# 8.3: An LCD for Multitrace Oscilloscopes

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## Abstract

A liquid crystal oscilloscope display for multiple waveforms uses an addressing technique which exploits the restricted patterns in such displays to achieve a higher contrast ratio than conventional multiplexing. The selection ratio depends on the number of waveforms displayed but not on matrix size.

## Introduction

Matrix displays for oscilloscopes and logic analyzers have to display multiple waveforms, which are mostly single valued functions of time. A large matrix (with 256 rows or more) is preferred so that the waveforms can be displayed without sacrificing finer details. The selection ratio obtained for a matrix with a large number of rows is low if the Alt and Pleshko line by line addressing technique (APT) is employed [1,2].

In order to achieve a high contrast ratio special techniques have been developed for oscilloscopes displaying single waveforms [3]. The N rows in the matrix are sequentially selected with low duty ratio (1/N) rectangular pulses of amplitude V. The column voltage is 0 volts for the 'ON' elements and a voltage V, (which is in-phase with the row select voltage) for the 'OFF' elements. Since the display has only one selected element ('OFF') per column, this technique achieves infinite selection ratio with 0 voltage across the 'OFF' elements which are points on the displayed waveform and $(2/N)^{1/2}.V$ across the background 'ON' elements.

In another technique, the correlation properties of pseudorandom binary sequences is used [4]. It is again possible to display a single waveform with infinite selection ratio.

Dual-traces have been displayed by using interleaved vertical electrodes, i.e., by using odd columns for one trace and even columns for the other. The horizontal resolution is sacrificed without any compromise in the selection ratio [5].

Alternatively, multitrace operation is possible if n waveforms are multiplexed in sequential frame periods. The selection ratio is $[n/(n-1)]^{1/2}$ without any compromise in horizontal resolution [5].

Theoretically, it has been shown by earlier workers [6,7] that a selection ratio higher than that of the APT can be obtained for restricted patterns. Further, the selection ratio is higher when most of the elements are 'ON' compared to the case when most of the elements are 'OFF', in a given column [6,7]. This theoretical conclusion has not been exploited for displaying multitraces in an oscilloscope.

In the present work we have developed an addressing technique for displaying multiple traces. It is important to note that the selection ratio depends only on the number of selected elements in a column (n = number of waveforms) and is independent of the total number of rows (N) in the matrix. This is in contrast to the results of Ref. 6 and 7, wherein the selection ratio is a function of both N and n.

## Technique

Consider a matrix with N rows and M columns. Let the number of waveforms to be displayed be n. As discussed above, a better selection ratio is obtained when (N-n) elements are 'ON' and n are 'OFF' in a given column. This will result in a negative contrast for twisted nematic displays and a positive contrast when the guest-host mode is used.
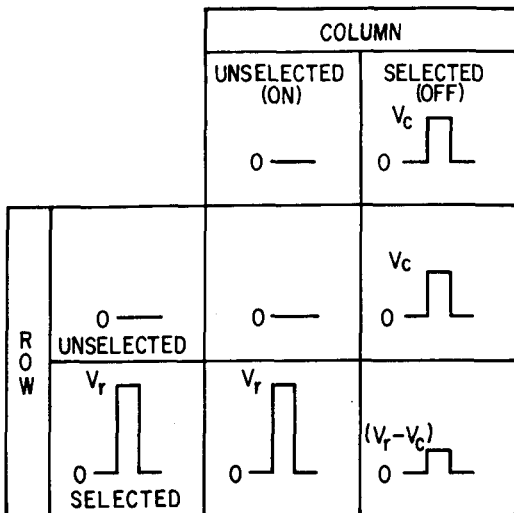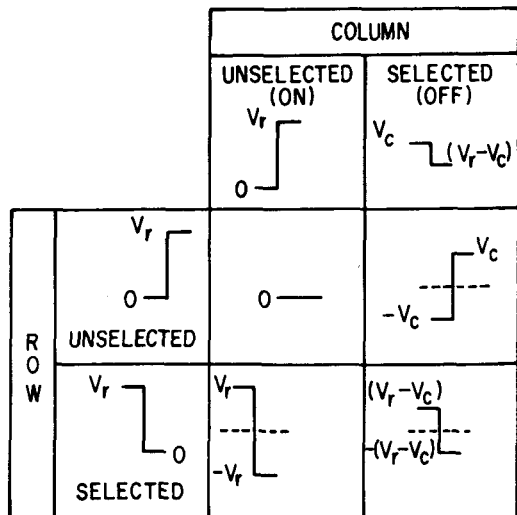


Fig: 1.a. D.C. Addressing of the Display.



Fig: 1.b. A.C. Addressing of the Display.

For the sake of clarity, we shall first discuss the dc addressing scheme (Fig. 1). The N rows in the matrix are selected one at a time with a row select voltage $V_r$ while the unselected rows are grounded. The column (data) voltage is chosen to be 0 volts for an 'ON' element (background pixel) and a voltage $V_c$, which is in phase with the row select voltage, for an 'OFF' element (selcted pixel which is a point on the waveform). Since there are n waveforms to be displayed, any column in the matrix will get a voltage $V_c$ for n time intervals and 0 volts in the rest of the (N-n) time intervals. The rms voltages across an element determines its state. The voltage across 'ON' and 'OFF' elements are given by

$$V_{ON_{(rms)}} = \left[\frac{V_r^2 + nV_c^2 + (N-n-1)0}{N}\right]^{1/2} \quad (1)$$

$$V_{OFF_{(rms)}} = \left[\frac{(V_r-V_c)^2 + (n-1)V_c^2 + (N-n)0}{N}\right]^{1/2} \quad (2)$$

The $V_{ON}/V_{OFF}$ ratio is optimized for $V_r/V_c = n^{1/2}$, which is independent of the total number of rows (N) in the matrix. Substituting this in equations (1) and (2) we get

$$V_{ON} = \left[\frac{2n}{N}\right]^{1/2} V_c = \left[\frac{2}{N}\right]^{1/2} V_r \quad (3)$$

$$V_{OFF} = \left[\frac{2n-2\sqrt{n}}{N}\right]^{1/2} V_c = \left[\frac{2\sqrt{n}-2}{N\sqrt{n}}\right]^{1/2} V_r \quad (4)$$

The selection ratio $V_{ON}/V_{OFF}$ is given by

$$R = \frac{V_{ON}}{V_{OFF}} = \left[\frac{2\sqrt{n}}{2\sqrt{n}-2}\right]^{1/2} = \left[\frac{\sqrt{n}}{\sqrt{n}-1}\right]^{1/2} \quad (5)$$

In order to compare this with the selection ratio obtained in APT the equation (5) is written in the form

$$R = \left[\frac{\sqrt{N_{eq}} + 1}{\sqrt{N_{eq}} - 1}\right]^{1/2} \quad (6)$$

where $N_{eq}$ gives the number of rows to be multiplexed to obtain the same selection ratio

$$\frac{V_{ON}}{V_{OFF}} = \left[\frac{2\sqrt{n}}{2\sqrt{n}-2}\right]^{1/2} = \left[\frac{\sqrt{(2\sqrt{n}-1)^2}+1}{\sqrt{(2\sqrt{n}-1)^2}-1}\right]^{1/2} \quad (7)$$

Hence $N_{eq}$ for this technique is $(2\sqrt{n}-1)^2$. Table 1 gives the selection ratio and $N_{eq}$ against the number of waveforms to be displayed.

The supply voltage is determined by the amplitude $V_r$. The 'ON' elements can be biased to $V_{s90}$(90% of the saturation in the transmission characteristics).

$$V_{ON} = V_{s90} = \left[2/N\right]^{1/2} V_r \quad (8)$$

$$V_{supply} = V_r = \left[N/2\right]^{1/2} \cdot V_{s90} \quad (9)$$

The supply voltage increases with the matrix size and is independent of the number of waveforms displayed (n). In order to achieve a dc free operation the phase of the row and column waveforms are reversed as in Fig. 2.

Comparison between the present technique and multitrace display by multiplexing the waveforms to be displayed frame by frame. $N_{eq}$ gives the number of rows to be multiplexed if APT is used in order to achieve the same selection ratio.

| n | Present technique | | Multitrace by frame multiplexing of waveforms | |
|---|---|---|---|---|
| | Selection ratio $\left[\frac{\sqrt{n}}{\sqrt{n}-1}\right]^{1/2}$ | $N_{eq}$ $(2\sqrt{n}-1)^2$ | Selection ratio $\left[\frac{n}{n-1}\right]^{1/2}$ | $N_{eq}$ $(2.n-1)^2$ |
| 1 | ∞ | 1.00 | ∞ | 1 |
| 2 | 1.848 | 3.34 | 1.414 | 9 |
| 3 | 1.538 | 6.07 | 1.225 | 25 |
| 4 | 1.414 | 9.00 | 1.155 | 49 |
| 5 | 1.345 | 12.05 | 1.118 | 81 |
| 6 | 1.300 | 15.20 | 1.095 | 121 |
| 7 | 1.268 | 18.41 | 1.080 | 169 |
| 8 | 1.244 | 21.68 | 1.069 | 225 |
| 9 | 1.225 | 25.00 | 1.060 | 289 |
| 16 | 1.155 | 49.00 | 1.033 | 961 |
| 25 | 1.118 | 81.00 | 1.020 | 2401 |

## Discussion

The selection ratio is independent of N, since the column voltage for the 'ON' elements is zero instead of a finite voltage. In practice n << N and hence there is no appreciable change in the selection ratio compared to the theoretical limits of techniques for restricted patterns discussed in Ref. 6 and 7. For single trace operation the technique achieves infinite selection ratio and the addressing waveforms are identical to those given in [3,5,8]. The addressing waveforms have been optimized, in the present technique for multitrace operation. As mentioned earlier the supply voltage for the present technique depends only on N.

It is preferable to add legends in oscilloscope displays. This can be done by including the legend at the top and its inverse video form at the bottom so that the number of elements selected in a column is constant. The number of selected elements in a column increases in this case and the selection ratio is lower compared to a display without legends.

The present technique can also be adopted for a case in which the number of selected elements is variable but always less than or equal to n (n << N). The number of selected elements can be adjusted to n for all the columns by adding n dummy rows to the addressing waveforms. The selection ratio will be $[\sqrt{n}/(\sqrt{n}-1)]^{1/2}$.

## Results

The addressing technique discussed above has been implemented on a 64x64 matrix TN display. Photograph 1 shows four waveforms being displayed. The selection ratio in this case is $\sqrt{2}(N_{eq} = 9)$. Photograph 2 shows a single waveform along with legends. The characters are formed by a 5x5 dot-matrix, with one row at top and bottom to separate the legends from the background. An additional 7 elements are selected in every column. The selection ratio is $[\sqrt{8}/(\sqrt{8}-1)]^{1/2}$, (i.e., $N_{eq}$ = 22). The commercial mixture RO-TN 701 is used in the display and the supply voltage is 7V.
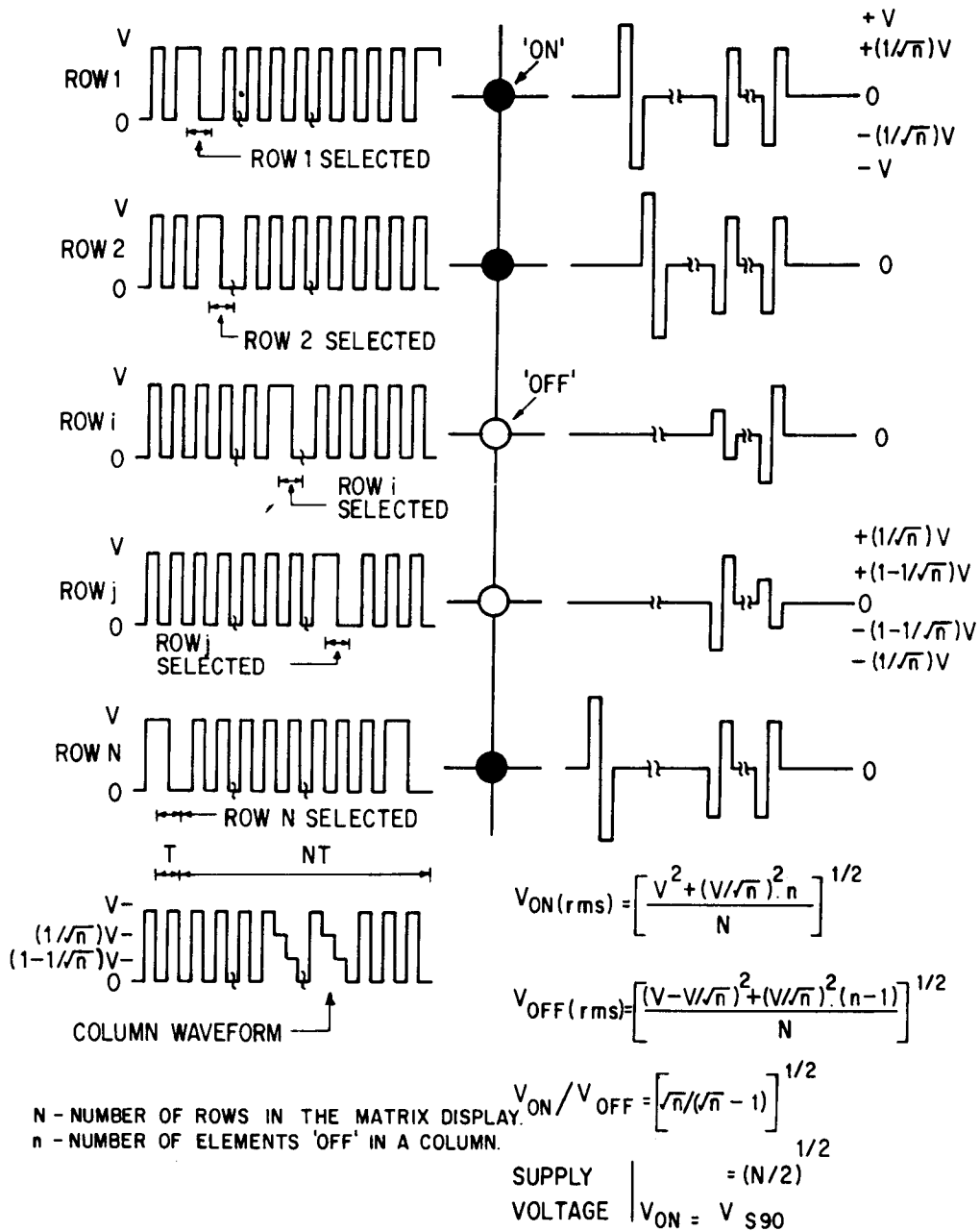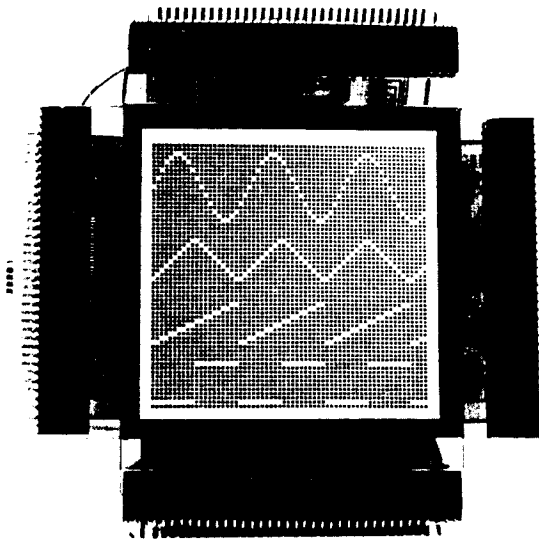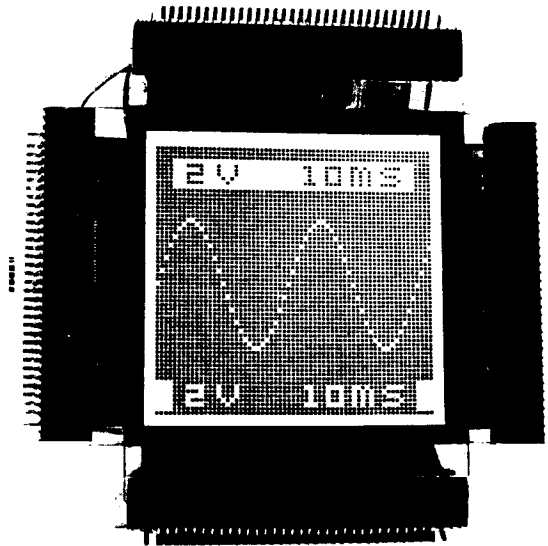
Fig: 2 REPRESENTATIVE WAVEFORMS FOR ADDRESSING MULTITRACE OSCILLOSCOPE DISPLAY.

$$V_{ON(rms)} = \left[\frac{V^2 + (V/\sqrt{n})^2 \cdot n}{N}\right]^{1/2}$$

$$V_{OFF(rms)} = \left[\frac{(V - V/\sqrt{n})^2 + (V/\sqrt{n})^2 \cdot (n-1)}{N}\right]^{1/2}$$

$$V_{ON}/V_{OFF} = \left[\sqrt{n}/(\sqrt{n} - 1)\right]^{1/2}$$

N – NUMBER OF ROWS IN THE MATRIX DISPLAY.
n – NUMBER OF ELEMENTS 'OFF' IN A COLUMN.

$$\text{SUPPLY VOLTAGE} \left| \begin{array}{l} = (N/2)^{1/2} \\ V_{ON} = V_{S90} \end{array}\right.$$

Photograph 1



Photograph 2

## Impact

Since the selection ratio is higher than that of APT, a better contrast can be achieved. The selection ratio is independent of the total number of rows in the matrix and hence displays with a large number of rows can be used increasing the Y resolution without sacrificing the contrast. Multiple waveforms with or without legends can be displayed. Typical applications are in multi-trace oscilloscopes and Logic Analyzers. This technique can also be adopted in applications wherein the number of selected elements is a variable with an upper bound n (n << N), typical application being displays for video games.

The selection ratio achieved in the present technique is $[\sqrt{n}/(\sqrt{n}-1)]^{1/2}$ which is higher in comparison with the earlier technique of sequential frame multiplexing of waveforms proposed by Shanks et al for multitrace operation, (Ref. 5) which gives a selection ratio $= [n/n-1]^{1/2}$ (Table 1).

In Ref.2 a multitrace oscilloscope discussed has a 64 rows matrix LCD with 32 lines multiplexing. If a comparable mixture is used one can display 11 waveforms, using the present technique without any limitations on the matrix size. With L. C. mixtures currently available one can easily construct a display for 16 traces ($N_{eq}$ = 49 lines) using the proposed technique.

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