How an LCD controller drives an LCD glass

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Liquid Crystal Displays (or LCDs) are widely used these days for visual display of data. They are controlled by a microcontroller/microprocessor. A typical LCD Subsystem consists of an LCD Controller and an LCD Glass. Inside an LCD Glass there are many small units, one unit is made up of two polarizers, between which are two electrodes, between which liquid crystals are present. An LCD controller drives alternating voltage across the two electrodes such that the average is zero (to avoid permanent alignment of crystals).

The LCD subsystem runs on a clock called the frame clock. When the RMS voltage across the electrodes is greater than the lighting threshold, then the LCD unit glows, otherwise it remains off. To understand the working of an LCD controller driving LCD glass in detail, firstly the basic understanding of some important terms is required. These important terms have been described as follows:-

- **LCD Frame Frequency** - The LCD controller frame frequency is defined as the number of times the LCD panel segments are energized per second. Its frame frequency must be selected to prevent the LCD display from flickering (LCD module frame frequency is too low) or ghosting (LCD module frame frequency is too high).

- **LCD Duty Cycle** - The duty cycle indicates the amount of time (ratio of time/Ton/Tperiod) the LCD panel segment is energized during each LCD controller frame cycle.

- **LCD Planes** - We basically have two planes in an LCD, i.e. front plane and back plane in each LCD segment. We apply the voltage to the front plane and backplane of each LCD segment to make it work.

- **Waveform Registers -** The LCD waveform registers control the on/off state for the segments controlled by the LCD pins. For a segment on the LCD panel to be displayed, data must be written to the LCD waveform registers.

- **LCD Bias** - In this paper, analysis is done for Static and Multiplexed Methods. For static, there are only two voltage levels – VSS and VDD, but for the Multiplexed Method we take

an example of on a 3V LCD glass and 1/3 bias LCD Controller. Here the LCD controller drives four voltage levels - VSS, Vll1 (1/3*VDD) , Vll2 (2/3*VDD) and Vll3 (VDD = 3V in this case) respectively. Here, all the three low level bias voltages, i.e. Vll's are generated using charge pump or resistor bias network.

- **ON threshold of the LCD glass –** The minimum RMS voltage difference required between the segmented LCD panel in order for it to glow.

An LCD Segment glows when its Back Plane and the front plane both are enabled, as described in the following figure –

FP	BP	Segment
0	0	OFF
0	1	OFF
1	0	OFF
1	1	ON
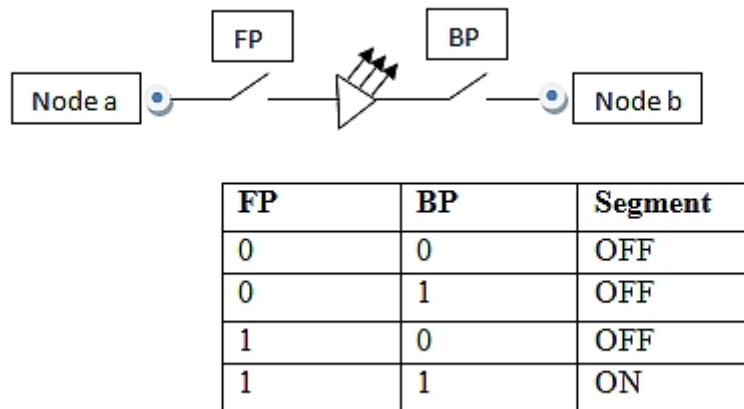
At this point it is important to mention that a DC voltage is never given across a segmented LCD. If DC voltage exists across the LCD segment, then any impurity ion present will migrate towards the electrodes under the action of a net electric field, and may become embedded at the surface of the segment. Therefore, even on removal of the voltage across the segment, an electric field across the segment may persist, due to captured charges, and may destroy the LCD segment.

Methods for driving LCD glass using voltage waveforms:

An LCD segment can be operated using two methods –

1. Static Method
2. Dynamic Method

Static Method of driving an LCD Glass

Static Method of driving an LCD Glass

Statically driven LCDs have only one common backplane (BP) and separate front plane (FP) for each LCD segment respectively. For glowing let's say 10 Segments, we need 11 Planes, i.e. 10 Front Planes and 1 Back Plane. Hence 11 I/O Pads will be required wherein one connect the BP of all the Segments together and individually control the 10 FP's using programming. So, to drive more number of LCD segments, more number of front planes are required. This limits the number of LCD segments that can be driven with a given number of pins.

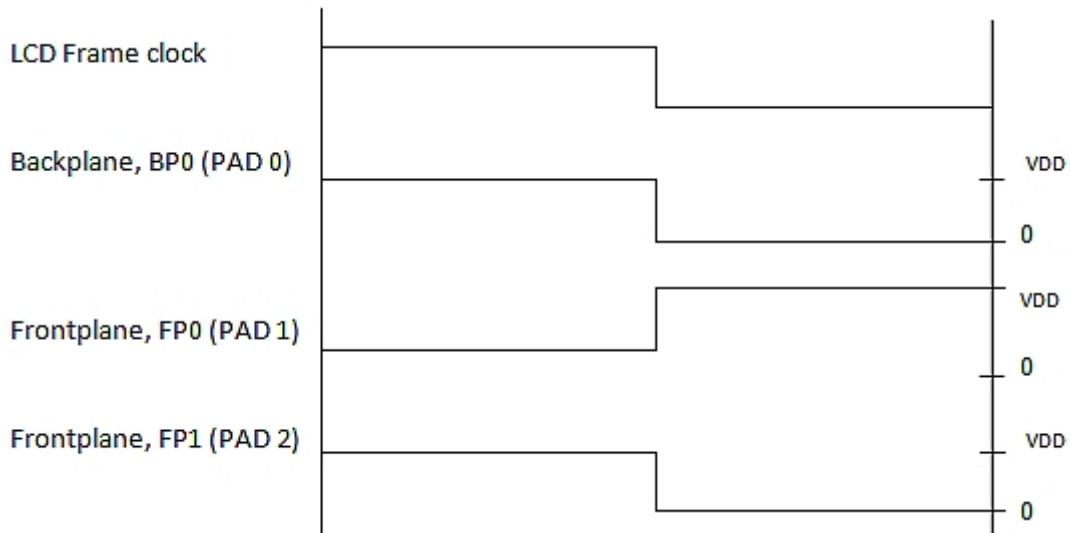Let us analyze the static method with the below Figure 1:

Figure 1

Here, PAD0 is connected as backplane (BP0), which will be common backplane to all LCD segments. PAD1 and PAD2 are connected as front-planes, FP0 and FP1 respectively. One can not tell by just seeing the voltage separately on FP and BP whether the LCD segment will glow or not. One has to calculate the RMS of the voltage between the terminals of a segment in a frame cycle, i.e. RMS (V(Front Plane)-V(Back Plane)).

Let us say, a segment has PAD0 and PAD1 connected across its terminals. The voltage waveform across the segment, i.e. (FP0 –BP0), has DC component as zero, which is our primary requirement and the RMS voltage comes out to be VDD = 3V, which is well above the threshold of the LCD glass (~ 1.3V) hence the segment glows.

On the other hand, let's take a case where a segment has PAD2 and PAD0 connected across its terminals. The voltage waveform across the segment, i.e.(FP2-BP0), is always 0V. Hence, the RMS Voltage across a frame clock becomes 0 Volts. Therefore this segment will not glow.

Here we can see that the RMS voltage in the ON case is "VDD=3V", which is highly greater than the

threshold for glowing (~1.3V). Hence, the statically driven LCDs will always have better optical properties, however the higher number of terminals makes them unfavorable to use. We will see that how the RMS Voltage in the ON Case decreases in the Multiplexed Method to understand how the "better optical property" comes into picture.

Multiplexed Method of driving an LCD Glass

Multiplexed Method of driving an LCD Glass

In the previous method we discussed about Static method of driving an LCD Glass. Here we will discuss Multiplexed method which is an important dynamic method used today to drive a LCD panel. Here, the segments of the display are organized into a matrix. Dynamically driven LCDs have multiple front plane electrodes connected to a single pin. It is quite clear that these types of waveforms must have more than two discrete voltage levels. Here, pulses of combinations of 4 LCD bias voltages (referred here as 0, vll1, vll2 and vll3) appear on both the planes across every LCD segment.

We repeat here that the LCD controller drives four voltage levels - VSS, Vll1 (1/3*VDD) , Vll2 (2/3*VDD) and Vll3 (VDD = 3V in this case) respectively. Here, all the three low level bias voltages, i.e. Vll's are generated using charge pump or resistor bias network. The voltage levels corresponding to selected phase for ON and OFF case are shown below:-

LCD Frame Clock

FP ON	0	Vll3
FP OFF	Vll2	Vll1
BP ON	Vll3	0
BP OFF	Vll1	Vll2

Also, we can select maximum of eight backplanes, where multiple backplane electrodes can be connected to a single pin. Backplanes are selected according to the duty cycle. Here, our LCD supports 8 duty cycle modes of operation. These modes of operation are as follows –

S.No. selected	Duty [2:0]	Duty cycle	Phases	No. of backplanes
1.	000	1/1	A	1
2.	001	1/2	AB	2
3.	010	1/3	ABC	3
4.	011	1/4	ABCD	4
5.	100	1/5	ABCDE	5
6.	101	1/6	ABCDEF	6

| 7. | 110 | 1/7 | ABCDEFG | 7 |
| 8. | 111 | 1/8 | ABCDEFGH | 8 |

Here, the positive half and negative half of frame clock is divided into no. of phases corresponding to the duty cycle selected. Lets say, duty cycle is selected as ½.Then, two Back planes, BP0 and BP1, say, will be selected. Here, the voltage waveform corresponding to each backplane will be active in one of phase and inactive in other phase, according to the configuration in LCDWF registers. For e.g., if BP0 and BP1 is configured to be active in phase A and phase B respectively, then the voltage waveform for BP0 and BP1 will be shown as below:-
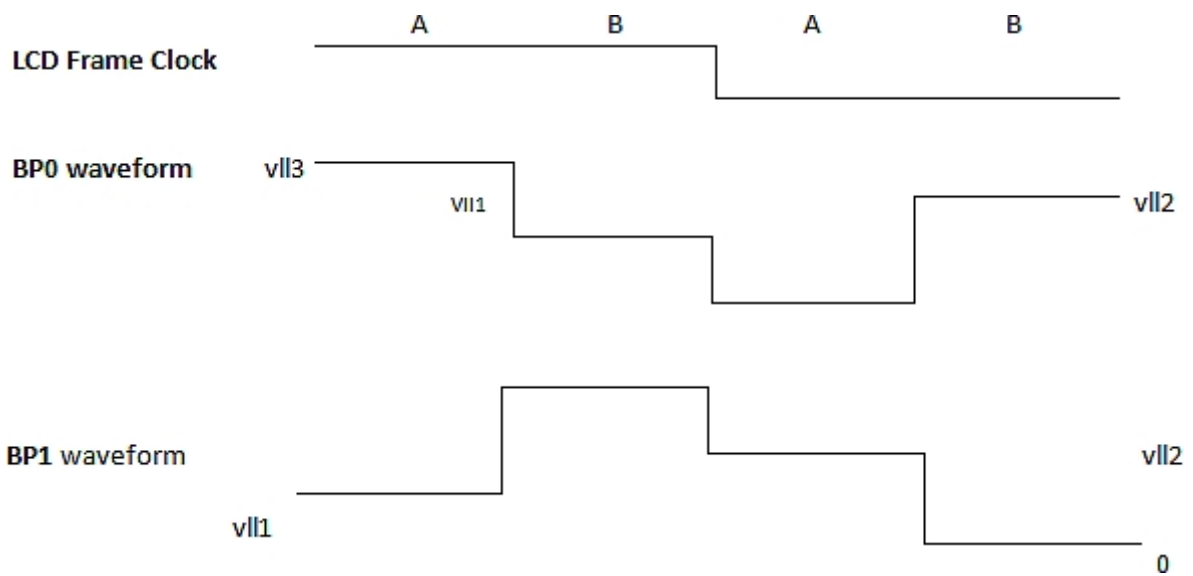
Some of possible cases for frontplane
Some of possible cases for frontplane(FP0):- Here, front plane FP0, waveform will modify according to the requirement.
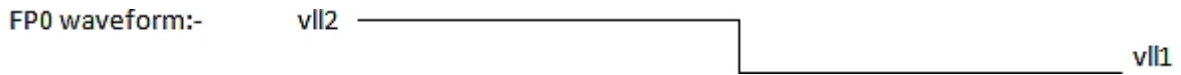
 1). FP0 –BP0 combination to be ON and FP0-BP1 combination to be OFF

2). FP0 –BP0 as well as FP0-BP1 combination to be ON

FP0 waveform:-

vll3

0
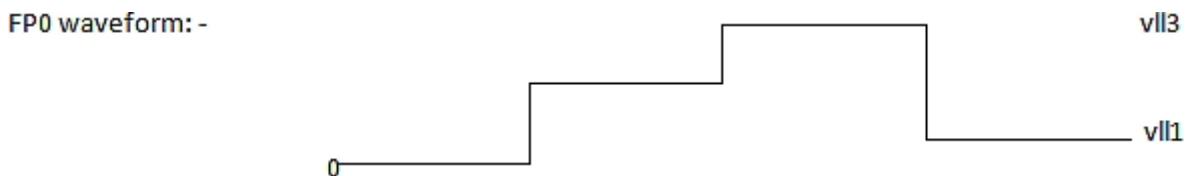
3). FP0 –BP0 as well as FP0-BP1 combination to be OFF

FP0 waveform:-   vll2

vll1

Here, it is important to note that dc component across FP0-BP0 in each case is zero. So, here for glowing, let's say 10 Segments, we need 7 planes, i.e. we can have combination of 5 Front Planes and 2 Back Plane. Hence 7 I/O Pads will be required. Thus, we see that number of driven LCD segments have further been increased.

Multiplexed method with eight backplanes selected:-duty = 8 from Figure 2. Here, in this case, since the no. of black planes is eight, so with one front plane, we can drive maximum of eight LCD segments. Hence, the no. of LCD pins used will be reduced. The waveform pattern with maximum of eight backplanes is shown below:-
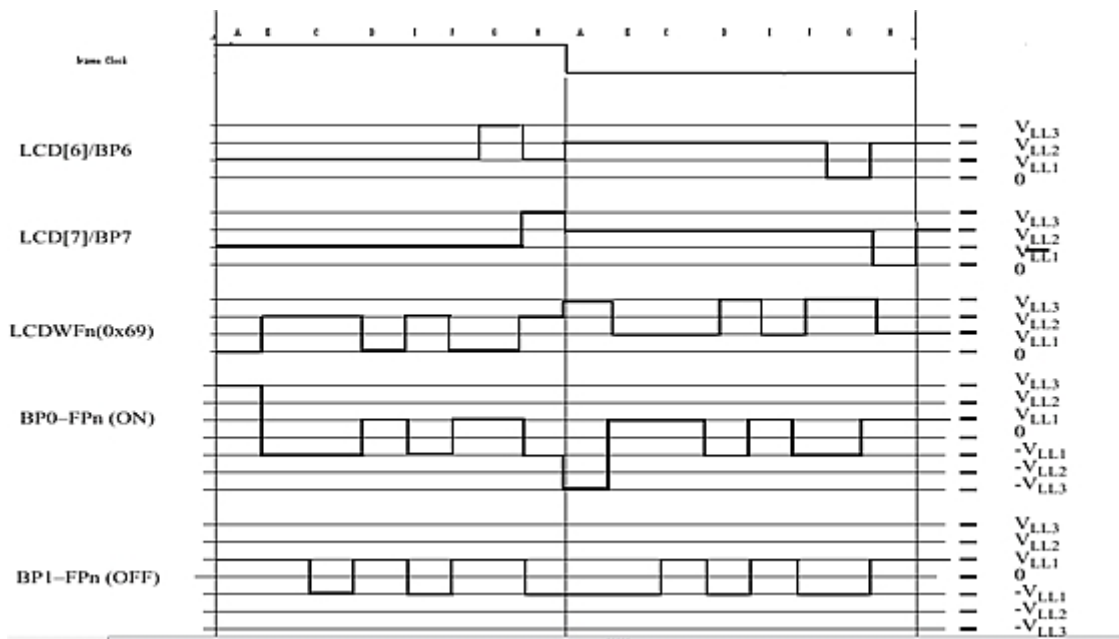

Figure 2

In the above figure drawn, we have:

LCD [6]/BP6 selected as back plane which is active in phase G and inactive in other phases.

LCD[7]/BP7 selected as backplane which is active in phase H and inactive in other phase
LCDWF[n]/FPn   selected as front plane, where we want frontplane and backplane combination to be ON corresponding to phase A,D,F,G only.

BP0 selected as backplane which is active in phase A and inactive in other phases.

BP1 selected as backplane which is active in phase B and inactive in other phases.

BP0 – FPn – Here, the DC component comes out to be zero and the RMS voltage comes out to be, SQRT $[2*(Vll3^2 + 7*Vll1^2) /16]$ = 1.414*VLL1 volts, which is well above the threshold of LCD glass. Hence, it represents the ON Case.

Close to threshold hence poor optical properties.

BP1 – FPn – Here, again the DC component comes out to be zero and the RMS voltage comes out to be, SQRT $[2*(8*Vll1^2) / 16]$= VLL1 Volts, which is well below the threshold of the LCD glass. Hence, OFF case.

Thus, multiplexed method is considered to be far better than static method in terms of LCD pins used, which will result in cost saving. But it is implicit that the design for such a controller will be more complicated.

Conclusions

- We discussed basics of LCD physics.
- We understood all the basic terminologies used for understanding an LCD controller
- We understood that an LCD controller uses discrete voltage levels to control the LCDs.
- We looked at two of the most adopted ways of integrating LCDs and critically analyzed both the static and multiplexed method.
- We also understood both the methods from the following perspectives:-
    - Optical clarity
    - Need of number of IOs
    - Need of number of discrete voltage levels
    - Complexity of LCD controller design perspective.

More about the authors

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