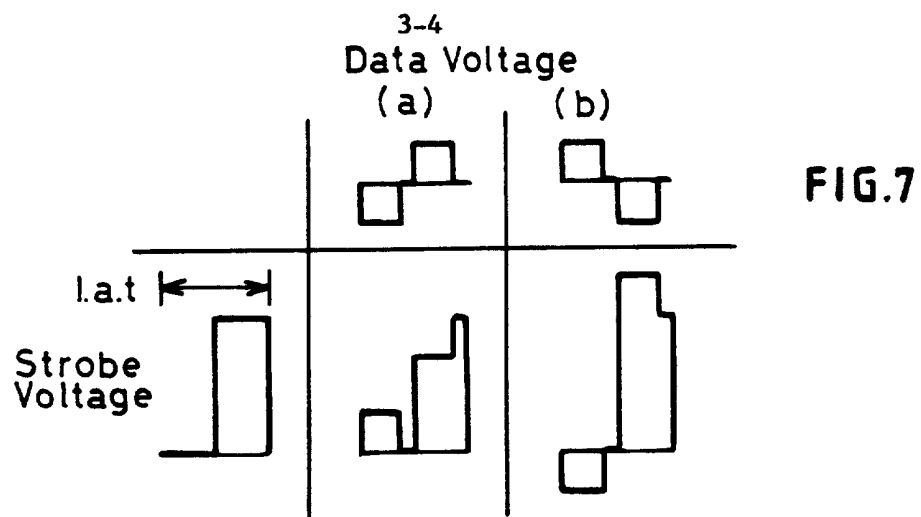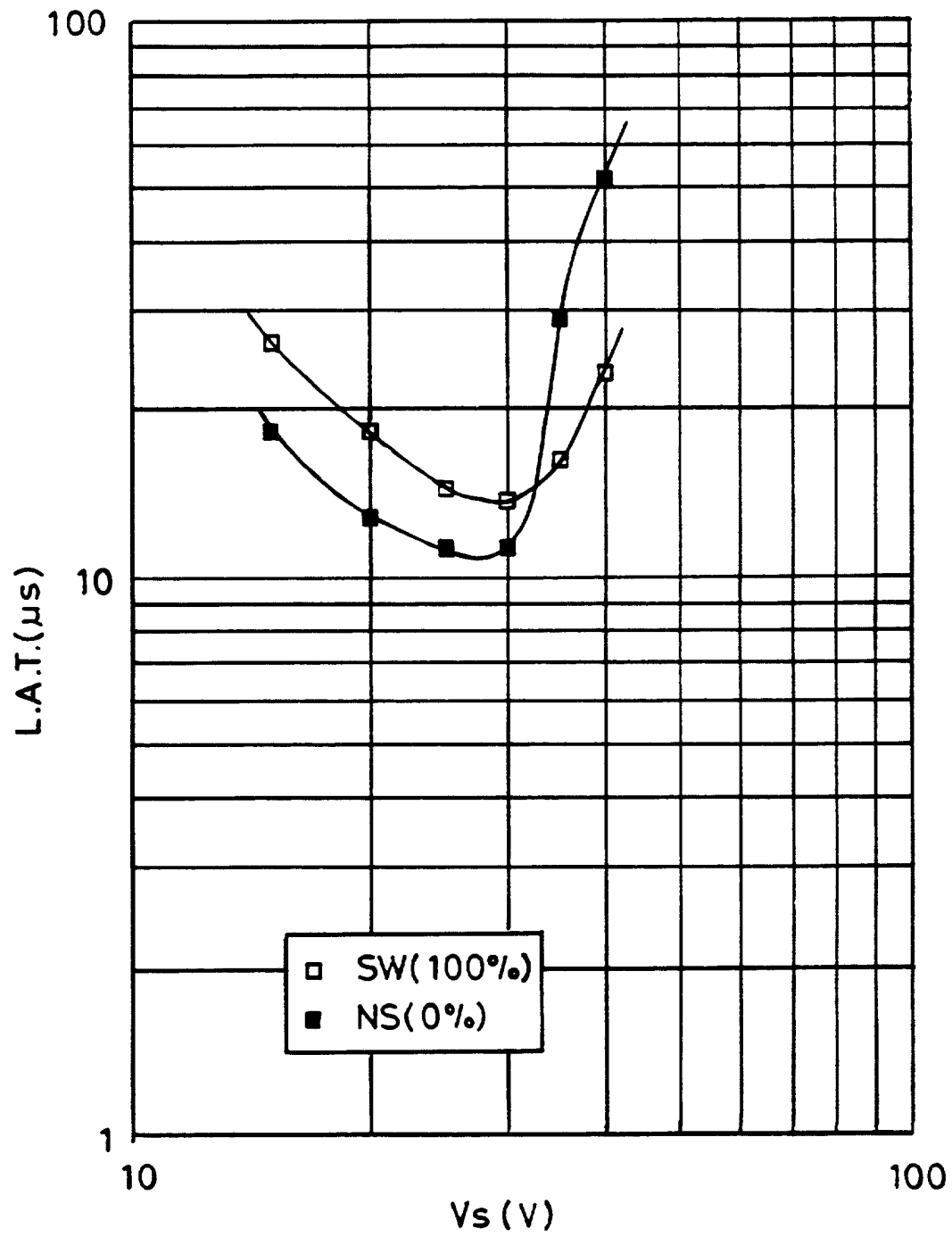d the second plurality of electrodes arranged parallel to each other, but perpendicular to the first plurality of electrodes, on the second wall of the device. A plurality of liquid crystal cells are thus defined at the point where these perpendicular electrode structures intersect. Because each liquid crystal cell does not have its own unique electrode connections some form of multiplexing is required to address the cells of the device. Usually a first signal, known as a strobe signal, is applied in succession to the first plurality of electrodes while a second signal is applied to each of the second plurality of electrodes. Thus, when the strobe signal is applied to a given electrode (hereafter referred to a row electrode) data signals may be applied to the second plurality of electrodes (hereafter referred to as column electrodes) to control the state of the cells in that row. One such multiplexing scheme, applied to ferroelectric liquid crystal displays, is described in the "JOERS/ALVEY Ferroelectric Multiplexing Scheme published in Ferroelectrics 1991, Volume 122, pages 63 to 79. In the scheme described in this prior art reference the plurality of second signals comprise either a first or second data waveform. The first data waveform comprises a positive going rectangular wave immediately followed by a

negative going rectangular wave of the same amplitude and duration. The second data waveform is the inverse of the first.

In a liquid crystal device array which is addressed using such a multiplexing scheme the column (data) waveforms are applied to all of the cells in their respective columns regardless of whether those cells are actually being addressed. In other words the column waveforms are applied to the cells of the device which are not receiving a strobe signal at that moment. When the array device is a ferroelectric liquid crystal (FELC) array the application of these waveforms is required to provide AC stabilisation of the liquid crystal material in the device. Consequently, these waveforms cannot be removed by, for example, arranging for the row driving circuitry to be open-circuit when a strobe signal is not applied. The floating row voltage would effectively be at a voltage level specified by an average of the voltage applied to the columns. For example, if all of the columns have a voltage V applied then the row electrode will also be at a voltage V resulting in zero potential across the liquid crystal in that row and no AC stabilisation. However, if some of the columns were at a voltage of V and some at a voltage of -V then the row voltage would be at an intermediate level and some AC stabilisation would be effected. As the contrast ratio and brightness are a function of the AC stabilisation voltage this technique could reduce the total power consumed by the panel but would generally lead to a spatial and temporal variation in image quality.

Such liquid crystal device arrays, particularly large area liquid crystal arrays, provide not inconsiderable driving problems because they comprise a large number of capacitors (the cells) connected by a series string of resistors (the electrodes). The AC waveforms applied to the column electrodes thus have to drive a distributed RC ladder at high frequency. This causes power dissipation in the resistances and the liquid crystal array device warms up. This causes a particular problem in ferroelectric liquid crystal array devices which are much more sensitive to temperature than, say, an equivalent nematic liquid crystal device.

It is an object of the present invention to provide a liquid crystal array device which is less susceptible to temperature variations.

It is another object of the invention to provide a driving arrangement for a liquid crystal array device for reducing this temperature variation.

It is a still further object of the present invention to provide a driving method for a liquid crystal array device which method reduces the effects of this temperature variation.

According to a first aspect of the present invention there is provided a device as set out in the appended claim 1.

According to a second aspect of the present invention there is provided a driving arrangement for a liquid crystal array device as set out in the appended claim 10.

According to a third aspect of the present invention there is provided a method of driving a liquid crystal array device as set out in appended claim 11.

The present invention concerns a hitherto unrecognised problem in the field of liquid crystal array devices and that is of temperature variations over the device caused by differences in the patterns being displayed. This pattern-dependent heating is a consequence of the different waveforms applied to the column electrodes of an array device because of the state of the liquid crystal cells in that column. For the sake of simplicity we confine ourselves to describing cells occupying either a white or a black state. However, the invention is also applicable to multi-colour displays and displays whose cells (or pixels) are capable of displaying more than two optical states (for example so called "grey scale"). If it is imagined that a column of a liquid crystal device comprises pixels which are all in the black state then the column driving waveform corresponding to black will be repeatedly applied to all of the cells in that column. Conversely, if it is imagined that the pixels in a particular column occupy the

states black, white, black, white etc. then the data waveforms relating to these two states are applied consecutively to all of the pixels in that row. Using prior art data waveforms, such as those described in the foregoing document, the heating effect of these two combinations of waveforms is rather different. Significant temperature variations can arise across a liquid crystal array device displaying these two patterns. Particularly for the case of a ferroelectric liquid crystal device this can cause problems of contrast between different parts of a display and even switching failures.

The present invention is based on the realisation that if the two waveforms described above (which result in extremes of power generation levels) are arranged to provide similar heating effects, the pattern dependent heating problem is significantly reduced. It has been appreciated that addition of a third signal level to the known two-level column data waveforms then the pattern-dependent heating effect is significantly reduced. The third signal level will typically be somewhere between the other two signal levels of the data waveform. Where the first two signal levels of the data waveforms are of equal magnitude but of opposite sign the third signal level is preferably zero volt.

The duration of the portion of the signal at the third signal level is important. Generally, as the length of this portion increases, the pattern-dependent heating effects are reduced. However, the portion at the third signal level preferably should not exceed one quarter of the duration of the data waveform because a longer portion would reduce the switching reliability of the device and/or the speed at which it could be addressed.

The first and second data waveforms in accordance with the invention may also comprise a further portion at the third signal level. This may be used to provide a signal which is balanced in time to still further reduce the difference in heating effects between the extreme data signals.

The present invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 shows a block schematic diagram of a liquid crystal array device in accordance with the present invention,

Figure 2 shows a typical τV characteristic for a ferroelectric liquid crystal display device,

Figure 3 shows the effect of AC stabilisation on the director of a ferroelectric liquid crystal molecule in an array device,

Figure 4 shows an example of a conventional driving scheme for a ferroelectric liquid crystal array device,

Figure 5 shows two voltage waveforms applied to the columns of a liquid crystal array device as a consequence of using the drive scheme shown in Figure 4,

Figure 6 shows the temperature dependence of a ferroelectric liquid crystal cell when driven by the prior art addressing scheme,

Figure 7 shows the data and resultant waveforms of one multiplex addressing scheme in accordance with the invention,

Figure 8 shows the two waveforms having extreme heating effects which are applied to the columns of a device in accordance with the invention,

Figure 9 shows the temperature dependence of a ferroelectric liquid crystal cell driven in accordance with the invention, and

Figure 10 shows a τV characteristic for a ferroelectric liquid crystal array device driven in accordance with the present invention.

Figure 1 shows a ferroelectric liquid crystal array device 10 comprising a first transparent wall 12 and a second transparent wall 20 spaced apart from the first wall by known means such as spacer beads (not shown). The wall 12 carries a plurality of electrodes 16 of transparent tin oxide on that surface of the wall that faces the second wall 20. The electrodes 16 are arranged parallel to one another and each extend between a first edge of the wall 12 and a second edge at which an electrical connector 14 is arranged to connect each electrode to a column driver 18. The wall 20 carries a plurality of transparent electrodes 22 also arranged in parallel with one another but at right angles to the electrodes 16 on the first wall. The electrodes 22 extend from a first edge of the wall 20 to a second edge at which an electrical connector 24 links them to a row

driver 26. Both the row driver 26 and the column driver 18 are connected to a controller 28 which will typically comprise a programmed microprocessor or an application specific integrated circuit (ASIC). Other electrode configurations can be applied to the liquid crystal device to provide , for example, a seven segment display, an r,θ display and so on. The liquid crystal device will also comprise polarising means and alignment layers (not shown) as is known to those skilled in the art. Alternate electrodes on each wall of the device may be connected to the row and column drivers at opposite edges of the walls. The operation of the device will be described in greater detail below.

Figure 2 shows a typical example of a τV characteristic for a ferroelectric liquid crystal device. Some ferroelectric liquid crystal materials have a minimum in their τV curves, which is useful for some driving schemes including the JOERS/Alvey driving scheme mentioned above. In figure 2 the region FS of the graph corresponds to a voltage-time product that will ensure that the cells of the device will switch fully to the other state. The region NS of the graph corresponds to voltage-time products that will not cause the cell to switch at all. A small band between these two regions denotes the partial switching region which corresponds to voltage-time products that will cause some, but not all of the area of a cell to switch. τV characteristics of ferroelectric liquid crystal materials with a minimum in the curves are generally affected by a pre-pulse in front of the main pulse. Therefore, the combination of the strobe and the non-switching data waveform, and the combination of the strobe and the switching data waveform usually have their own τV curves. The former must result in a τV product that falls in the region NS in its curve, and the latter must result in a τV product that falls within the FS region in its curve. In addition, either of the data waveforms on their own must result in a τV product that falls in the NS region. To compound the difficulties, the ferroelectric LCD is particularly sensitive to temperature and as the device heats up, the position of the τV switching curve moves.

Figure 3 shows positions of the directors of ferroelectric molecules under various driving conditions. The line RD corresponds to a rubbing direction applied to the faces of the cell in order to orient the liquid crystal molecules. Figure 3 shows a

plan view of molecules as observed normal (perpendicular) to the liquid crystal device which corresponds to the conventional viewing angle. When a DC voltage of a first polarity is applied to the cell the molecule will occupy the position DC shown by a dotted line provided the magnitude of the voltage is high enough. The same applies for an inverted signal and the position DC'. When the display has no voltage applied the directors relax to one or other of the positions OFF or OFF'. The two positions AC and AC' are the so called AC stabilised positions which the directors occupy as a result of the data waveforms applied to the columns of the display. These positions are important because they permit the angle through which the directors are switched to be altered which allows good contrast to be maintained for the display.

Figure 4 shows one of the examples of the conventional driving schemes, which is the so called J/A driving scheme. In this figure, data voltage (a) gives switching and data voltage (b) gives non-switching to pixels which are on the scanning electrode selected by strobe voltage. Therefore it can be easily understood that the frequency of the applied voltage to pixels depends on the pixel pattern or the information displayed on the column to which the pixel belongs. For example, if the black and white states are displayed line by line (row by row) on one column, the applied voltage to the pixels on this column is like that shown in Fig. 5(a). If only the black state is displayed on one column, the applied voltage to the pixels on this column is like that shown in Fig. 5(b). The fundamental frequencies $\omega$ of the applied voltages in Fig. 5(a) and 5(b) are $\pi/\text{l.a.t.}$ and $2\pi/\text{l.a.t}$ respectively, where l.a.t. refers to the line address time that is the time that each line is strobed. This means that the frequency of the voltage applied to the pixels depends on the pixel pattern, consequently the power dissipation also depends on the pixel pattern. This fact gives temperature variation over the panel area by the pixel pattern, which reduces the driving margin.

From Figs. 4 and 5, it can be easily understood that the fundamental frequency $\omega$ of the voltage applied to the pixels changes from $\pi/\text{l.a.t.}$ to $2\pi/\text{l.a.t}$ by the pixel pattern. The applied voltage patterns which give the lowest and highest power dissipation, are Fig. 5(a) and 5(b) respectively.

Figure 6 shows experimental results using small FELC test cell with 1 x 1 cm$^2$ electrode area. The figure shows temperature change of the surface of the FELC Cell-A applying square waveforms corresponding to Figs.5(a) and (b) in the curves shown by white squares and black squares respectively. The l.a.t was 10 µs, the amplitude of the voltage was 10V. The spacing of this cell was about 1.8 µm and contains ferroelectric liquid crystal material SCE8 (Merck Ltd., Merck House, Poole, U.K.). It can be easily seen that the pixel pattern affects the temperature of the surface of the cell. Even in this small test cell temperature variation by the pixel pattern is more than 1.5 degrees.

Although other driving schemes have been suggested, almost all of these have data voltages which are DC balanced within a line address time (to prevent dielectric breakdown of the ferroelectric liquid crystal cell). Therefore, pixel pattern dependence of the dissipated power is an essential problem for FELCDs, especially large area, small cell spacing FELCDs.

Figure 7 shows one of the examples of driving schemes which address the above mentioned problem. This corresponds to the conventional J/A driving scheme, but each of data voltages has periods with a voltage of zero when the polarity change occurs, where 'polarity change' means polarity changes from plus to minus, from minus to plus, from plus to zero, from zero to plus, from minus to zero, or from zero to minus. In data waveforms the ratio of periods of the pulse and the gap with voltage of zero is 3:1. Even in this driving scheme, the power dissipated by the array depends to some extent on the pixel pattern.

Figure 8 shows examples of applied voltages to pixels during driving, using the driving scheme shown in Fig.7. Figures 8(a) and (b) show the cases which give the lowest and highest frequency of the applied voltage respectively which correspond to the waveforms of figure 5 for the conventional J/A driving scheme.

Figure 9 shows temperature increase of the above mentioned small test cell applying the waveforms shown in Fig. 8. Figure 9 corresponds to figure 6 for the conventional J/A driving scheme. Temperature variation by the pixel pattern is only about 0.2 degree centigrade, which is much smaller than that of the conventional J/A driving scheme, approximately 1.5 degree centigrade.

This invention helps to enable large area, video rate FELCDs. Using the driving wave set in which each of data voltages has periods with voltage to be released of zero when the polarity changes from plus to minus, or from minus to plus ('plus' and 'minus' include zero), the power dissipation variation over the panel can be much reduced. Consequently non-uniformity of temperature over the panel will be reduced so that the multiplexing operating window of the whole panel will be increased.

Figure 10 shows the driving window of one of the driving schemes belonging to our invention. FELC Cell-B with the thickness of 1.8 $\mu$m and the material of FLC-1 developed by us was used. Data voltage types shown in figure 7 with an amplitude of 5.77$V_{op}$ were used with a three slot strobe pulse. This strobe pulse comprised a first slot of zero volt followed by two slots of $V_s$ such that the application of the strobe to adjacent rows overlapped (see UK Patent number 2,262,831). It is clear that this new type of data waveform gives a satisfactory drive window.

**CLAIMS:**

1. A liquid crystal array device comprising a liquid crystal material contained between two walls, a first and a second plurality of electrodes defining a plurality of cells and driving circuitry for applying a first signal in succession to the first plurality of electrodes and for applying a plurality of second signals to each of the second plurality of electrodes, each second signal comprising one of at least a first waveform and a second waveform, the first waveform and the second waveform each comprising first and second signal levels, wherein the first waveform and the second waveform further comprise at least one portion at a third signal level different from the first and second signal levels to provide a limited difference in heating effect upon the array between a signal comprising a plurality of first waveforms and an alternating succession of first and second waveforms.

2. A liquid crystal array device as claimed in Claim 1, wherein the third signal level of the first and second waveform is between the first and second signal levels.

3. A liquid crystal array device as claimed in Claim 2, wherein the first and second waveforms are bi-polar waveforms and the third signal level is zero volt.

4. A liquid crystal array device as claimed in Claim 3, wherein the first signal level and the second signal level are equal in magnitude.

5. A liquid crystal array device as claimed in any one of Claims 1 to 4, wherein the portion of the respective first and second waveforms at the third signal level comprises at most one quarter of the duration of the respective first and second waveforms.

6. A liquid crystal array device as claimed in any one of the Claims 1 to 5, wherein the first and second waveforms comprise a further portion at the third signal level.

7.     A liquid crystal array device as claimed in Claim 6, wherein the first waveform comprises a portion of first signal level followed by a portion of third signal level followed by a portion of second signal level followed by a portion of third signal level and the second waveform comprises a portion of second signal level followed by a portion of third signal level followed by a portion of first signal level followed by a portion of third signal level.

8.     A liquid crystal array device as claimed in any one of the Claims 1 to 7, wherein the RMS voltage of a signal comprising one of the first and second waveforms followed by the same one of the first and second waveforms and the RMS voltage of a signal comprising the first waveform followed by the second waveform are substantially equal.

9.     A liquid crystal array device as claimed in any one of the Claims 1 to 8, wherein the liquid crystal material is ferroelectric.

10.     A driving arrangement for a liquid crystal array device, which device comprises a liquid crystal material contained between two walls and a first and a second plurality of electrodes defining a plurality of cells, the driving arrangement comprising: means for applying a first signal in succession to the first plurality of electrodes and means for applying a plurality of second signals to each of the second plurality of electrodes which second signals each comprise one of at least a first and a second waveform, the first and second waveforms each comprising first and second signal levels, wherein each of the first and second waveforms further comprise at least one portion at a third signal level different from the first and second signal levels for providing a limited difference in heating effect when a signal comprising a plurality of first waveforms is applied to the device and when a signal comprising alternating first and second waveforms is applied to the device.

11.     A method of driving a liquid crystal array device, which device comprises a liquid crystal material contained between two walls and a first and a second plurality of

electrodes defining a plurality of cells, the method comprising applying a first signal in succession to the first plurality of electrodes and applying a plurality of second signals to each of the second plurality of electrodes which second signals each comprise one of at least a first and a second waveform, the first and second waveforms each comprising first and second signal levels, wherein each of the first and second waveforms further comprise at least one at the third signal level different from the first and second levels for providing a limited difference in heating effect upon the array when a signal comprising a plurality of first waveforms is applied to the array and when a signal comprising alternating first and second waveforms is applied to the array.

**Application No:** GB 9610321.3 **Examiner:** Mr.G.M Pitchman
**Claims searched:** 1 to 11 **Date of search:** 12 August 1996

## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

    UK Cl (Ed.O): G5C (CHB)

     Int Cl (Ed.6): G09G 3/36

Other:    ONLINE: EDOC WPI JAPIO INSPEC

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | Relevant to claims |
|---|---|---|
| A | EP 0642113 A1     (PHILIPS)-see abstract | 1-11 |
| A | WO 95/24715 A1    (SECRETARY OF STATE FOR DEFENCE)-see abstract | 1-11 |

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