An Intelligent Driving Scheme for High-Voltage Display Drivers

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ABSTRACT

An algorithm to reduce the power consumption in bistable display drivers is presented. This algorithm can also be used in other flat panel displays like OLEDs, standard (S)TN LCDs,... and is very important for battery-powered applications. The complete block diagram of the low-power high-voltage display driver and a comparison of the normalized frame energy for different driving schemes and different patterns are presented.

INTRODUCTION

In bistable displays, a combination of high voltage driving waveforms (up to 100 V) and very low internal power consumption is required. To reduce the power consumption, special high-voltage driver circuits have already been designed [1]. An extra decrease of the power consumption can be realized by adding an additional block of programmable logic to the display drivers, which calculates the most efficient waveforms to apply on the rows and columns for each image on the screen. The two principles which are used to obtain an efficient waveform are the use of intermediate voltage levels and the adaptation of the waveform on the image. The waveforms discussed in this paper are for cholesteric texture LCDs with 16 different gray levels.

CALCULATION OF THE WAVEFORMS

To drive a bistable display, several waveforms are possible. First of all, there is a difference between conventional and dynamical driving waveforms. Dynamical driving of the displays is faster than the conventional way, but it is not possible to use gray levels. So we will make use of conventional driving schemes. Another big difference in the way to drive displays is the use of unipolar and bipolar waveforms. In this paper we will concentrate on the bipolar waveforms, but the principles used can also be applied on unipolar waveforms. A bipolar driving scheme has to be used when the liquid crystal does not withstand DC stressing. To determine the voltage levels of the waveforms in conventional driving schemes, information about the electro-optical characteristics of the liquid crystal, is needed. The reflectivity of the cholesteric texture liquid crystal as a function of the rms value of the applied voltage pulse, is shown in Fig. 1.

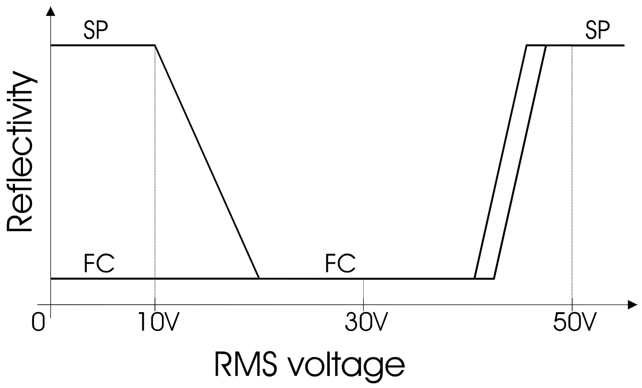


Fig. 1 Reflectivity
Reflectivity of the cholesteric texture liquid crystal as a function of the rms voltage of the applied voltage pulse.

An AC pulse with an rms voltage of 50 V brings the pixel in the stable planar state (SP) and a pulse of 30 V puts the pixel in the focal conic state (FC). To obtain gray levels, the pixel waveform has to be a combination of the previous two so we are in a point of the graphic on the rising slope.

In Table 1, the standard bipolar driving schemes (A1-A4) are shown. The difference between the driving schemes is the number of the intermediate levels of 0 V. For example, the line-select waveform of the driving scheme A2 is a pulse of 40 V to -40 V with an intermediate level of 0 V. When the selected pixel must be in the FC-state, the waveform applied on the column is a pulse of 10 V to -10 V with an intermediate level of 0 V, so the resulting waveform over the pixel is a pulse of 30 V to -30 V. The timing of the voltage levels must be exactly right.

	Line select	Line non-select	Column FC	Column SP
A1	40 -40	0	10 -10	-10 10
A2	40 0 -40	0	10 0 -10	-10 0 10
A3	0 40 -40 0	0	0 10 -10 0	0 -10 10 0
A4	0 40 0 -40 0	0	0 10 0 -10 0	0 -10 0 10 0

Table 1 Voltage levels
Consecutive voltage levels during 1 line time of standard bipolar waveforms

In these traditional driving schemes, the same row-select and row-non-select waveforms are used for all rows. Ditto for the different gray values. Which one of these 4 is the best concerning the power consumption, depends on the image.

It is possible to reduce the power consumption by adapting these traditional waveforms. First of all, the use of more intermediate levels results in reduced power consumption. For the row-select, there are 2 interesting waveforms, which are shown in Fig. 2. The difference between the two waveforms is the zero-level at the beginning and the end of a line addressing time. Whether a zero-level at the beginning and/or at the end of the row-select waveform is used, depends on the pixel values of that row on the one hand and on the pixel values of the row before and the row after on the other hand. As already mentioned, the timing of the voltage levels must be exactly right.

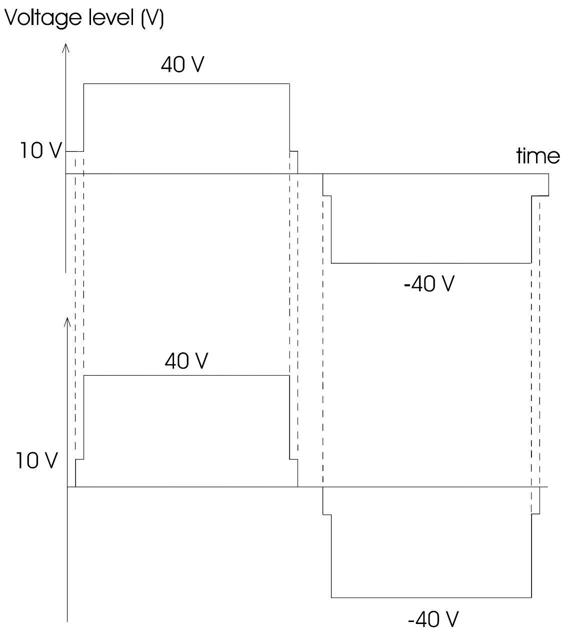
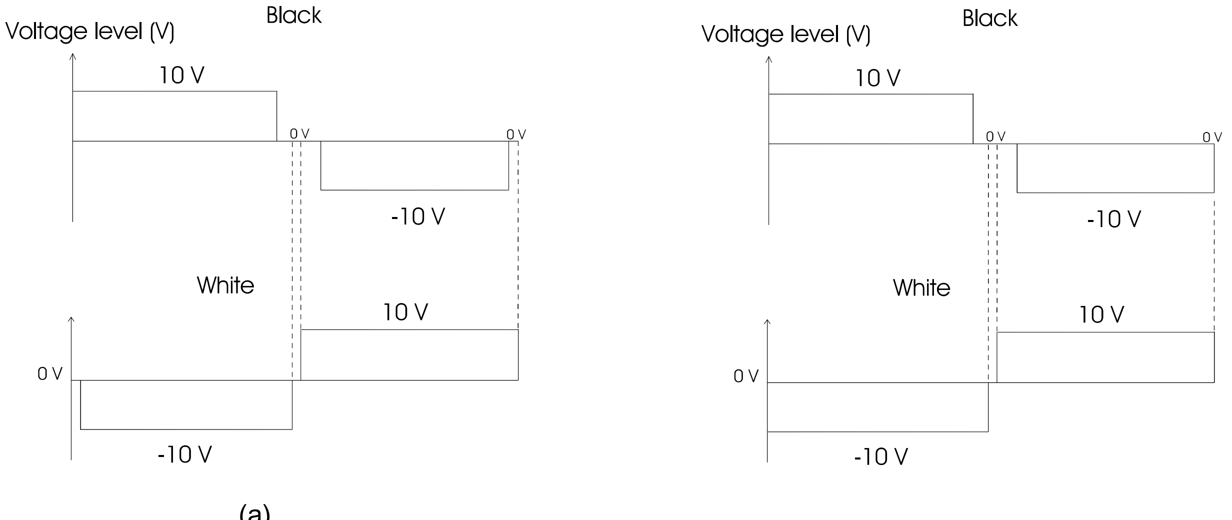


Fig. 2 Possible row-select waveforms



(a)

(b)

Fig. 3 Possible column waveforms
Waveforms for black and white in case (a) black isn't followed by white
(b) black is followed by white

Also for the data signals on the columns, there are different possibilities. The waveforms for black and white depend on whether there is an immediate succession of black and white. When black is not followed by white (and white not preceded by black), the applied waveforms for black and white respectively, are shown in Fig. 3a.

By immediate succession of black and white, the zero-level at the end of black and at the beginning of white has a disadvantage on the power consumption. So in this case it is better to use the waveforms shown in Fig. 3b.

The waveform for a gray pixel is given in Fig. 4. The exact point in time the waveform goes from 10 V to –10 V in the first half cycle and from –10 V to 10 V in the second half cycle depends on the exact gray shade.

When a kind of intelligence is added to the display driver that calculates the most efficient waveforms to apply to the display rows and columns every time a new image has to be written, the power consumption will be reduced even more. The block diagram of the low-power high-voltage display driver is shown in Fig. 5.

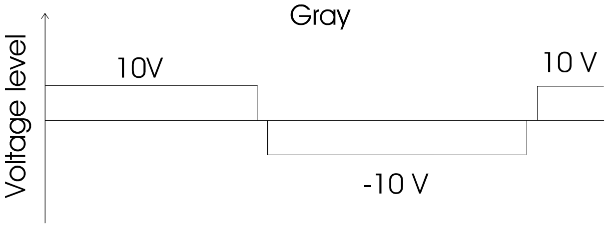


Fig. 4 Possible column waveforms
Voltage levels applied to the column for a gray pixel

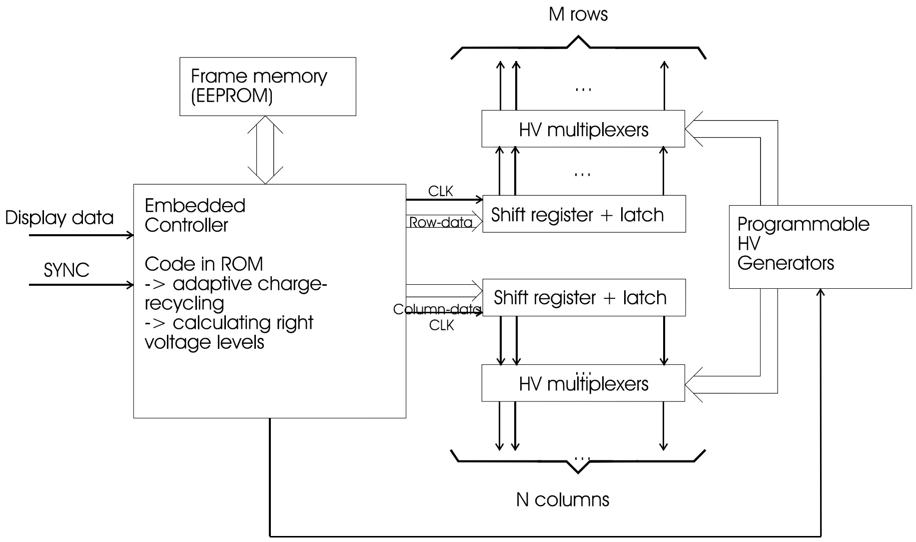


Fig. 5 Block diagram of the low-power high-voltage display driver

EXPERIMENTAL RESULTS

To have an idea of the power consumption that can be realized, we compare the normalized frame energy of our new driving scheme with the traditional schemes A1..A4 for different kinds of images. The results are given in Table 2 for a passive matrix with 12 rows and 12 columns. The normalized frame energy α is the total energy consumption in the driver during 1 frame time, divided by $R*K*C_0$ where R and K are the amount of rows and columns respectively and C_0 the pixel capacitance : $\alpha = \dfrac{\Delta E_{tot}}{R*K*C_0}$

We calculated α for 10 different display images: the first 6 images consist only of pixels in the ‘FC’ or ‘SP’ state, image 7-9 is a mix of black-white-gray and the last image exists only of gray pixels. In Table 3, the procentual power consumption of the new driving scheme against the traditional ones is given. Let's first look at A4: the power saving in case of pattern 1, 2 or 5 is only 20%, 39% and 30% respectively. However, a completely black or white image is not a realistic one. When we look at the other image patterns, the power saving is much more. For a completely gray image, the power saving is even 58%. Compared to A2, this power saving for a completely gray image is 52%.

APPLICATIONS

The algorithm proposed in this article can be used not only for bistable displays (cholesteric LCD, bistable nematic, electrophoretic), but can be used for every kind of flat panel display (OLEDs,...). It is very important in battery-powered applications like PDAs, e-books, smartcards, digital watches,...

	A1	A2	A3	A4	New driving scheme
All pixels "FC"	517	350	500	333	268
All pixels "SP"	1028	728	900	600	366
Checker board	589	356	700	467	244
Horizontal lines	583	350	700	467	247
Vertical lines	772	539	700	467	325
Double horizontal lines	683	450	700	467	287
Mix1	705	557	742	594	317
Mix2	743	628	794	680	332
Mix3	758	691	842	774	349
All pixels gray	794	761	900	867	367

Table 2 Normalised frame energy α ($J/F = V^2$)

	A1	A2	A3	A4
All pixel "FC"	52	77	54	80
All pixel "SP"	36	50	41	61
Checker board	41	69	35	52
Horizontal lines	42	71	35	53
Vertical lines	42	60	46	70
Double horizontal lines	42	64	41	61
Mix1	45	57	43	53
Mix2	45	53	42	49
Mix3	46	51	41	45
All pixels gray	46	48	41	42

Table 3 Procentual relation between the new driving scheme and the traditional ones

CONCLUSION

A power consumption saving of about 50% is realised making use of the algorithm proposed in this article. This way, a very advanced high-voltage driver is realised with an ultra-low power consumption which can be a real breakthrough in the domain of driving bistable displays for modern applications.

REFERENCES

[1] J.Doutreloigne, H. De Smet, and A. Van Calster, "A New Architecture for Monolithic Low-Power High-Voltage Display Drivers", Proceedings of the 20th International Display Research Conference IDRC2000, (Palm Beach, Florida, USA), pp. 115 - 118, September 2000.