P-40: Flicker-Free Restricted-Pattern Addressing Techniques with Low Supply Voltage

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Abstract

Addressing techniques for displaying restricted patterns in RMS responding matrix LCDs are proposed. Their salient features are high selection ratios and low supply voltages that are independent of the matrix size. High resolution displays in oscilloscopes and Logic Analyzers can be driven without flicker.

Introduction

Alt & Pleshko have shown that the maximum selection ratio (ratio of RMS voltage across the *ON* pixels to the RMS voltage across the *OFF* pixels) is $\sqrt{(\sqrt{N}+1)/(\sqrt{N}-1)}$, wherein N is the number of address lines that are multiplexed [1]. A higher selection ratio can be achieved when restricted patterns are displayed [2,3].

Correlation properties of pseudo random binary sequence(PRBS) waveforms were exploited to achieve infinite selection ratio when a single waveform is displayed in a matrix LCD [4]. An addressing technique for displaying multiple waveforms in matrix LCDs was proposed [5] by the author in the year 1986. Selection ratio of this technique is independent of matrix size and just depends on the number of waveforms *w* (also equal to the number of selected pixels in each column) being displayed.. Here, selected pixels (points on the displayed waveforms) get a lower RMS voltage as compared to the background. Hence this technique is referred to as Restricted Pattern Addressing Technique - Negative Contrast (RPAT-NC). It is also possible to get higher voltage across the selected pixels as compared to the background pixels[6]. This technique is referred to as Restricted Pattern addressing Technique- Positive Contrast(RPAT-PC). Advantages of RPAT-NC and RPAT-PC are:

- Good contrast ratio can be achieved even with large matrix of TN-LCD since the selection ratio of RPATs is independent of the matrix size and higher than the conventional technique.
- Standard row and column drivers can be used since the addressing technique is simple and similar to the conventional addressing technique..

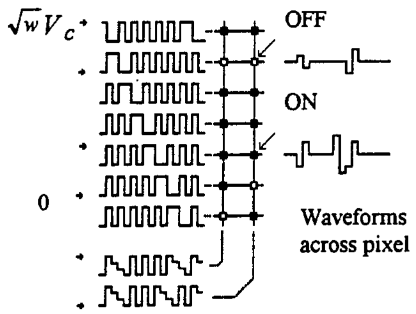

Figure 1: Typical waveforms of RPAT-NC

Figure 1 gives the typical waveforms for RPAT-NC for N=7. Voltage across any pixel in a display addressed with RPATs is zero during most of the time intervals in a period as illustrated in figure 1. This will result in flicker if N is very large. In addition to this problem, the amplitude of the row select pulse increases with N, the number of rows being multiplexed. This will lead to frame response phenomenon in fast responding LCDs. New addressing techniques are proposed to over come this problem in this paper.

Principle

Oscilloscopes, Logic Analyzers and Electro-Cardio-Graph (ECG) displays mostly display single valued functions of time. If *w* waveforms are displayed in these displays, then only *w* pixels in a column carry information while rest of the (N-*w*) pixels are background pixels. This restriction in the displayed patterns is exploited to improve the display performance for applications mentioned above.

Driving matrix LCDs is similar to multiplexing in communication[7,8]. Waveforms applied to the N row electrodes of a matrix LCD are orthogonal to each other. Column waveforms depend on the data to

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be displayed in a column since information is multiplexed through the column electrodes. Column waveforms are generated by taking orthogonal transform of the data to be displayed. The data to be displayed is assigned a value +1 for *OFF* pixels and -1 for *ON* pixels, when the pattern to be displayed is general (without any restrictions on the pattern).

New addressing techniques for displaying restricted patterns are based on assigning a value 0 to the background pixels. This is similar to assigning the non-select voltage of the row waveform to be the column voltage for the background pixels in RPAT-NC and RPAT-PC. Assigning 0 to be the data (d_i) for background pixels results in selection ratios that are independent of the matrix size. There is still some flexibility in assigning a value for the *w* pixels, which are points on the waveforms being displayed on the oscilloscope. These selected pixels can be assigned either +1 or -1. Assigning +1 to the *w* pixels results in negative contrast with background pixels getting a higher voltage compared to the selected pixels. Background pixels get a lower voltage across them as compared to selected pixels when the data (d_i) for the selected pixels is -1. Column waveforms are generated based on the following equation

$$C(t) = \sum_{i=1}^{N} d_i \times O_i(t) \qquad (1)$$

wherein d_i is the data in the i-th row of the given column and $O_i(t)$ is the orthogonal waveform applied to the i-th row of the matrix LCD. Principle explained here is general and can be used with any set of orthogonal functions.

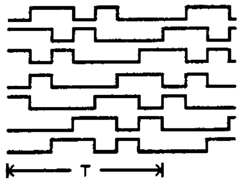
Techniques

The N rows in a matrix display are driven with waveforms corresponding to a set of orthogonal functions. Hardware complexity of the drive electronics varies considerably on the choice of the orthogonal functions. Simple orthogonal functions derived from Hadamard matrices, pseudo random binary sequences or walsh functions are preferred.. These orthogonal functions take a value of +1 or -1 only. Here the generation of row waveforms is simpler as compared to other orthogonal functions derived from a set of sine or cosine functions or slant matrices. Multiplication in equation (1) is also avoided with these orthogonal functions. Hence generation of column waveforms is simple. Number of voltage levels in the column waveforms is also less when data to be displayed is assigned -1 or +1(for ON and OFF pixels respectively).

The pseudo random binary sequence(PRBS) used by Shanks and Holland [4] (for addressing Non-multiplexed oscilloscope displays) is a good choice for row waveforms for the following reasons.. The number of transitions (from +1 to -1 or from -1 to +1) in the waveform is a constant for the PRBS and its shifted versions are the same. Waveforms applied to the matrix LCDs get distorted due to the resistance of the indium tin oxide and capacitance of the pixels. Error in the RMS voltage across the pixels due distortion in the waveform is same for all the pixels if the number of transitions in the addressing waveforms are equal. Hence brightness uniformity of pixels will be better if PRBS waveforms are used. Figure 2 gives the PRBS of length 7 and its shifted versions. Frequency spectrum of these waveforms are also same since they are identical except for the shift in time domain. This is also an useful property since brightness non-uniformity of pixels due to variations of threshold voltage and electro-optic characteristics with frequency is minimised by using PRBS sequences.

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

(a)



(b)

Figure 2: (a) Matrix of PRBS and its shifted versions and (b) Corresponding waveforms.

PRBS sequences are not orthogonal. Hence they are not suitable for multiplexing . However these sequences can be converted to orthogonal form by adding a column of +1 to the matrix in figure 2 as shown in figure 3. Length of the PRBS is $(2^L - 1)$ wherein L is an integer indicating the number of stages (flip-flops) necessary in the shift register circuit used for generating these sequences. Number of transitions in a waveform shown in Figure 3 is either $2^{(L-1)}$ or $(2^{(L-1)} + 2)$. This difference is not much for very long sequences and in any case less than that of Walsh functions, wherein the number of transitions ranges from 0 to 2^L. Any N waveforms $(N \leq (2^L - 1))$ out of the $(2^L - 1)$ waveforms can be

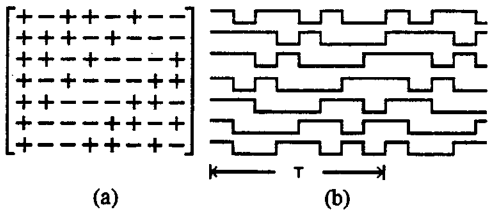


Figure 3: (a) Orthogonal matix based on PRBS and (b) Corresponding waveforms.

used for driving the N rows of a matrix LCD. *Let* $O_1(t), O_2(t), O_3(t), \ldots, O_N(t)$ be the N orthogonal waveforms applied to rows of a Matrix LCD. Hence

$$\int_T O_i(t) O_j(t) dt = \begin{cases} 1 & \forall i = j \\ 0 & \forall i \neq j \end{cases} \quad (2)$$

Amplitude of these waveforms is either Vr or -Vr corresponding to +1 or -1 in the orthogonal function. Let w be the number of pixels in each column that are driven to a selected state Then (N-w) pixels in each column are the background pixels. Let i , k , . . . s be the rows in a column wherein the pixels are selected , while rest of the pixels in that column are background pixels. The column waveform is chosen to be proportional to the sum of the orthogonal functions applied to the i , k , . . . s rows of the matrix display. Hence the column waveform is

$$O_c(t) = O_i(t) + O_k + \ldots + O_s(t) \quad (3)$$

when $d_i = +1$. This technique will be referred to as PRBS-NC. Column waveforms is as given below

$$O_c(t) = -\left(O_i(t) + O_k + \ldots + O_s(t) \right) \quad (4)$$

when $d_i =$ -1, this will result in selected pixels getting a higher RMS voltage as compared to the background pixels. Hence this technique will be referred to as PRBS-PC.

Typical addressing waveforms for PRBS-NC are shown in Figure 4. The row waveforms are identical for both PRBS-NC and PRBS-PC. Polarity of the column voltages is reversed in the case of PRBS-PC as compared to PRBS-NC (Figure 5). Column waveforms have $(w+1)$ voltage levels and suitable (8 or 16 level) column drivers are readily available.

Analysis

Voltage across pixel is the difference between row and column waveform. RMS voltage across the pixels is given in equation (5)

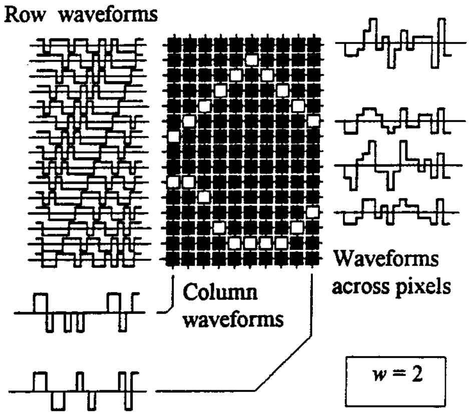


Figure 4: Typical waveforms of PRBS-NC.

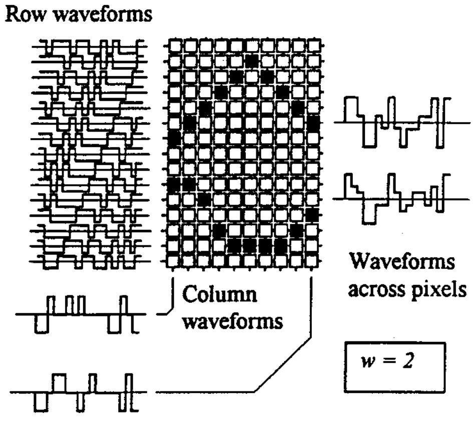


Figure 5: Typical waveforms of PRBS-PC

$$V_{pixel}(RMS) = \sqrt{\frac{1}{T} \int_T \left(O_j(t) - O_c(t) \right)^2 dt} \quad (5)$$

Selection ratio is optimum when $V_r = \sqrt{w}$

Optimum Selection ratio for PRBS-NC is

$$SR = \sqrt{\frac{\sqrt{w}}{\sqrt{w} - 1}} \quad \forall \quad d_i = 1 \quad (6)$$

This is same as that obtained for RPAT-NC[5].

Maximum selection ratio for PRBS-PC is

$$SR = \sqrt{\frac{\sqrt{w} + 1}{\sqrt{w}}} \quad \forall \quad d_i = -1 \quad (7)$$

which is same as that of RPAT-PC[6]. Thus the selection ratios for both these techniques are independent of the matrix size. N_{eq}[5] gives the number of lines that are to be multiplexed using the Alt & Pleshko technique to achieve the same selection ratio (equation 6 or 7) as the present technique. N_{eq} for PRBS-NC and PRBS-PC are

$$N_{eq}(PRBS-NC) = \left(2\sqrt{w}-1\right)^2 \tag{8}$$

and

$$N_{eq}(PRBS-PC) = \left(2\sqrt{w}+1\right)^2 \tag{9}$$

Supply voltage for the drive electronics is given by the maximum swing in the addressing waveforms and is given by the following equation

$$V_{Supply}(PRBS-NC) = \sqrt{(2w)}\,V_{Saturation} \tag{10}$$

Supply voltage for PRBS-NC is independent of matrix size and just depends on w, the number of selected pixels in a column. Supply voltage of RPAT-NC is given below for comparison,

$$V_{Supply}(RPAT-NC) = \sqrt{(N/2)}\,V_{Saturation} \tag{11}$$

Hence the reduction in supply voltage is given by

$$R = \frac{V_{Supply(PRBS-NC)}}{V_{Supply}(RPAT-NC)} = 2\sqrt{\frac{w}{N}} \tag{12}$$

Similarly the comparison of supply voltages for PRBS-PC to that of RPAT-PC is given below

$$\frac{V_{Supply}(PRBS-PC)}{V_{Supply}(RPAT-PC)} = 2\sqrt{\frac{w}{N}}\left(\frac{\sqrt{w}}{\sqrt{w}+1}\right) \tag{13}$$

Results

N_{eq} for PRBS-NC and PRBS-PC as functions of w are shown in Figure 6. N_{eq} is 9 and 25 for PRBS-NC and PRBS-PC respectively, when four waveforms (w=4) are displayed. Hence TN-LCDs with faster response times as compared to the STN-LCDs can be used in displays for Oscilloscopes.

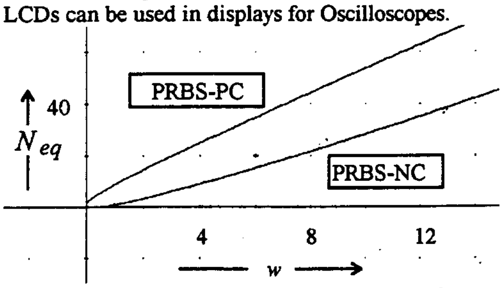


Figure 6: N_{eq} vs w for PRBS-NC & PRBS-PC.

Figure 7 gives the plot of equation (12) as a function of N for several values of w. Supply voltage for PRBS-NC is just 25% of that required for RPAT-NC, when N is 256 and w=4. Hence 75% reduction in supply voltage is possible when PRBS-NC is used. Reduction in supply voltage is even more for higher values of N. It is important to note that supply voltage decreases with w and is equal to $\sqrt{2}\,V_{saturation}$ as in the case of non- multiplexed oscilloscope display in reference [4].

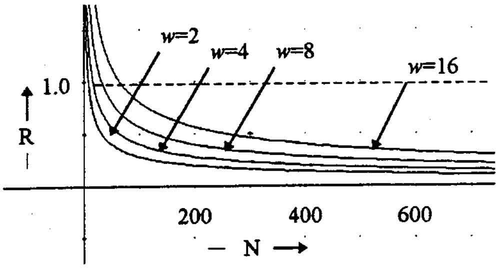


Figure 7: Supply voltage comparison R vs N

Conclusion

PRBS-NC & PC can be used for displaying restricted patterns with TN-LCDs (with faster response times as compared to STN-LCDs), since selection ratio of these techniques are high. Limited alphanumeric information can also be displayed by using dummy rows as discussed in reference [5]. Frame response and flicker are suppressed due to high address duty factor(unity) of PRBS-NC & PC. Low supply voltage which is independent of matrix size is an additional advantage of these techniques especially in portable devices.

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