S3·4 A New Addressing Technique for Fast Responding STN LCDs

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ABSTRACT

A New addressing technique with a high address duty ratio for obtaining high contrast ratio, good brightness uniformity and gray shades in RMS responding matrix LCDs; especially the fast responding STN LCDs will be presented.

BACKGROUND

The LCDs exhibit RMS response to the applied electric field over a wide range of scanning frequencies. However as the period of the addressing waveforms become comparable to the response times of the liquid crystal cell light transmission through the:

1) ON pixels decreases and
2) OFF pixels increases

resulting in reduced contrast and brightness of the display. This is referred to as the Frame response phenomenon and is easily observable in fast responding STN LCDs[1,2] with a large number of rows being multiplexed (N). The use of conventional technique based on selecting one row at a time [3,4] to drive fast responding STN displays leads to frame response phenomenon for the following reasons:

1) amplitude of the row select pulse is large and increases with N and
2) time interval between the row select pulses also increases with N.

The addressing technique plays an important role in suppressing the frame response.

The multi-line selection method like Improved Hybrid Addressing Technique (IHAT) is effective for suppressing the frame response[5,6] since both amplitude of the row select pulse and the time interval between row select pulses can be reduced without any compromise in the selection ratio(SR.). IHAT can achieve high contrast ratio and good brightness uniformity of pixels at reduced supply voltage. However the number of time intervals to complete a cycle (NC) is higher in IHAT as compared to the conventional techniques. It is desirable to have NC as low as possible so that frame modulation can be adopted for displaying gray shades. A new addressing technique is proposed to overcome this problem.

SEQUENCY ADDRESSING TECHNIQUE (SAT)

Principle

It is well known that any addressing technique needs a set of orthogonal functions to form the row waveforms[7] A set of orthogonal block pulses is the basis for the line by line technique. The Rademacher functions are used to select L rows simultaneously in IHAT. The column waveforms are obtained by orthogonal transform of the data to be displayed in each column of matrix. The condition for maximum SR. must be incorporated to obtain high contrast. Hence any orthogonal transform like Haar, Slant, Walsh, Hadamard transform etc. may be used for addressing matrix displays.

The SAT is based on Hadamard transform and the principle of selecting multiple rows in a subgroup as in IHAT. This choice has been made since the hardware and addressing waveforms are simple. The elements in hadamard matrices consist of +1 or −1 only and larger matrices can be generated using the kronecker products.

Technique

The N rows in a matrix are divided in to (N/L) subgroups with L rows in each subgroup. At a given instant of time a subgroup is selected with voltages corresponding to one of the column vectors (row select pattern) of the matrix shown in fig 1. The row select voltage is + Vr for 1 and −Vr for −1 respectively. The column voltage is generated as follows. The data to be displayed in the selected subgroup of a column (ON and OFF pixels are represented as logic 1 and 0 respectively) is compared bit by bit with row select pattern (logic 1 for +1 and logic 0 for −1)using EX-OR gates. The number of mismatches (logic 1 at ex-or gate outputs) is counted using an adder. The number of mismatches (i) can range from 0 to L. The column voltage is :

$$Vi = ((L-2i)/ L)Vc \qquad (1)$$

wherein Vc is the maximum amplitude of the column voltage. The selection ratio is maximum when :

$$Vr = (N^{1/2}/L)Vc \qquad (2)$$

and the maximum selection ratio is :

$$(Von/Voff)_{RMS}=((N^{1/2}+1)/(N^{1/2}-1))^{1/2} \qquad (3)$$

The same as the Alt & Pleshko limit[3] This technique is same as IHAT except for the row select matrix and hence the number of time intervals in a cycle. The row select matrix is derived from Hadamard matrices and other orthogonal functions. Examples of the row select matrices are given in Figure 1. Hence the number of time intervals to complete a cycle is almost same as the conventional technique. Inversion of any row or column and rearranging the rows or columns of this matrices does not change the orthogonality condition while the uniformity of the pixels can be improved by proper choice of the row select sequences.

The choice of L , the number of rows in a subgroup is important from the point of view of frame response. The address duty factor of conventional technique is 1/N where as it is L/N for SAT. Hence the time interval between row select pulses is reduced by a factor L and hence the higher values of L is desirable. However the hardware for generating the column voltage (number of EX-OR gates and Adders) also increases with L and hence it is desirable to select the minimum value of L with which the frame response can be suppressed. Fig.2 and 3 gives the contrast ratio vs row select pulse width for a fast and slow response STN cell respectively when L=7and N=490. The circles in these figures represent the conventional addressing technique while the triangles shows the contrast ratio for SAT.The contrast ratio is higher than the conventional technique for a STN LCD with average response time of 50 mS as shown in fig.2. Here a row select pulse of 20 uS (frame frequency of about 100 Hz) is adequate to obtain a good contrast ratio. From the fig. 3 it is clear that the row select pulse can be as wide as 100 µS (frame frequency of about 20 Hz) for a STN LCD with average response time of 250 mS, when SAT is used.

Suppressing frame response

The multi-line selection technique with higher address duty factor is suitable for driving fast STN LCDs. The number of voltage levels in the column waveform increases with L, the number of rows selected simultaneously. The hardware (the number of ex-or gates and adders) required for generating the column voltage also increases with L. Hence the choice of L should be such that frame response is suppressed effectively with minimum value of L. The choice of L will depend on the response times of the LCD used.

The contrast ratio for various values of L is given in Table 1 when row select time is 20 and 40 µS. The efficiency with which the frame response is suppressed can be quantified by the ratio CR_L/CR_{static} , where CR_L is the contrast ratio for a given L and CR_{static} is the contrast ratio when the pixel is driven by square waveforms with same selection ratio. The percentage efficiency for different values of L is also given in table 1. From the table it is clear that a performance very close to Active Addressing can be achieved by selecting L=7. The hardware complexity is considerably lower than that of Active Addressing. Thus it is possible to select a suitable L value to suppress the frame response with minimum increase in the hardware complexity when IHAT or SAT is used for driving the fast responding STN LCDs.

Reducing brightness non-uniformity

The brightness uniformity of pixels depend on the frequency spectrum of the waveform across the pixel and it is desirable that the frequency lies in the region where the V_{th} is almost constant. The number of transitions in the addressing waveform should preferably same for reducing the non-uniformity arising from the distortion in the addressing waveforms. It is possible to reduce these non-uniformity by proper choice of row select sequences in IHAT and SAT.

Figure 4 shows the test patterns used for studying the brightness uniformity of pixels. Figure 5 shows the variation of transmission and the contrast ratio depending on the pattern displayed in a column when conventional addressing is used. The transmission of ON pixel shown in this figure varies considerably depending on the pattern displayed in a column resulting in poor brightness uniformity of pixels. The transmission of ON pixel is only 4.8% (very close to OFF state) when alternating ON and OFF pattern is displayed in a column as compared to 51.2% when most of the pixels are ON in a column. The maximum difference between ON transmission in figure 5 is 46.4%. The figure 6 gives the variation of ON pixel transmission and the contrast ratio for the same patterns in a column when SAT is used for driving the display. The maximum difference in ON pixel transmission is only 4.7%. From figure 5 and 6 it is clear that brightness uniformity of pixels is good when SAT is used for driving LCDs.

Displaying gray shades.

The principle of conventional methods for gray shade generation viz. Pulse width modulation and Frame modulation can be easily extended to SAT. The use of pulse width modulation results in high frequency waveforms across the pixels which may lead to brightness non-uniformity of pixels. The principle of frame modulation when extended to SAT is called cycle modulation and it is possible to achieve eight gray shades without much flicker. The electro-optic response curves for gray shades generated using cycle modulation is shown in Fig.7.

CONCLUSION

Sequency Addressing Technique(SAT), a new addressing technique for driving RMS responding LCDs,especially the fast responding LCD is proposed. The SAT can achieve high contrast ratio , good brightness uniformity of pixel and gray shades in fast responding STN LCDs with limited increase in hardware complexity of drive electronics.

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Table 1. Frame response - A comparison

L	CONTRAST RATIO 20 μS	CONTRAST RATIO 40 μS	EFFICIENCY 20 μS (%)	EFFICIENCY 40 μS (%)
1	25	7	38	10
3	49	29	75	43
7	59	50	91	75
15	58	48	89	72
31	52	38	80	57
63	57	48	88	72
127	55	46	85	69
240	61	52	94	78

$$\begin{bmatrix} + & + & + & + & - & - & - & - \\ + & - & + & - & - & + & - & + \\ + & + & - & - & - & - & + & + \\ + & - & - & + & - & + & + & - \end{bmatrix} \qquad \begin{bmatrix} + & + & + & - & - & - & - & + \\ + & + & - & + & - & - & + & - \\ + & - & + & + & - & + & - & - \\ - & + & + & + & + & - & - & - \end{bmatrix}$$

L=4 L=4

$$\begin{bmatrix} + & - & + & - & + & - & + & - & - & + & - & + & - & + & - & + \\ + & + & - & - & + & + & - & - & - & - & + & + & - & - & + & + \\ + & - & - & + & + & - & - & + & - & + & + & - & - & + & + & - \\ + & + & + & + & - & - & - & - & - & - & - & - & + & + & + & + \\ + & - & + & - & - & + & - & + & - & + & - & + & + & - & + & - \\ + & + & - & - & - & - & + & + & - & - & + & + & + & + & - & - \\ + & - & - & + & - & + & + & - & - & + & + & - & + & - & - & + \end{bmatrix}$$

L=7

Figure 1. Row select matrices for SAT.

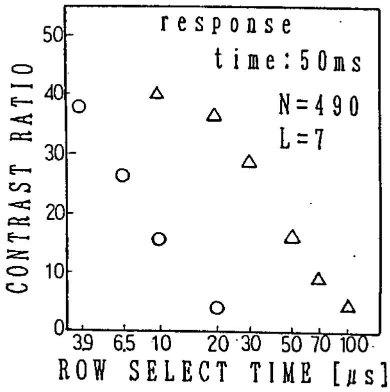

Figure 2. Contrast ratio vs row select time for fast STN LCD.

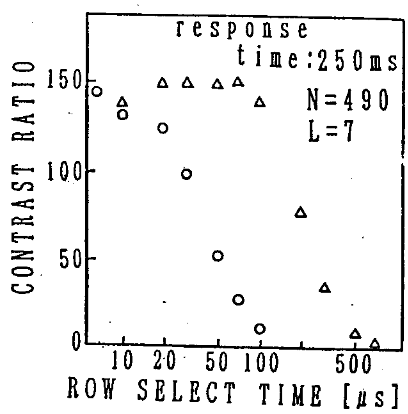

Figure 3. Contrast ratio vs row select time for slow STN LCD.

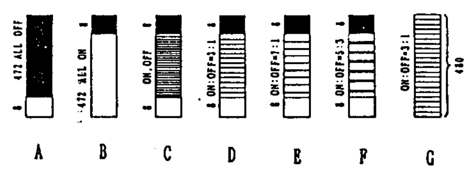

Figure 4. Test patterns.

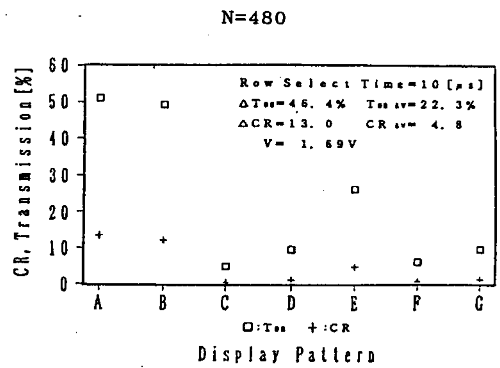

Figure 5. Brightness uniformity - APT.

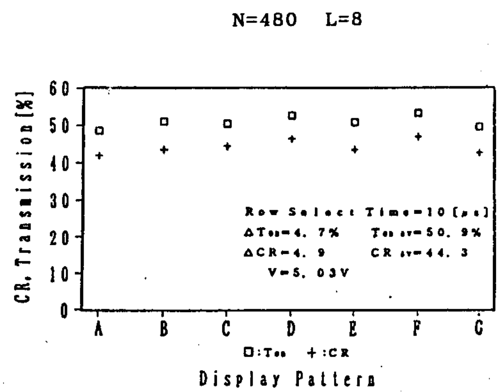

Figure 6. Brightness uniformity - SAT.

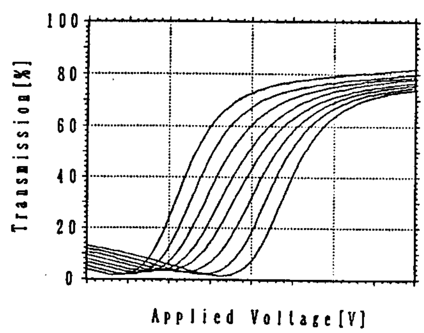

Figure 7. Transmission curves of CM-SAT.