A 64-Step Gray Scale Driver Chip for a 132×64-Pixel Passive Matrix OLED

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Abstract: A mixed-signal driver chip for a 132×64-pixel passive matrix OLED panel is presented. The chip has a 64-step gray scale control using the PWM method and two-step voltage pre-charge technology to pre-charge the OLED pixels. It consists of a digital controller, SRAM for display data memory, a DC-DC voltage converter, reference current generators, a pre-charge voltage generator, 64 common drivers, and 132 segment drivers. The single chip is a typical current-drive circuit. It has been implemented in a Chartered 0.35μm 18V HV (DDD) CMOS process with a die area of 10mm×2mm. Test results show that the power consumption of the whole chip and all pixels with a constant driving current of 100μA while displaying the highest gray scale is 294mW with a 12V high voltage supply and a 3V low voltage supply.

Key words: OLED; gray scale; PWM; pre-charge; segment driver; common driver
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1 Introduction

Among present display technologies, such as the cathode ray tube (CRT), liquid crystal display (LCD), field emission display (FED), plasma display panel (PDP), and organic light emitting display (OLED), the OLED is now attracting much attention as a next generation flat panel display (FPD)[1~4]. The OLED has several excellent and unique characteristics, including a wider viewing angle, faster response, soft display, wider temperature range, better vibration resistance, lower manufacture cost, and lighter weight. Typically, it has two kinds of panel structures-passive matrix (PM) and active matrix (AM) display[5,6]. They are classified according to whether there are active driving transistors in each pixel. The PM-OLED pixel is modeled as a complex of a diode and a capacitor. The PM-OLED panel has a simpler structure that is easier to fabricate, and it is used widely in small panels such as those in cellular phones, digital cameras, and MP3 players. However, there are some problems in PM-OLED panel driving technology[6], and today there are no mature PM-OLED driver chips in the Chinese mainland. In this paper, we present a new driver chip design scheme and introduce a mixed-signal driver chip with 64-step gray scale control for a 132×64-pixel PM-OLED.

2 Electronic properties of PM-OLED

Lighting theory and the basic structure of the PM-OLED pixel, which consists of a stack of thin organic layers between a transparent anode and a metallic cathode, have been described previously[2]. The pixel structure is always represented by a combination of a diode and a capacitor in parallel. The model is shown in Fig.1.

Indium-tin-oxide (ITO) is connected to the anode of each pixel in a column, and a metal wire is connected to the cathode of each pixel in each row. The following analysis is based on this model. If a pixel is driven by a constant current, the capacitor is first charged up. No current flows through the diode, and the pixel is dark. When the pixel voltage reaches the threshold voltage of the diode, the driver current begins to flow through the diode.

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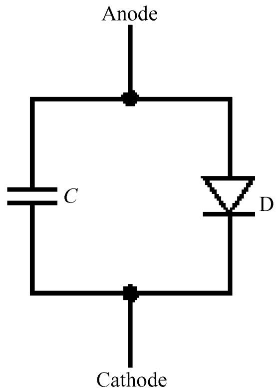

Fig.1 PM-OLED pixel model

The luminance of a PM-OLED pixel is linearly related to the current fed into the pixel. Thus, naturally, the current controls the brightness of a PM-OLED. There are two current driving methods. One is pulse amplitude modulation (PAM), and the other is pulse width modulation (PWM)[7]. The PAM method produces a gray scale by varying the current amplitude, whereas the PWM method does so by dividing time on a constant current. When increasing the gray scale and panel resolution, PAM is difficult to control. Therefore, the driver IC in this paper uses PWM, supplying a constant current to the panel.

3 A mixed-signal driver chip system

A block diagram of a mixed-signal driver chip system for a 132 × 64-pixel PM-OLED matrix panel is shown in Fig. 2. There are four main circuit blocks: (1) a digital controller, (2) a display data SRAM, (3) driver circuits, and (4) a DC-DC voltage converter.

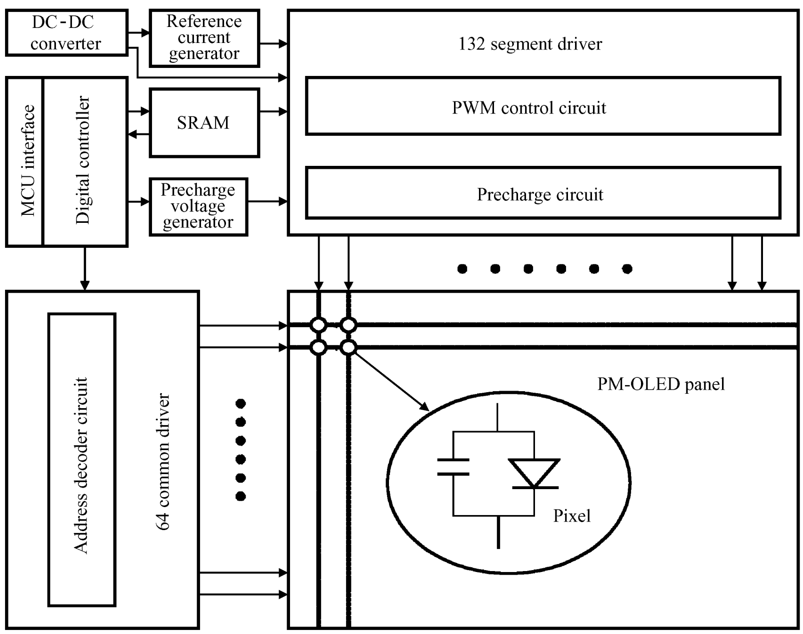

Fig.2 Block diagram of PM-OLED driver chip

As shown in Fig. 2, the digital controller is the core and command center of the display driver. It deals with the input display data or instructors from the MCU. The former is sent to the SRAM, and the latter is translated into different control signals to control the whole chip. The MCU interface is compatible with 8080 or 6800 MCU series. The SRAM stores pixel data for display, and it is composed of an n-row by m-column × 6-bit address array. Each 6-bit datum is a gray scale value for one pixel. The DC-DC voltage converter is a switching voltage generator circuit. It is accompanied by an external application circuit that can generate a high voltage supply of over 15V from a low voltage supply, which is typically 3V. Architectures of DC-DC converters used in OLED drivers are similar to those in Ref. [8]. Further description is not provided here. The driver circuits contain 64 common drivers, 132 segment drivers, a pre-charge voltage generator, and reference current generators. The 64 common drivers and 132 segment drivers are connected to the panel electrodes and are driven directly. If the display is turned on, the segment drivers read out the display data line by line from the SRAM. Then the data are transformed to driving current. At the same time, the common drivers select each row sequentially to cooperate with the segment drivers

3.1　Pre-charge voltage generator

Each PM-OLED pixel is equivalent to a diode in parallel with a parasitic capacitor. When a pixel is driven by a constant current, the capacitor is first charged. No current flows through the diode, and the pixel is dark until the pixel voltage reaches the threshold voltage of the diode. If each column is initially discharged, the charge-up time can dramatically eat into the available row time. For lower signal currents, the diode threshold will never be reached. Thus, overcoming the parasitic problem is the initial challenge in PM-OLED driver design.

PM-OLED drivers can be designed to supply either a pre-charge current or a pre-charge voltage. In the former, a fixed current applied for a programmed time raises a known capacitance to a specific voltage. In the latter, the specific voltage source can be connected, and the column capacitance will charge through the source. We choose the voltage pre-charge method in the chip for the sake of precision. The specific voltage source called V_{pre} is produced by the circuit as shown in Fig. 3.

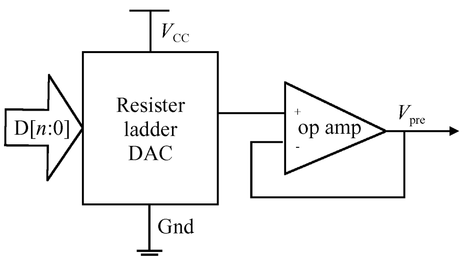

Fig. 3　Circuit of pre-charge voltage source

The pre-charge voltage generator contains an n-bit resistor-ladder DAC and a source follower. The power supply V_{CC} can be divided by resistors and reproduce the specific voltage. We need a source that is able to supply enough pre-charge current, i. e., a source follower.

In theory, stepwise charging can minimize power dissipation[9]. We design two pre-charge voltages. One is V_{pre}, and the other is V_{DD}, which is an external low voltage supply and is typically 3V. The two-step voltage charge method effectively saves power consumption. Simulation indicates that power dissipation can be reduced by over 10% by the use of the two-step voltage charge method.

3.2　Segment drivers

A simplified architecture of one segment driver of the chip is shown in Fig. 4. It can realize a 64-step gray scale display with the PWM method. I_{ref} is the reference current of the chip, which is obtained from reference current generators and can be adjusted to realize a 256-step contrast control. I_0 is the display reference current. Each segment driver copies the current to drive the selected pixel. In the circuit, there is a current switch. The control signal comes from the SRAM. If the switch turns on, the driver current flows to the pixel. If the switch turns off, driver current disappears. Thus, the gray scale information is transferred from the SRAM to the driver current.

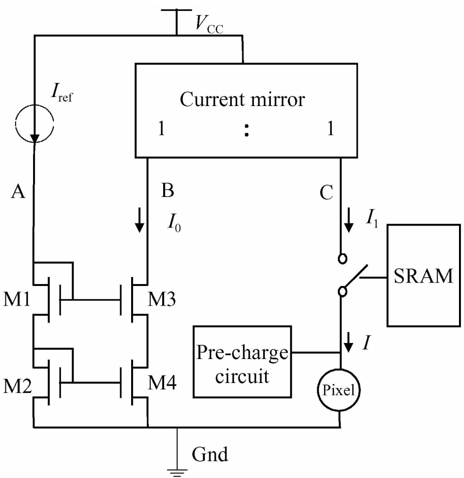

Fig. 4　Simplified architecture of one segment driver

In order to produce the switch control signal, the SRAM becomes a litter more complex. Some latches and counters are needed. The 6-bit display data for one pixel are read to the latch and transferred to the counter. At the beginning of each display period, the counter counts from 0 to 63. When the counter number is equal to the value of the display data, the switch turns off. The 64-step PWM is thus accomplished.

4 Test results

A die photograph of the chip is shown in Fig.5. It has been implemented in a Chartered 0.35μm 18V HV (DDD) CMOS process with a die area of 10mm × 2mm. We use a 128 × 64-pixel OLED panel named VGG12864G supplied by Beijing Visionox Technology. The test results of one segment driver are shown in Fig.6. It depicts the voltage output waveform pulse, which is composed of pre-charge to V_{DD}, pre-charge to V_{pre}, normal display and discharge, in every display period. The results are as expected. Some test results of the single driver chip are summarized in Table 1. Operation of the panel display has been verified through successful performance, as shown in Fig.7. The power test shows that the power consumed of the whole chip and the panel with a constant driver current of 100mA is about 294mW at a 12V high voltage supply and a 3V low voltage supply, when all pixels are displaying the highest gray scale.

Table 1 Some test results of the single driver chip

Gray scale steps	64
Maximal segment output current	980mA
Maximal common sink current	>125mA
Output current variation	<3%
Frame frequency	75/150Hz
Logic voltage	2.4～3.3V
High voltage	9～18V

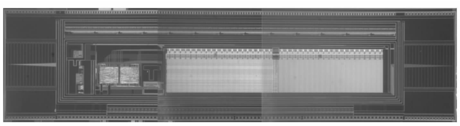

Fig.5 Die photograph of the whole chip

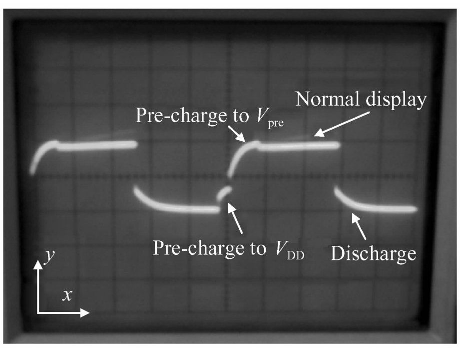

Fig.6 Test result of one segment driver (y-axis: 5V/grid, x-axis: 20μs/grid)

Fig.7 A gray scale photograph taken directly from the panel

5 Conclusion

We have developed a single driver chip with a 64-step gray scale control for a PM-OLED in a Chartered 0.35μm 18V HV (DDD) CMOS design rule with a die area of 10mm × 2mm. It is applicable for a 132 × 64-pixel PM-OLED panel with high gray scale image. The test results show that our chip can operate efficiently. As a driver chip used in portable devices, it needs more attention on power consumption.

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实现 64 级灰度显示的无源 OLED 驱动芯片的设计

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摘要： 设计出了一种实现 64 级灰度显示的单片混合信号驱动芯片，它采用脉冲宽度调制方法和两级电压预充方式，适用于驱动 132×64 像素的无源 OLED 显示屏. 芯片内部主要包括数字控制器，显示数据存取器，DC-DC 电压转换器，参考电流产生器，电压预充电路产生器，64 个行驱动电路和 132 个列驱动电路. 它已经用 Chartered 0.35μm 18V 高压 CMOS 工艺制作完成，芯片面积约为 10mm×2mm. 测试结果表明芯片性能良好，在电源低压为 3V，高压为 12V，显示电流为 100mA 并处于最高级灰度显示的条件下，芯片与面板的总功耗为 294mW.

关键词： 有机电致发光二极管；灰度显示；脉冲宽度调制；预充；列驱动；行驱动

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