A PWM Data Driver with Different RGB Driving Voltages for Bistable Displays

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Abstract: *A data driver was developed for the flexible bistable displays application. In the data driver, PWM driving method was adopted to increase the gray levels of cholesteric liquid-crystals displays (Ch-LCDs). Furthermore, three independent power and ground pairs were used to drive different Ch-LCs RGB cells.*

Keywords: Pulse-Width-Modulation; Bistable display; Cholesteric liquid-crystal.

Introduction

Flexible displays are widely studied for portable display applications. It is due to that flexible displays are thin, lightweight, and can be manufactured by low-cost process [1]. Among all the flexible display technologies, bistable display is the most likely technology for future production. Bistable displays that have pixel memory under zero bias condition don't need constant refreshing step and hence consume low power. It is very suitable for using in e-paper or e-book applications.

Cholesteric liquid-crystal displays (Ch-LCDs) are reflective displays with bistability and high reflectance. It can be fabricated on glass or plastic substrates [2,3]. Recently, the Ch-LCs attract much attention on the bistable display application. Many studies have been developed to bring it to mass production, especially in the flexible displays area [4]. For Ch-LCs, the different process conditions of RGB cells make them with different driving voltages. Besides, the sharp transfer curve also limits the maximum gray levels when using the conventional voltage driving method.

In this paper, we developed a data driver for bistable display applications. The developed data driver used the Pulse-Width-Modulation (PWM) driving method to provide more gray levels. Due to the different operating voltages for RGB Ch-LCs, three pairs of power and ground were used to drive RGB Ch-LCs, respectively. In this data driver, 8-bits data inputs and 320-channel outputs with three driving voltages for RGB cells were designed.

Circuit Structure

Fig. 1 shows the reflectance vs. voltage curves of Ch-LCs for red, green, and blue colors, respectively. As shown in the figure, the driver circuit needs three different voltages to drive the Ch-LCs of different colors. For example, if the scan driver supplies 35V on the row line, then the maximum driving voltage of data drivers is ~ 7V for the blue color and 14V for the red color. In addition, due to the sharp transfer curve of Ch-LCs, the maximum gray levels are limited when using the voltage driving method.

In this study, the pulse-width-modulation (PWM) method was used to overcome the limited gray levels of Ch-LCs.

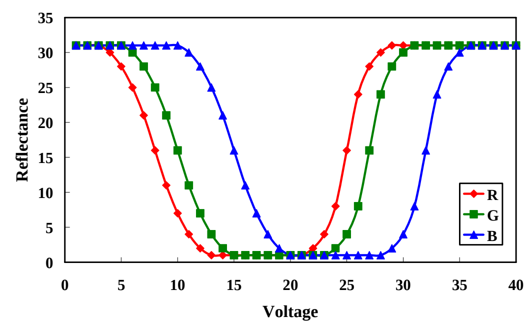

Figure 1. The reflectance vs. voltage curve of cholesteric liquid-crystal for R, G, and B colors.

The diagram in Fig. 2 shows the functional blocks of the data driver used in this study. Two major features of this data driver are PWM driving and different driving voltages for RGB cells. The PWM generator generates the constant voltage signals with different pulse-width according to the input data. And then the pulse-width modulated signals were level-shifted to a predetermined voltage levels.

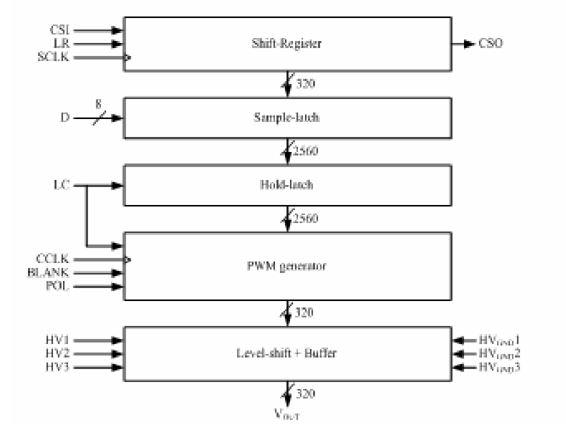

Figure 2. Functional block diagrams of different RGB driving voltages for a PWM data driver.

The detail circuit diagram of the data driver with RGB cells is shown in Fig. 3. Each individual RGB cell was assigned an independent power and ground pair. The input digital codes were sequentially sampled by sample-latch circuits and then putted into the hold-latch circuits. All the input data were arranged in the RGB order in the hold-latch circuits. When the sample-and-hold processes were completed, a trigger signal came in to start the PWM transferred procedure. The input data were compared with the counter outputs and then the compared results generated the corresponding pulse-width signals. After the PWM-transferred step, the input digital codes were transferred to low-voltage pulse-width modulated signals. The low-voltage level signals were then level-shifted to the predetermined high-voltage level signals according to the RGB order to drive the corresponding RGB Ch-LCs.

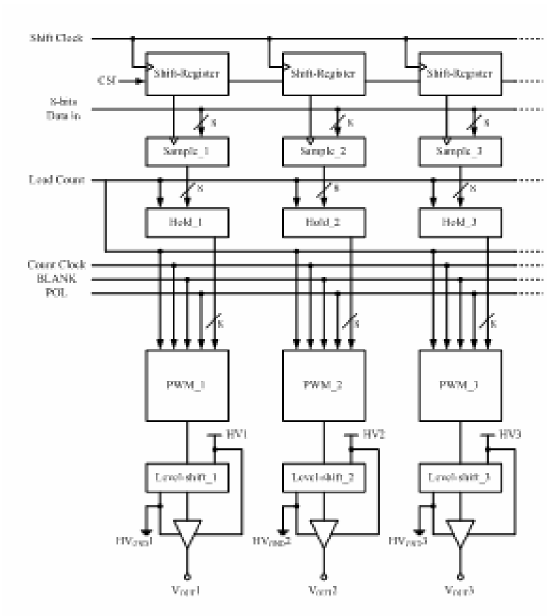

Figure 3. The proposed RGB circuit for a PWM data driver.

Simulation Results

Fig. 4 is the simulation results for different RGB signals with the same pulse-width. The predetermined voltages of R, G, and B signals were 20V, 15V, and 10V, respectively. The symbols of v(out40_9), v(out40_10), and v(out40_11) represented the 9th, 10th, and 11th column lines, respectively. According to the RGB order, they also represented the R, G, and B output pins, respectively. From this figure, the simulation results showed that the data driver generated the corresponding driving voltages for R, G, and B Ch-LCs. When the pixel cells in the display panel were arranged in the RGB order, the data driver can thus drive the pixels with suitable driving voltage according to the material properties of Ch-LCs.

Figure 4. The simulation results for different RGB signals with the same pulse width.

Fig. 5 is the simulation results of the modulated pulse-width signals according to the given gray levels. This figure showed that the gray-level was 9 for the red color, 138 for the green color, and 255 for the blue color. The bottom of the figure merged these three signals and showed the different pulse-width and different driving voltage waveform. According to the design of this data driver, the PWM driving can provide the maximum of 256 gray-levels. The PWM driving method is operated with constant voltage and will not be limited by the sharp transfer curve of Ch-LCs. Thus the PWM driving method can have more gray levels than the conventional voltage driving method.

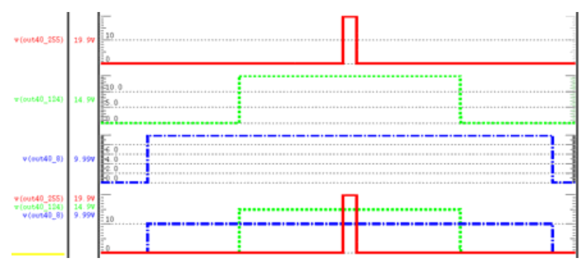

Figure 5. The simulation results of different pulse-width RGB signals.

Table 1 is the summary of the IC specification for the data driver studied in this paper. The low-voltage input is 3.3V and the high-voltage output is up to 40V. The PWM driving with 256 gray-levels is designed in this data driver. At least 15MHz sample frequency and 30MHz pixel frequency can be used in this data driver. Finally, this data driver can output 320 channel per device.

Table 1. IC Specification

Low-voltage DC	3.3V input voltage
High-voltage DC	40V output voltage
Driving method	PWM gray-level conversion
Gray level	256 gray levels
Sample frequency	15MHz
Pixel frequency	30MHz
Output channel	320 outputs per device

Conclusion

A data driver for driving flexible bistable displays has been developed in this study. The input digital codes were translated to pulse-width modulated signals to drive the Ch-LCDs. Up to 256 gray levels can be displayed on the panels according to the material properties. In addition, a maximum voltage of 40V can be individually used to drive each Ch-LCs RGB cells. The simulation results successfully revealed these two functions of driving the Ch-LCDs.

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