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Highly Multiplexed Dot-Matrix LCD Suitable for Wide Temperature Range

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ABSTRACT

Double Layered Super Twisted Nematic LCD (D-STN) which can be operated by 1/128 duty ratio is presented.

Two conflicting requirements; good visibility and a wide operating temperature range are fulfilled through optimization of cell parameters, such as twist angle, pretilt angle of liquid crystal to glass substrate and elastic properties of liquid crystal material.

The response time of LCD decreases with increasing temperature. Hence at high temperature, the "frame response" phenomenon is observed and this results in reduction of contrast ratio. We propose multiple line selection (MLS) method for increasing in contrast ratio at high temperature.

INTRODUCTION

With the progress in car electronics, drivers are able to get various informations. Hence the information display plays an important role in conveying this information to the drivers. Recently, some display devices, such as CRT or TFT-LCD, have been used for high density information display. However, each display has the following disadvantages.

CRT: Space requirement, high voltage requirement and the possibility of high pressure explosion in the case of car crash.

TFT-LCD:High cost due to its complex structure and low yield in long production processes.

Asahi Glass introduced double-layered super-twisted nematic (D-STN) LCD for low information density displays in '91-SAE[1]. D-STN LCD also has potential for high density displays, but there were some problems to realize the highly multiplexed D-STN LCD with a wide temperature range of operation. One of the problems is the limitation of the temperature range, caused by the formation of domains. Another problem is decrease of the contrast ratio due to the "FRAME RESPONSE" phenomenon at high temperature.

The purpose of this paper is to outline the approaches for solving these two problems by optimizing cell parameters and using a new diving method.

STRUCTURE OF D-STN LCD

As shown in fig.1, A D-STN LCD is composed of two liquid crystal layers. One is a conventional STN layer, on which voltage is applied. The other STN layer is a compensation layer of identical thickness, but without electrodes and twisted in opposite sense. The linearly polarized light passing through the first STN layer in its nonselect-state becomes elliptically polarized light that are strongly wavelength dependent. But

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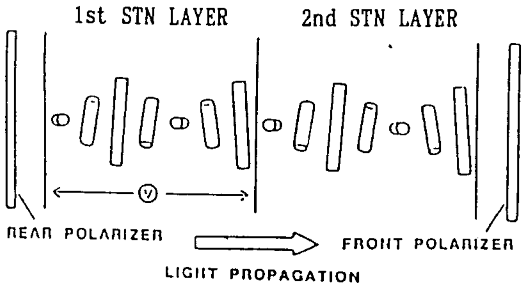

fig.1 Schematic description of the D-STN LCD display

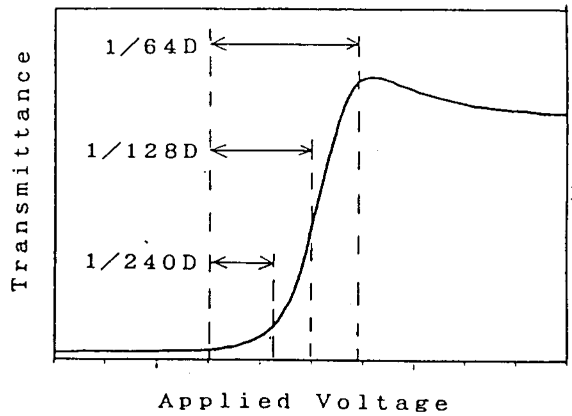

fig.2 On/off ratio of driving voltage for various duty ratio

whatever the first STN layer does to the light, the passive compensation layer undoes and restores the linear polarized state to be absorbed in the second crossed polarizer. The nonselect-state thus appears dark. The select-state of the STN layer is not compensated by the passive layer and light passes through the second polarizer.

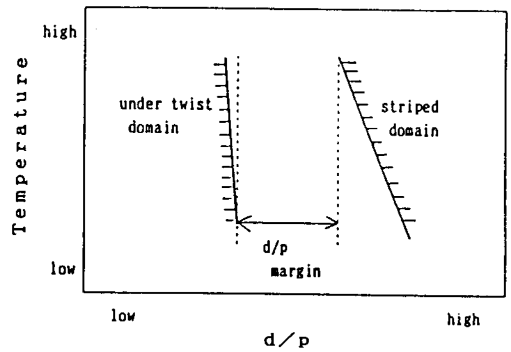

fig.3 Typical temperature dependence of the "d/p margin"

OPTIMIZATION OF CELL PARAMETERS

DOMAINS - When a D-STN LCD is driven at high duty, steep voltage versus transmittance(T-V) curve is necessary since on/off ratio of driving voltage becomes smaller than that of low duty (fig.2). When the steepness of T-V curve is increased, some unfavorable phenomena can occur. One potential problem is the misalignment of the liquid crystal molecules which causes visible domains. The possibility of the formation of domains is strongly influenced by the ratio between the cell gap (d) and the helical pitch of LC material (p). As shown in fig.3, "under twist domain" will occur in a lower d/p region and "striped domain" will occur in a higher d/p region. So a domain free state can be obtained within a certain range of d/p values and this range is called "d/p margin". "d/p margin" is narrower when the temperature range of operation is wider.

OPTIMIZATION OF CELL PARAMETERS - In table 1, changing direction of cell and LC parameters for improvement of steepness of T-V curve are shown. There are some approaches to obtain a steeper T-V curve, such as adopting high k33/k11, high k33/k22, low $\Delta\varepsilon/\varepsilon_{\perp}$ of LC materials, large twist angle, small tilt angle. All of these operations , however, make the d/p margin narrow, so it is important to estimate the degree of influence on "under twist domain" and "striped domain" when each parameter is changed to obtain a same improvement in the steepness of T-V curve.

Regarding the estimation of "under twist domain", we simulated the phenomena by calculating the dif-

parameters	direction for improvement of steepness	degree of influence on following phenomena	
		under twist domain	striped domain
Twist Angle	increase	HIGH	LOW
Tilt Angle(1~5°)	decrease	HIGH	HIGH
Tilt Angle(5~10°)	decrease	MEDIUM	MEDIUM
K33／K11	increase	MEDIUM	LOW
$\Delta\varepsilon/\varepsilon_\perp$	decrease	LOW	MEDIUM

table 1 Influence of changing cell and LC parameters on domains.

ference between free-energy of real twist state and that of under twist state . As a result, adopting low $\Delta\varepsilon/\varepsilon_\perp$ of LC materials is the most effective way to obtain a steeper T-V curve without rising the lower limit of the "d/p margin". Decreasing the pretilt angle below a certain value and increasing the twist angle are found to be unfavorable.

Concerning the "striped domain", we made experiments on some parameters and we also simulated the phenomena[2)] using Helfrich model[3)]. As a result, adopting a high twist angle and high k33/k11 of LC materials are effective to obtain a steeper T-V curve without changing the upper limit of the "d/p margin". Decreasing the pretilt angle below a certain value was found to be the most unfavorable. These results are also summarized in table 1.

As discussed in the paragraph of "STRUCTURE OF D-STN", the condition of compensation is satisfied for the nonselect-state of D-STN. However, when the viewing direction is oblique, the transmittance of nonselect-state increases. This fact means the compensation is not satisfied in the oblique angle, so optical optimizations are necessary. Fig.4 shows Δ nd dependence of transmittance of nonselect-state at some oblique angles. At a certain value of Δ nd, the transmittance shows the minimum value for each oblique angle.

Considering the above mentioned result, the parameters of highly multiplexed D-STN LCD which has a wide operating temperature range was optimized.

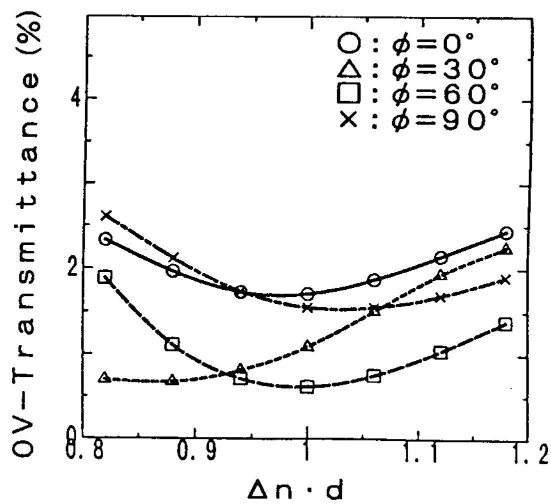

fig.4 Δ nd dependence of transmittance for several viewing angle
(θ =40°, ϕ =0°,30°,60°,90°)
θ : tilt angle from the normal direction to the cell
ϕ : azimuth angle from the main viewing direction of the cell

FRAME RESPONSE PHENOMENA AT HIGH TEMPERATURE - Another problem in highly multiplexed D-STN LCD is the decrease of contrast ratio due to the "frame response" phenomenon at high temperature. As the viscosity of liquid crystal(LC) material in high temperature region becomes low, the response time of LC molecules is comparable to the period of addressing waveform. As shown in fig.5, in the conventional waveform, the LC molecules respond to each high voltage select pulse, and relax during the time interval between two high voltage select pulses. This phenomenon decrease the transmittance of select-state, and increase the transmittance of nonselect-state. As shown in fig.6, this phenomenon is more noticeable as the duty ratio is higher, because the select pulse in high duty is greater than that in low duty.

High frame frequency is one of the easiest ways to get rid of the problems (fig.7). But the serious picture nonuniformity occurs when a LCD is driven at high frame frequency, so this technique is not successful.

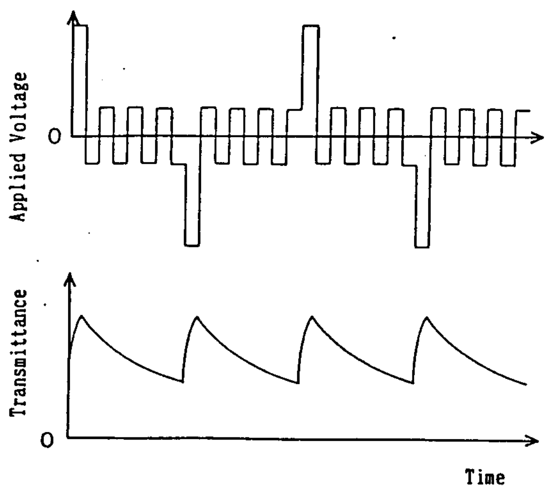

fig.5 Schematic description of the "frame response" phenomenon

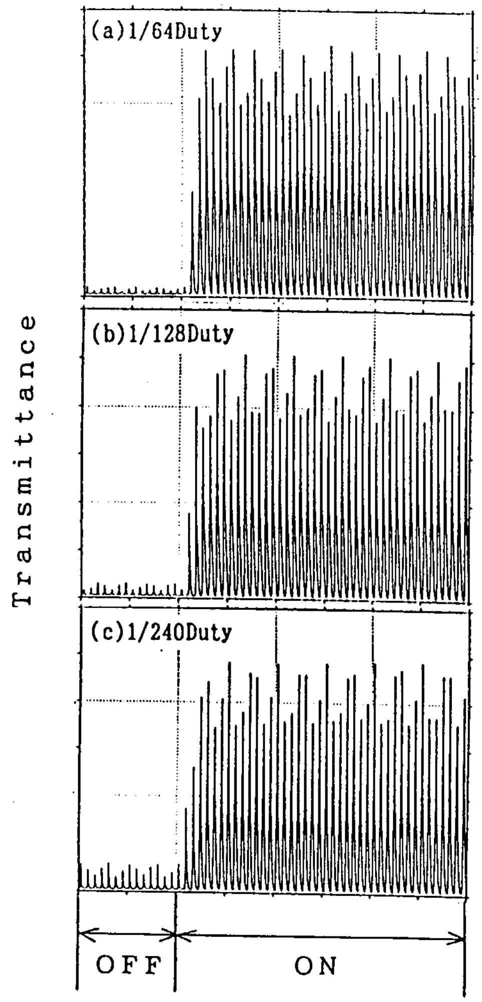

fig.6 Frame response phenomenon in D-STN LCD driven with the conventional waveform for various duty ratio.
Fr=70Hz, Temperature=80℃.

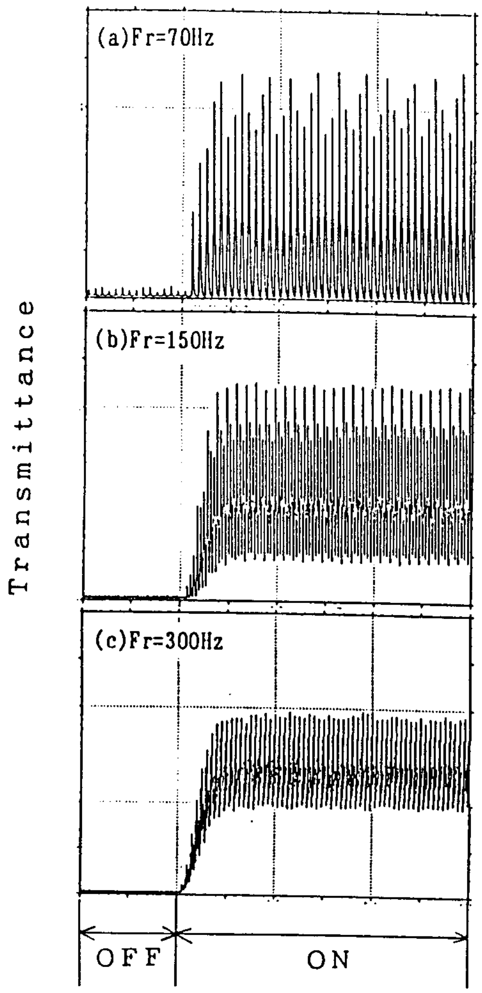

fig.7 Frame response phenomenon in D-STN LCD driven with the conventional waveform for various frame frequency.
Duty ratio=1/128duty
Temperature=80°C.

NEW DRIVING METHOD FOR INCREASING IN CONTRAST RATIO AT HIGH TEMPERATURE - From the last paragraph, it is clear that the small select pulses and the short time interval between the select pulses are effective to suppress the "frame response" phenomenon, and these approaches can be realized if multiple scanning lines are selected at a time. Several multiple-line selection (MLS) methods were proposed[4),5)], and Improved Hybrid Addressing Technique (IHAT), which is one of MLS methods, was proposed for fast responding LCDs by Optrex and Asahi Glass[6)]. Using this technique, the "frame response" phenomenon can be suppressed without any picture nonuniformity. Hence, this technique is also effective to get rid of the decrease of contrast ratio in high temperature region. Fig.8 shows the "frame response" phenomenon at high temperature when LCD is driven with IHAT. In this case, the number of lines multiplexed and the pulse width are same as those of the conventional waveform shown in fig.7-(a).(1/128duty; Fr=70Hz) Comparing two figures, it is obvious that the "frame response" phenomenon of IHAT is smaller than that of conventional waveform.

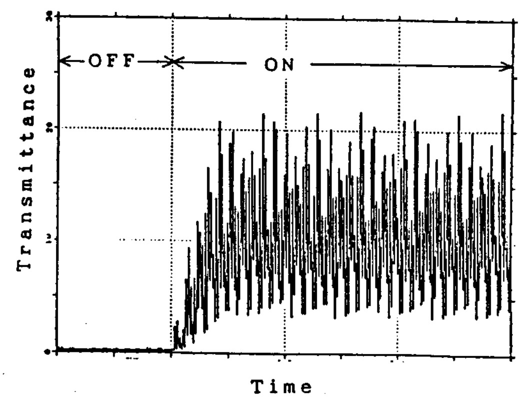

fig.8 Frame response phenomenon driven with the IHAT.
Temperature=80°C
Number of lines multiplexed = 129
Number of line selected at a time =3
Pulse width = pulse width of conventional waveform.
(fig.7-(a): 1/128duty, Fr=70Hz)

CHARACTERISTICS OF HIGHLY MULTIPLEXED D-STN

Some electro-optical properties of the optimized cell in driving the conventional waveform and IHAT are presented. Measuring conditions are 1/128 duty and same pulse width in each waveform, and three scanning line are selected at a time in IHAT. The driving voltage in each waveform is decided to get maximum contrast ratio at a viewing direction normal to glass substrate.

TEMPERATURE DEPENDENCE OF ELECTRO-OPTICAL PROPERTIES - Fig.9 shows the temperature dependence of contrast ratio. In the case of IHAT, the contrast ratio is greater than 50:1 in the range of -30°C to 80°C and has less temperature dependence in comparison with the conventional waveform.

Fig.10 shows the temperature dependence of the response time. There is no appreciable change in the response time between the two waveforms.

As shown in fig.11, the temperature dependence of driving voltage exhibit almost the same tendency for both the waveforms.

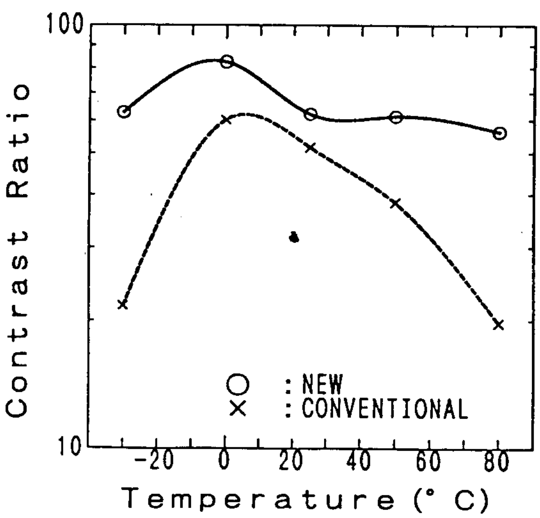

fig.9 Temperature dependence of contrast ratio

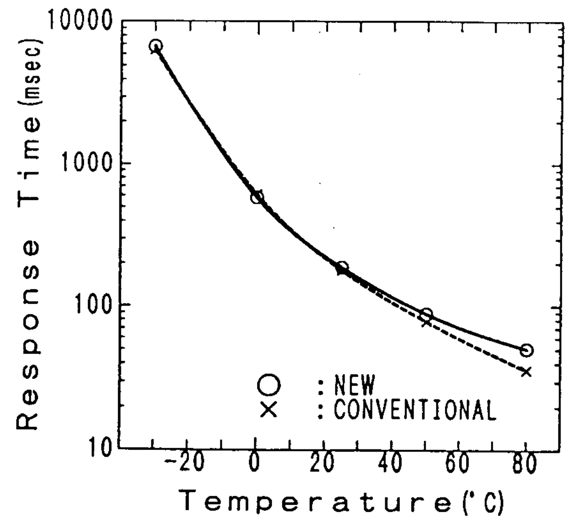

fig.10 Temperature dependence of average response time

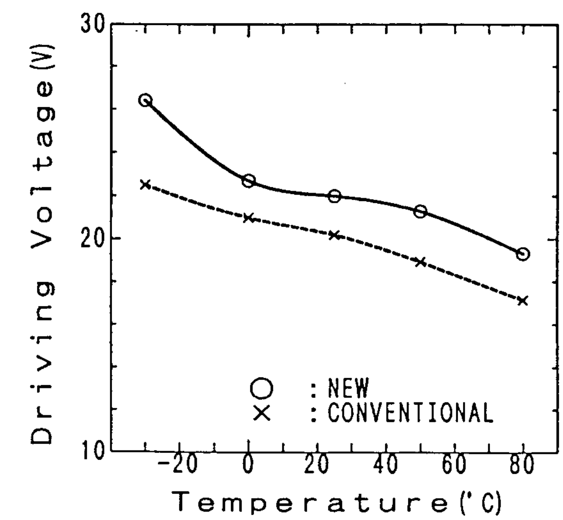

fig.11 Temperature dependence of driving voltage

CONCLUSION

The highly multiplexed D-STN, which enable to drive 1/128 duty, was developed. Using new waveform, the contrast ratio exceeds 50:1, through out the temperature range of −30°C to 80°C.

These techniques can also be adopted for color display which is required in advanced navigation systems.

The highly multiplexed D-STN LCD is one of the most promising candidate for the automotive information displays, and this is the first step of D-STN LCD for high density information display for automobile applications.

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