OLED into Mobile Main Display

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Introduction

A decade after the Electro-luminescent (EL) effect was first discovered, organic light-emitting diode (OLED) technology has finally come into commercial use for mobile phones, MP3s and digital cameras. From the 1st commercial single chip OLED driver IC introduced in 2001, there were over 17 million units shipped for the mobile phone display market in 2003 according to Display Search. This year, OLED is also being employed in mobile phone main display models. OLED technology is taking off in mobile display; and sales of OLED modules this year are expected to reach about 30 million units.

Linked to OLED technology and development, the OLED driver IC acts as one of the key parts. It not only matches panel resolutions from low Mux ratio to high Mux ratio but also applies some special features such as: current control for each RGB; wider IC operating temperature (-40 to 85 °C); internal DC-DC voltage booster; and a Graphic Acceleration Command Set; - all available in existing single chip OLED driver ICs from Solomon Systech, improving OLED lifetime and reliability, as well as enhancing the display performance.

Common Mobile Display Resolutions

Sub-display

In general, there are three kinds of resolution for mobile phone sub-display on the market: 80x48, 96x64 and 96x96. In 2003 the major OLED shipments were of the area color type, which is a monochrome display with typically 2 to 3 different colors. Generally speaking, this is a proven technology in the sub-display market. In the future, area color OLED sub-display will be applied in low cost applications and full color OLED sub display will be applied in high-end applications like camera phones, 3G mobile phones and smart/PDA phones.

Main display

There is a wide range of mobile phone main display resolutions, from 96x64 to 640x320. However, we can still find some major display resolutions such as 96x65 and 101x80 in candy bar mobile phones, 128x128 in clamshell mobile phones, 132x176, 176x220 in many clamshell/camera phones and 320x240 in 3G/smart phones.

This year, the first mobile phone applying OLED as a main display appeared in China. The technology of OLED, including the panel and driver IC, is ready for the market. More and more phone makers are considering OLED for main display solutions; some of them have started designing OLED into their new products. In the near future, OLED will be one of the major players in mobile main display technology.

End products using Solomon Systech Single Chip OLED ICs

OLED Driver and Module Designs

Compared to LCD modules, emissive OLED display does not require a backlight and LED driving circuit. A typical OLED module is only around 1 to 1.5mm thick, while the thickness of a LCD module is at least 3mm. Hence, an OLED module can fit perfectly into the ultra-thin flip cover of a clamshell type mobile phone.

A highly integrated OLED driver/controller IC consists of row driver, column driver, DC-DC converter, timing controller, graphic display data RAM and MCU interface. It provides a concise solution to OLED module makers for designing up-to-date OLED products for mobile devices. Moreover, software engineers can also save much time in developing mobile applications by using built-in graphic controller functions from the OLED drivers IC (see figure 1).

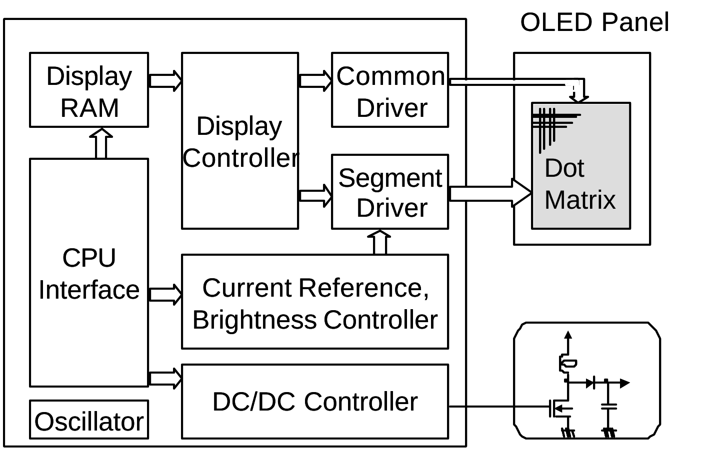


Figure 1: Function Block Diagram of an Integrated OLED Driver

The higher the Mux ratio of display resolution, the greater is the difficulty and technique in using a passive matrix OLED panel, so some OLED panel makers are intending to choose active matrix OLED technology for Mux ratios over 132. This is quite similar to the difference between STN LCD and TFT LCD technology. One predicted that the high Mux ratio display would probably be dominated by active matrix OLED (AMOLED) because of its display quality and panel size; and the low Mux ratio display would be dominated by passive matrix OLED (PMOLED) because of its cost and flexibility. However, many AMOLED products are still in the lab and have not yet been fully commercialized. PMOLED panel makers have been working hard to make bigger panel-size and higher Mux ratio OLED products, and trying to share in the huge mobile display market of TFT and STN LCD.

Although PMOLED technology is facing some problems on high Mux ratio applications, one can resolve the problem by choosing proper driver ICs to produce high Mux ratio OLED products. For example, using a cascadable driver IC in split panel module can double the Mux ratio from 88 to 176 and yield a 132RGBx176 resolution (see figure 2). To achieve this, driver IC should have more functions: (a) instead of LCD voltage driving scheme, current driving technology should be applied; (b) because of high data transfer rate and high power consumption in full color applications, graphic data RAM with controller functions, gray scale table and power saving mode should be integrated, which would also benefit the lifetime and reliability of the OLED; (c) to reduce external components and save costs, internal power management systems should be built in. With all of these, PMOLED technology will much more easily penetrate the full color mobile phone main display arena.

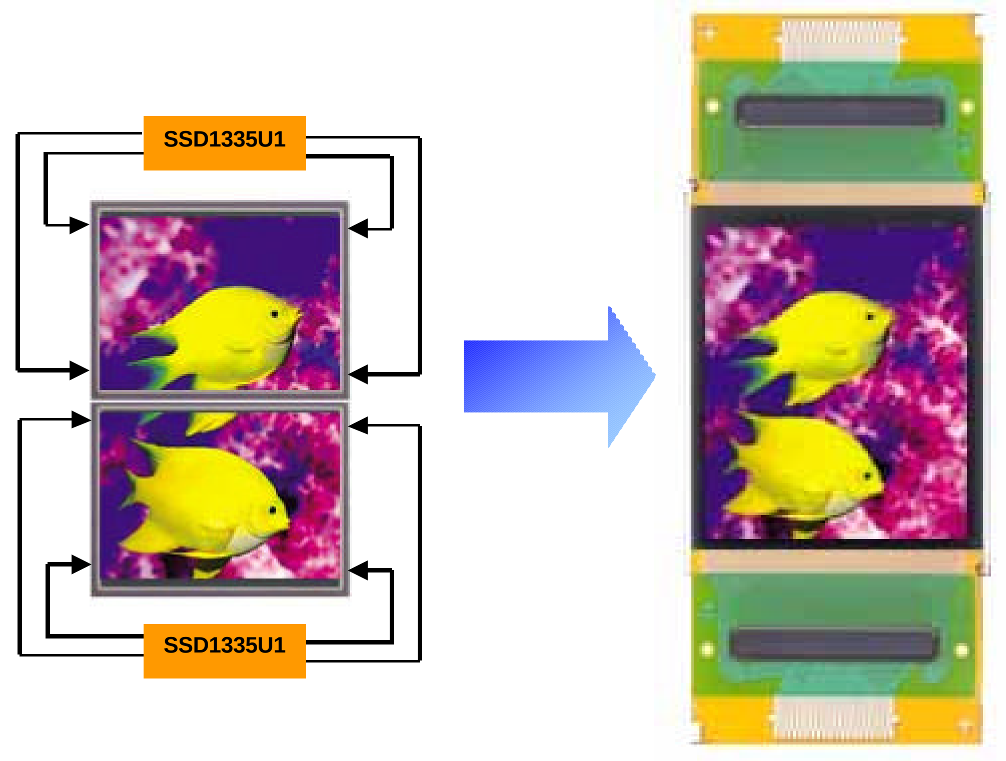


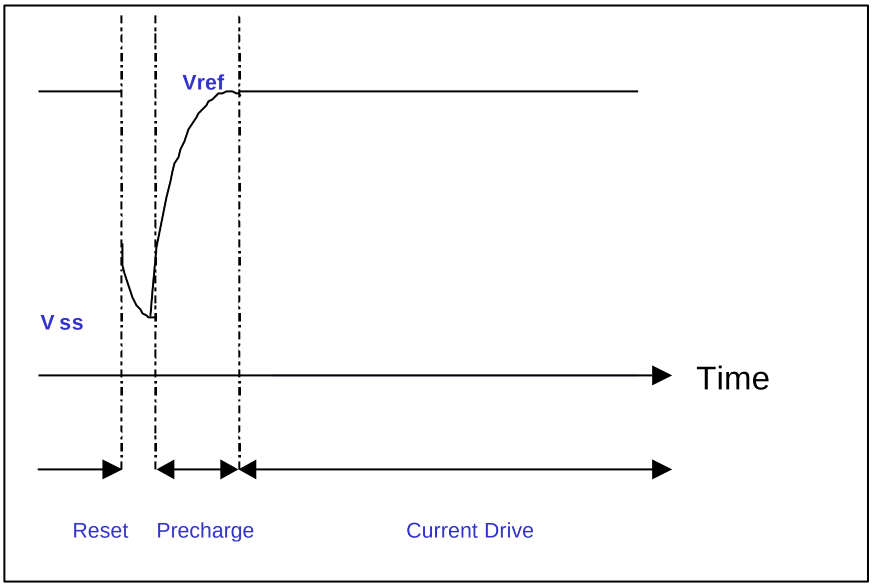
Figure 2: 132RGB x 176 resolution

In the following paragraphs, SSD1338 from Solomon Systech is taken as an example to introduce some key features and technologies in detail.

Advanced Driving Technology

Driving technology

Passive color OLED display requires a sophisticated driving scheme and signal interchange system. The SSD1338 driver has a multiplex addressing driving algorithm for dot-matrix color OLED display. Each driving cycle is composed of discharge (reset), voltage pre-charge and current drive phases (see figure 3).



	Reset to discharge previous image data in capacitor	Precharge to charge up capacitor	Current Drive to drive diode
Pixel Off	Vss	Vss	Vss
Pixel On	Vss	Vref	Driven by current I

Figure 3: Driving cycle (reset, precharge and current drive phases) correspondent to pixel on/off voltages.

Graphic Controller Functions

SSD1338 has an embedded 132x132x18 bit SRAM (GDDRAM) as display buffer. It gives the OLED panel display a maximum 132 x 132 resolution with 262k color depth, and programmable 256, 65k, 262k color modes. With 8-bit and 16-bit 6800-series and 8080-series Parallel Interface and Serial Peripheral interface, SSD1338 is enabled to communicate with MCU at high speed, and smoothly display color pictures and video data in 3G phones.

The Graphic Display Data RAM (GDDRAM) is a bit-mapped static RAM holding the bit pattern to be displayed. The size of the RAM is 132 x 133 x 18bits. For mechanical flexibility, re-mapping on both Segment and Common outputs can be selected by software. For vertical scrolling of the display, an internal register storing display start line can be set to control the portion of the RAM data to be mapped to the display.

Each pixel has 18-bit data. Each sub-pixels for color A, B and C have 6 bits. The arrangement of data pixels in the graphic display data RAM is shown below (see table 1).

Column Address	Normal	0			1			2			:	129			130			131			
	Remap	131			130			129			:	2			1			0			
Data Format		A5	B5	C5	A5	B5	C5	A5	B5	C5		A5	B5	C5	A5	B5	C5	A5	B5	C5	
		A4	B4	C4	A4	B4	C4	A4	B4	C4		A4	B4	C4	A4	B4	C4	A4	B4	C4	
		A3	B3	C3	A3	B3	C3	A3	B3	C3	:	A3	B3	C3	A3	B3	C3	A3	B3	C3	
		A2	B2	C2	A2	B2	C2	A2	B2	C2		A2	B2	C2	A2	B2	C2	A2	B2	C2	
Row		A1	B1	C1	A1	B1	C1	A1	B1	C1		A1	B1	C1	A1	B1	C1	A1	B1	C1	
Address		A0	B0	C0	A0	B0	C0	A0	B0	C0		A0	B0	C0	A0	B0	C0	A0	B0	C0	COM
Normal	Remap																				OUTPUT
0	132	6	6	6	6	6	6	6	6	6		6	6	6	6	6	6	6	6	6	COM0
1	131										:										COM1
2	130																				COM2
:	:	no. of bits of data in this cell																			:
130	2																				COM130
131	1										:										COM131
132	0																				COM132
SEG OUTPUT		SA0	SB0	SC0	SA1	SB1	SC1	SA2	SB2	SC2	:	SA129	SB129	SC129	SA130	SB130	SC130	SA131	SB131	SC131	

Table 1: 262k Color Depth Graphic Display Data RAM Structure

Gray Scale and Gray Scale Table

The full color display supports 6-bit 64 gray scale levels for each RGB color display. It makes use of pulse width modulation (PWM) of the current drive time to set different gray scale levels. The gray scale display is produced by controlling the current pulse widths from the segment driver in the current drive phase. The gray scale table stores the corresponding pulse widths (PW0 ~ PW63) of the 64 gray scale levels (GS0~GS63). The wider the pulse width, the brighter the pixel will be. Therefore, the brightness of each pixel is defined in the graphic display data RAM in terms of pulse width in the gray scale table.

This single gray scale table supports all the three colors A, B and C. The pulse widths are entered by software commands.

In 262k-color depth, 6 bits represent each color. So color A, B and C each have 64 gray scale levels (see table 2).

Color A, B, C RAM data (6 bits)	Gray Scale
0	GS 0
1	GS 1
2	GS 2
3	GS 3
4	GS 4
:	:
:	:
:	:
60	GS 60
61	GS 61
62	GS 62
63	GS 63

Table 2: Relation between graphic data RAM value and gray scale table entry for three colors in 262K-color mode

The situation is different in 65k color depth mode. As shown in the figure below (see table 3), color B sub-pixel RAM data has 6 bits, representing the 64 gray scale levels from GS0 to GS63. Color A and color C sub-pixel RAM data have only 5 bits, representing 32 gray scale levels from GS0, GS2, …, to GS62.

Color A, C RAM data (5 bits)	Color B RAM data (6 bits)	Gray Scale
0	0	GS 0
-	1	GS 1
1	2	GS 2
-	3	GS 3
2	4	GS 4
:	:	:
:	:	:
:	:	:
30	60	GS 60
-	61	GS 61
31	62	GS 62
-	63	GS 63

Table 3: Relation between graphic data RAM value and gray scale table entry for three colors in 65K-color mode

In *65k* color depth mode, the meaning of values inside data RAM with respect to the gray scale level can best be illustrated in the example below. (DCLK: Display clock)

Gray Scale (Pulse Width)	Value/DCLKs
PW0	0
PW1	2
PW2	5
:	:
PW62	120
PW63	125

Table 4: Gray Scale Table

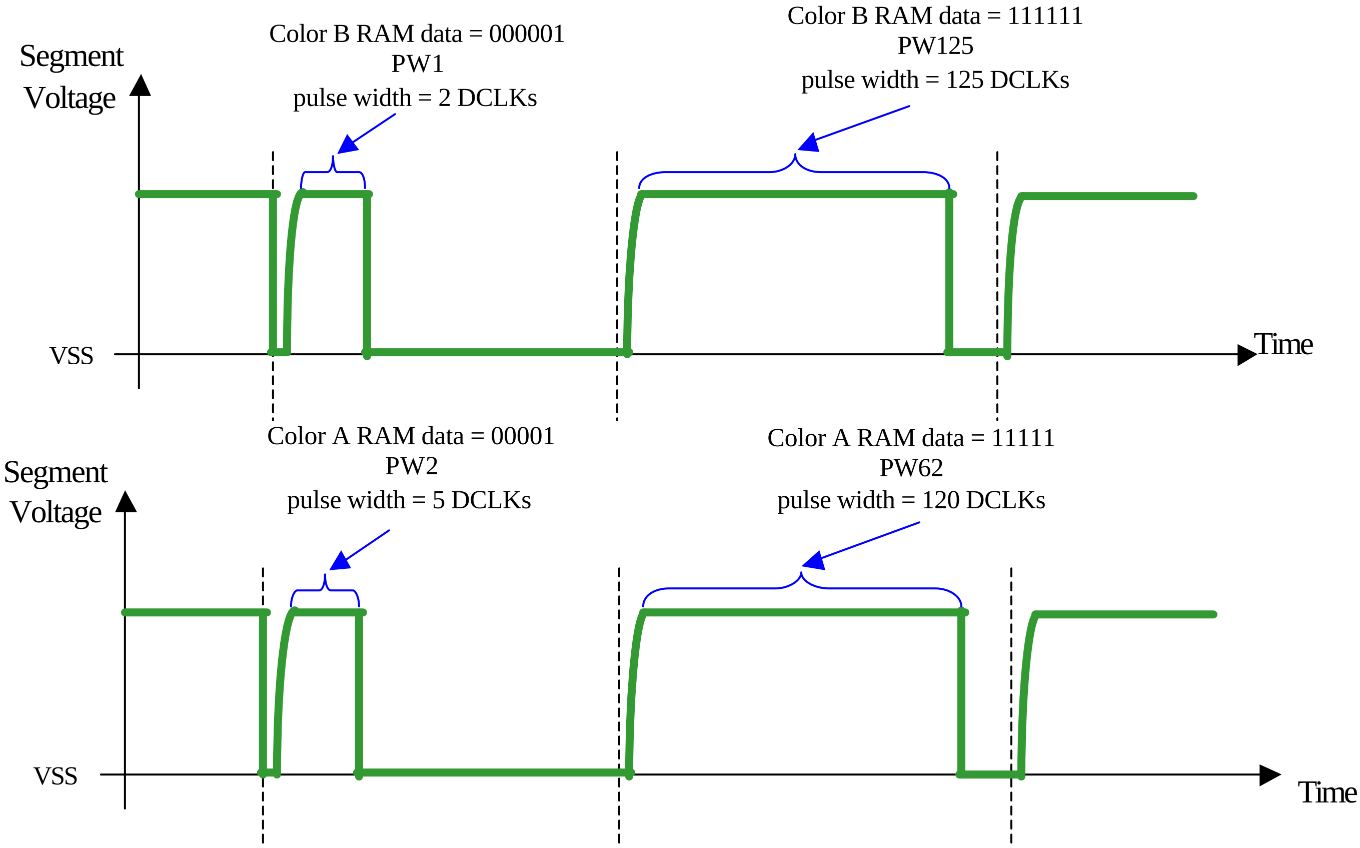


Figure 4: Illustration of relation between graphic display RAM value and gray scale control in 65K color depth mode

Power Management System

This is a switching voltage generator circuit, designed for handheld applications. In SSD1338, an internal DC-DC voltage converter with an external application circuit (shown in the figure 4 below) can generate a high voltage supply V_{CC} from a low voltage supply input V_{DD}. V_{CC} is the voltage supply to the OLED driver block. The application circuit below is an example of an input voltage of 3V VDD generating V_{CC} of 12V @20mA ~ 30mA application.

The VCC output voltage level can be adjusted by R1and R2, and the reference formula is:

VCC = 1.2 x (R1+R2) / R2

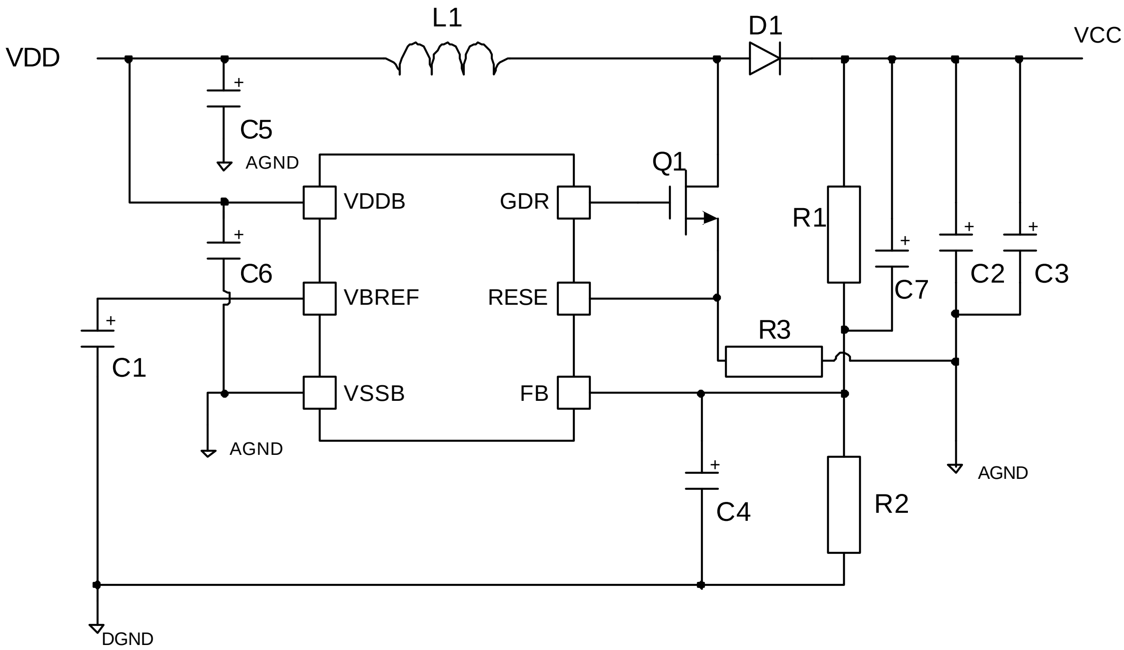
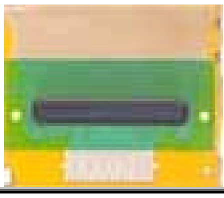
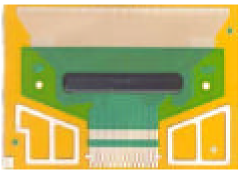
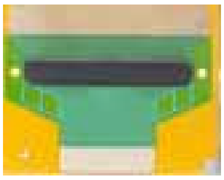
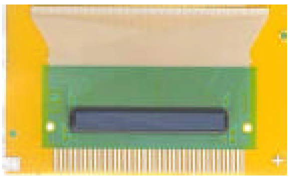


Figure 4: An internal DC-DC voltage converter with an external application circuit.

IC Package Design

As well as the slim die COG solution, the COF package is a good solution for mobile OLED modules. A suitable COF design will increase the OLED module production yield rate, save panel size and enhance mobile application flexibility.

			
SSD1335U1 101RGB x82 262k colors	**SSD1335U2** 132RGBx88 262k colors	**SSD1338U** 96RGBx96 262k colors	**SSD1338U1** 130RGBx130 262k colors

Conclusion

Whether PMOLED or AMOLED technology dominates the market and gains market share from STN and TFT LCD, OLED technology will have a very important role in the display market. In addition to gaining market share, it will also create many new display markets because of its special characteristics - things that STN and TFT LCD do not have. For OLED IC, more advanced features are under development, such as: color balance change control and current uniformity control for high resolution panels; enhanced graphic controllers making OLED applications easy to use; and power saving schemes for portable devices. All of them, inside OLED driver ICs, will combine with OLED panels to make OLED displays brighter and bigger, more power-saving and cost effective. The future is OLED: it's bright!