Dot inversion implementation using bootstrapping in LCoS with frame buffer pixels

***Yulong Song*[1,2]*, Zhihua Ling*[1]**
1. Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130033, China,
2. Graduate School of Chinese Academy of Sciences, Beijing 100039 China
ciom-LC@126.com

Abstract: *The pixel bootstrapping method is successful to be applied to implement the dot inversion without addition complex controls in LCoS with frame buffer pixels. The relations of common voltage modulation method and bootstrapping method are analyzed. The dot inversion in frame-by-frame addressing method is explained. The dot inversion and the data voltage loss compensation are implemented by bootstrapping and common voltage modulation, respectively. And the scheme of bootstrapping dot inversion is given. The simulation was done by HSPICE.*

Keywords: LCoS micro-displays; dot inversion; bootstrapping technique.

Introduction

To eliminate the DC effect which leads to ion accumulation and liquid crystal degradation, liquid crystal device must operate at AC voltage. The common inversion modes have frame inversion, row inversion, column inversion and dot inversion which are implemented by common voltage modulation or high source driver voltage method with static common voltage. The common voltage modulation method can reduce the voltage swing of data driver output, but not be applied to implement column and dot inversions. The high source driver voltage method is the most straightforward method, in which the analog voltages required for the positive and negative half-cycles (relative to the common electrode) are provided directly by the data driver, which must have an output voltage range equal to double the RMS voltage required by the liquid crystal. The gate line pulse in the active matrix must have sufficient amplitude to guarantee charging of the pixel capacitance in the worst case and to avoid the excessive leakage of pixel voltage. And as a rule, low voltage silicon circuit technologies are denser and so lead to more functions on a chip or smaller, low cost micro-displays, so low voltage LCoS devices are under development by many researchers.

Common voltage modulation is one candidate for low voltage LCDs. But it can't implement the dot inversion to obtain the better image quality. IBM introduced the bootstrapping technique to the LCoS and has implemented the frame and row inversion. But it is difficult to implement the dot inversion due to the line-by-line addressing method in LCoS with DRAM-like pixels. So we applied the bootstrapping technique to the LCoS with the frame buffer pixels [3,4] in order to obtain the dot inversion with very simple controls.

Bootstrapping

Bootstrapping technique had been applied to the integrated gate driver of an amorphous silicon active matrix TFT-LCD by P.Maurice [2]. And then it has been to liquid crystal on silicon to implement pixel inversion [1].

As is well known, Bootstrapping can raise the output voltage of a driver circuit by boosting an internal node by capacitive adding the positive edge of a pulse to the voltage of an internal circuit node.

One edge of a bootstrap pulse is coupled directly to the pixel electrode after the pixel has stored the analog voltage supplied by the data driver. The effect is to shift the pixel voltage by a precise increment to the level required for the particular inversion state.

The Bootstrapping method was compared with the common voltage modulation method below. The pixel capacitor is composed by the liquid crystal capacitor and the compensation capacitor as shown in Figure2. Based on this pixel structure, there are some relations between the common voltage modulation method and the bootstrapping inversion method. Common voltage modulation method couples the voltage to the common electrode. In fact, it is one bootstrapping technique, too. They both can reduce the voltage range of the data driver and the power dissipation.

Dot inversion in LCoS with frame buffer pixels

The row and frame inversions are implemented by IBM researchers. Although the possibility of column and dot inversions using the bootstrapping method has been mentioned by E. S. Schig in [1], it is difficult to obtain these two inversions because of the line by line addressing method when the pixel structure is DRAM-like.

But, when the pixel structure is the frame buffer pixel circuit, the frame by frame addressing method is adopted and so the dot inversion is easy to implement.

In the line by line addressing method, it can be considered that dot inversion is the combination of row inversion and column inversion and so it must be obtained by doubling the data driver output voltage range.

In frame by frame addressing method, the whole panel can be divided into two non-overlapped two parts. And in this case, dot inversion can be considered to be the combination of the two opposite frame inversions. Dot inversion explanation in the frame by frame addressing mode is shown in Figure1.

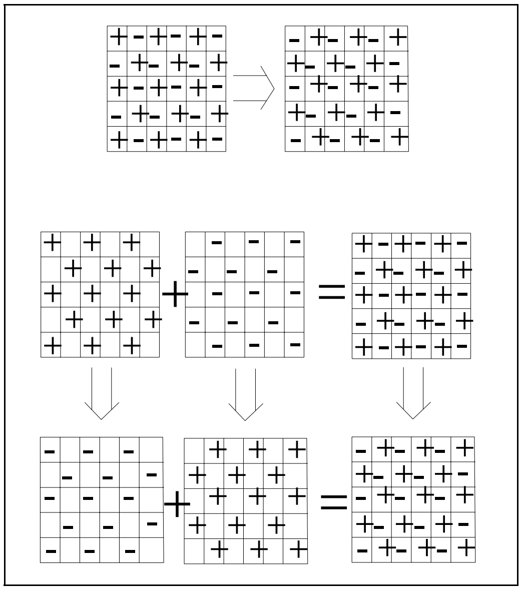

Figure 1. Dot inversion explanation in frame by frame addressing method

In LCoS with frame buffer pixels all the pixels with the same polarity positive or negative are connected together. So in this case dot inversion can be implemented by two opposite bootstrapping signals. It is very simple compared with bootstrapping method described in [1].

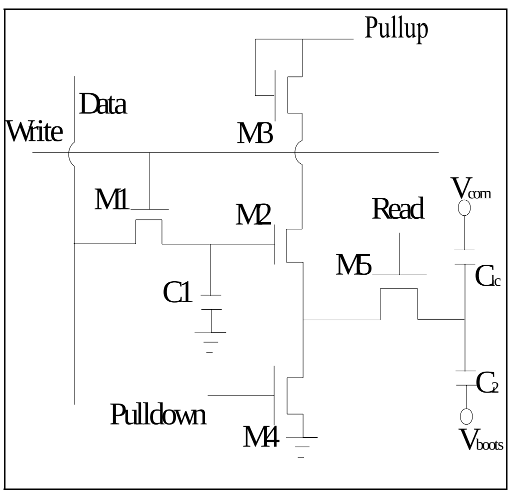

Figure 2. Frame buffer pixel circuit

The operation is shown below. The frame terminals are defined by the write signal or the read signal. In this paper, the time terminals are based on the write signals. At time T1 the data for the positive frame and for the negative has been prepared. The date signals are stored in the capacitor C1 line-by-line respectively from T1 to T2. After that, the last frame pixel charge stored in the pixel capacitor is cleared from T3 to T4. The interval between T2 and T3 is vary from zero to several line times and interval shorter, performance better. The next frame gray scale decision time is from T4 to T5 which the data voltage transfers from C1 to the pixel capacitor. After time T5, the read transistor is turned off and the bootstrapping pulse positive edge is coupled to the electrode of compensation capacitor.

In [1], the design consideration has been reported that the ability to provide sufficient capacitance between the pixel electrodes and the bootstrap lines. Capacitive voltage division between the pixel capacitor and the compensation capacitor vary with data voltage because the liquid crystal capacitance and the stray capacitance are voltage-dependent. The compensation capacitance should be large enough to minimize the effect of the voltage-dependent capacitance. In LCoS, the pixel is very smart, so the liquid crystal capacitance is small enough to ensure the device performance.

The erroneous data voltage mentioned in [1] doesn't appear in frame-by-frame addressing method. The light flash is synchronized with the bootstrapping signals.

In frame buffer pixels, the data voltage transferred from the C1 to pixel capacitor has a loss equal to the threshold voltage of MOSFET M2 which is constant not considering the threshold voltage shift. The common voltage is offset to compensate the data voltage loss.

Simulations

The simulation was done by HSPICE. The results are shown in figure 5, 6, and 7. The four pixels, P11 P12 P21 and P22, are included in simulation, as shown in figure4. P11 and P22 are connected with signal Boots1, while P12 and P21 are connected with signal Boots2. The signals Boots1 and Boots2 are shown in Figure3. In simulation, the voltage 2v and 4v outputted from data driver and stored in capacitance C1 is denoted the same gray level in positive negative. The common potential is determined by two factors, the bootstrapping voltage and the voltage loss within the data voltage transferring. Based on the consideration aforementioned, the simulation result shows that the dot inversion can be obtained, seen from Figure5, 6, 7.

Conclusion

In this paper, we succeed to apply the pixel bootstrapping method to implement the dot inversion without addition complex controls in LCoS with frame buffer pixels. The relations of common voltage modulation method and bootstrapping method are analyzed. The dot inversion in frame-by-frame addressing method is explained firstly. The dot inversion and the data voltage loss are both implemented by bootstrapping signals. And the scheme of bootstrapping dot inversion is given.

References

1. E. S. Schig, J. L. Sanford, An SXGA reflective liquid crystal projection light valve incorporating inversion by pixel bootstrapping, IBM J.RES.DEVOLOP.VOL.44 NO. 6 pp. 909-917, 2000
2. P.Maurice, H.Lebrun, High resolution projection valve with the amorphous silicon AMLCD technology, Proc. SPIE 3296, pp. 92-99, 1998.
3. Sangrok Lee, James C. Morizio, and Kristina M. Johnson, Novel Frame Buffer Pixel Circuits for

liquid crystal on silicon microdisplays [J], IEEE JOURNAL OF SOLID STATE CIRCUITS, 2004, 39(1), pp.132-139.

4. Yulong Song, Zhihua Ling, A Microdisplay of Liquid Crystal on Silicon with a Novel Pixel Circuit, Chinese Journal of Liquid Crystals and Displays, 2005, 20(4), pp.328-332.

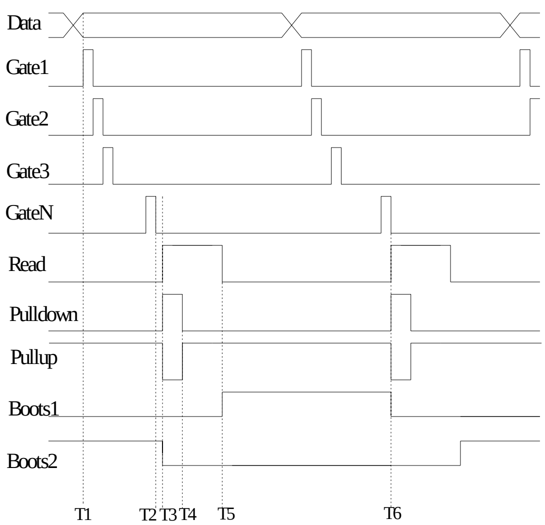

Figure 3. Timing and waveforms for bootstrapping dot inversion in LCoS with frame buffer pixels

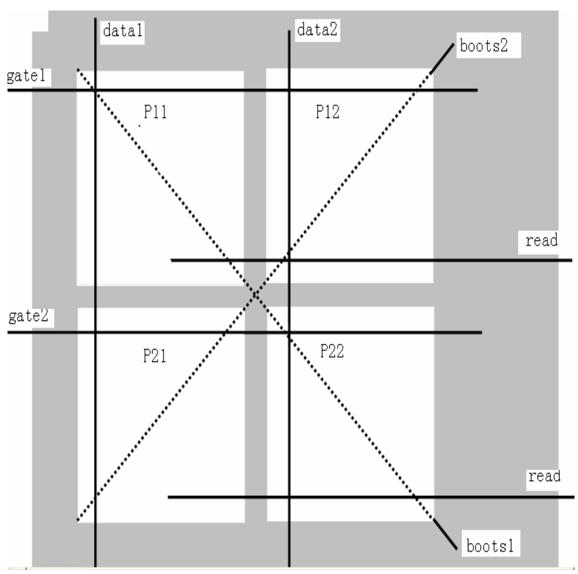

Figure 4. Pixel array schematic

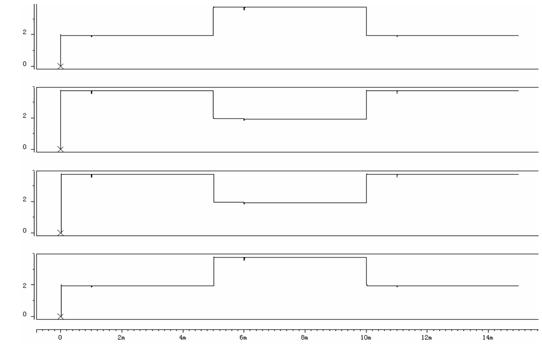

Figure 5. Voltage of capacitance C1 in pixels P11 P12 P21 P22

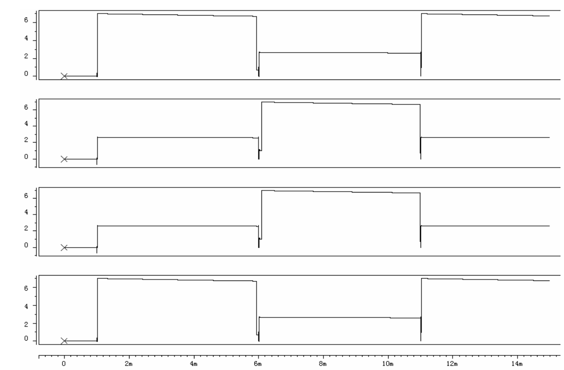

Figure 6. Potential of pixel electrodes in pixels P11 P12 P21 P22

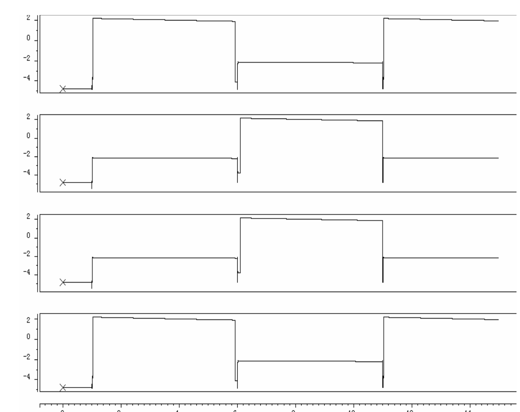

Figure 7. Voltage of pixels P11 P12 P21 P22, respectively

Yulong Song was born in Shandong, P. P. China, in September 1980. He received the B.S. degree in Optical Engineering from Changchun University of science and technology, P. R. China, in 2002. He is currently pursuing the Ph.D. degree in the liquid crystal physics and display devices in the Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, P. R. China