Monolithic CMOS Power Supply for OLED Display Driver / Controller IC

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Abstract

This paper presents design considerations of a power supply IC to meet requirements for new generations of display panel technologies, especially for OLED display panels. Major factors include current consumption, efficiency and size. An integrated DC-DC boost converter with current-limited minimum-off-time PFM control is designed with a standard 0.35μm CMOS process. Simulation results show that the efficiency can be over 80% for a load current ranging from 1mA to 100mA for an OLED display driver/controller IC application.

I. INTRODUCTION

The portable telecommunication market has been growing rapidly, especially shifting the focus from GSM and CDMA to wide bandwidth 3G technologies. With wider bandwidth, these cellular phones not only support voice message, but also multimedia applications. In order to cope with the technological change, cellular phone display technology needs to be enhanced. Beginning with the heart of the display system, the display driver / controller plays a very important role, which efficiently improves the display interface.

At present, Super-Twisted Nematic (STN) LCD driver IC is dominant in the display driver market [1]. However, Organic Light-Emitting Diode (OLED) displays (Figure 1) are expected to take off over the next decade [2]. The main advantages of OLED are simpler construction, thinner, better viewing angle (160 degree), saturated emissive color, lower power consumption, etc. The comparison of STN and OLED panel display technologies are shown in Table 1.

Figure 1: The OLED Driver with Controller IC

Table 1: Comparison of STN and OLED flat panel display technologies

	STN	**OLED**
Viewing Angle	*50^{o}*	*160^{o}*
Response Time	*10 ms - 100 ms*	*< 1 ms*
Driving Method	*Passive*	*Passive for PMOLED* *Active for AMOLED*
Contrast Ratio	*~ 8:1*	*~ 100:1*
Power Consumption with Backlight	*~ 100 mW*	*~ 10 mW*

An STN LCD driver IC is needed to provide a high voltage of 10 to 18V for the STN display panel (charging and discharging the panel), with a current consumption of the order of 100μA. From a supply of 1.8 to 3.3V, a 3x to 6x charge pump circuit is suitable for integrated STN LCD display IC as it requires fewer external components and no inductor. On the other hand, OLED pixels are self-luminous. While it requires no backlighting and electrical current to supply the OLED panels, the current consumption of an OLED driver is larger than 40mA, which also depends on the application and the mode of operation. It is not appropriate to build a charge pump to supply such a large loading current. Instead, inductor-based switch-mode power supply should be considered.

II. REVIEW ON OLED DISPLAY DRIVER IC

As mentioned above, OLED panels are current-controlled devices. The electrical model and the structure of an OLED is shown in Figure 2 and Figure 3 [3], respectively, where D is the light emitting diode and C is the parasitic capacitor of one pixel. Electrons and holes are injected from the cathode and anode electrodes, respectively, into the electron transport layer (which can also be the emission material) and the hole transport layer. The charge carriers then migrate under an applied electric field to form electron-hole pairs (excitons) which then recombine, resulting in light emission.

The maximum source current of each segment driver is around 300μA. The total current required is determined by the number of segments in the panel. For example, a 128 x 128 matrix panel has 128 segments, and therefore, the maximum total current consumption from the power supply is around 40mA. The threshold voltage of OLED panels is typically in the range of 2 to 10V. From a supply of 1.8 to 3.3V, a boost DC-DC converter is required in the OLED display driver IC.

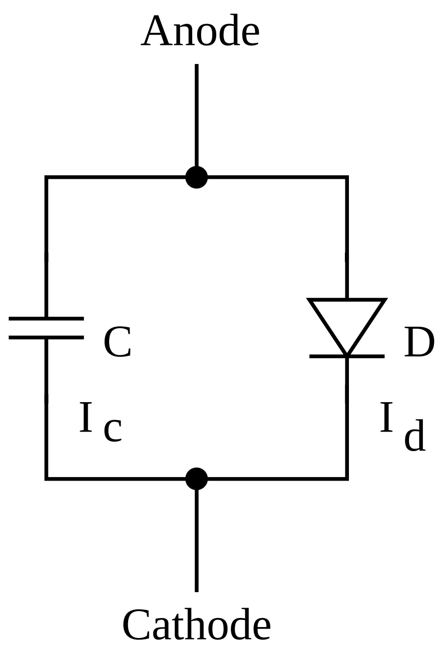

Figure 2: The electrical model of OLED

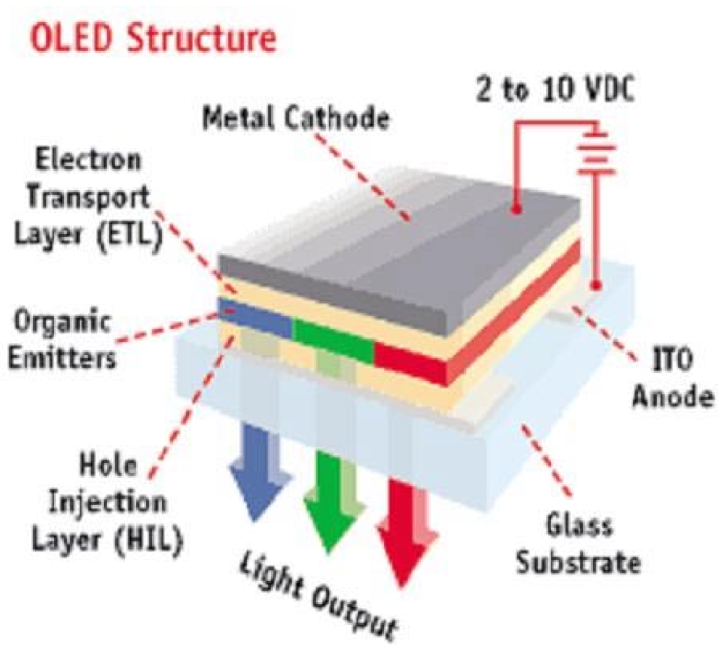

Figure 3: The structure of OLED

Since the pattern of the cellular phone display varies and the cellular phone would have power save mode, the loading current of the OLED panel would be changing. Therefore, a good DC-DC converter should provide high efficiency in a large range of load.

III. CONTROL TECHNIQUES FOR OLED DRIVERS: PWM vs PFM

In terms of switching frequency, there are two control topologies for a switching converter: the pulse width modulation (PWM) control and the pulse frequency modulation (PFM) control [4]. For a PWM converter, the output ripple voltage is usually smaller and easier to be filtered. Also, the higher the switching frequency, the smaller the components (L and C) are needed in the power stage. However, in the light load condition, the efficiency of the PWM control would decrease due to switching / gate drive loss, and such power loss is dominant when comparing to conduction loss. For the application with power save mode, the efficiency can be optimized in a PFM converter because the switching loss would decrease with the low switching frequency at light load condition.

As for battery-operated portable electronic devices, the two critical design issues are size and efficiency. In a PWM control scheme, more than 2 external components are needed for compensating the closed-loop system [4]. The number of external components in the compensation network depends on the mode of control (current-mode control or voltage-mode control), and the mode of operation, (DCM or CCM operations [5]). For example, 5 extra components are required for a voltage-mode CCM boost converter. However, in the PFM control scheme, compensation is done through the change in switching frequency, and no explicit compensation network is needed, and therefore, fewer external components are required.

Moreover, cellular phone often operates in the standby mode, which means that the loading current of a display panel is small. Thus, the efficiency at light load condition is very important. Based on the above criteria, the PFM control scheme is more suitable in the OLED display driver application.

IV. CURRENT-LIMITED MINIMUM-OFF-TIME PULSE FREQUENCY MODULATION

The current-limited minimum-off-time PFM scheme is widely used in the industry when comparing to other PFM schemes, which is shown in Figure 4 [6]. The output voltage is fed back through a voltage divider to a comparator and compared with the bandgap reference voltage. The output of this comparator controls the trigger of a one-shot multivibrator (maximum on-time). Another comparator looks at the peak inductor current as a voltage across a current sense resistor in the source of the power NMOS. When the output is less than desired voltage, the SR flip-flop turns the power NMOS on until the voltage across the current sense resistor is equal to the reference voltage V_{pk}. Then the flip-flop resets, turning off the power NMOS, the one-shot (minimum off-time) is triggered. The power NMOS remains off for the duration of the one-shot. If the output voltage is still out of regulation, the flip-flop will set again and the cycle repeats itself. Besides, a variable resistor, R_{fb1}, can be used to control the output voltage such that the boost converter can provide high efficiency during the power save mode.

V. SIMULATION RESULTS

This controller is implemented with a standard 0.35μm CMOS process. The simulation results are shown in Figure 5. The maximum efficiency is 87 %, which is corresponding to the power save mode at output voltage 10 V with 10mA load current. The efficiency is 80 % at output voltage 18 V with load current 100mA when the OLED display panels are in heavy load condition. The results show that this control scheme provides high efficiency over a wide range of load condition.

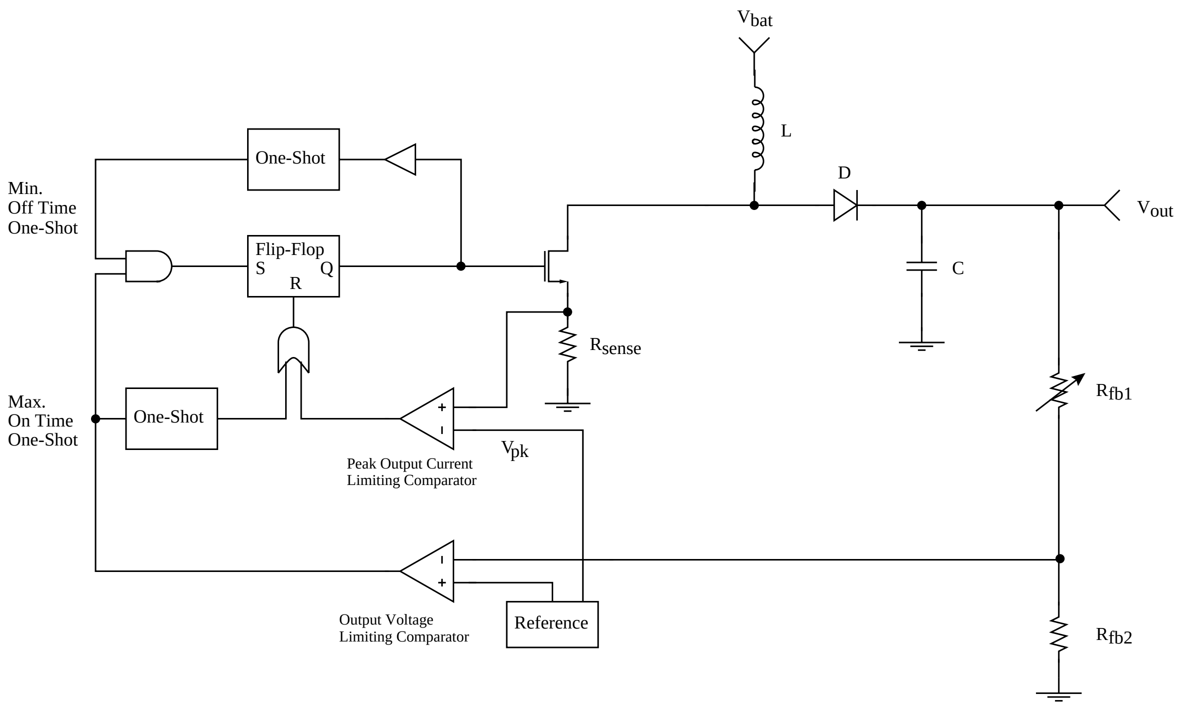

Figure 4: Current-limited minimum-off-time PFM DC-DC boost converter

VI. CONCLUSIONS

Due to high current consumption in the demand of color features in portable telecommunication market, switch-mode power supply would be one of the best solutions for OLED display driver ICs. And the current-limited minimum-off-time PFM controller is suitable in this application as it does not only reduce the external components comparing to PWM control schemes, but also provides high efficiency over a wide range of load condition.

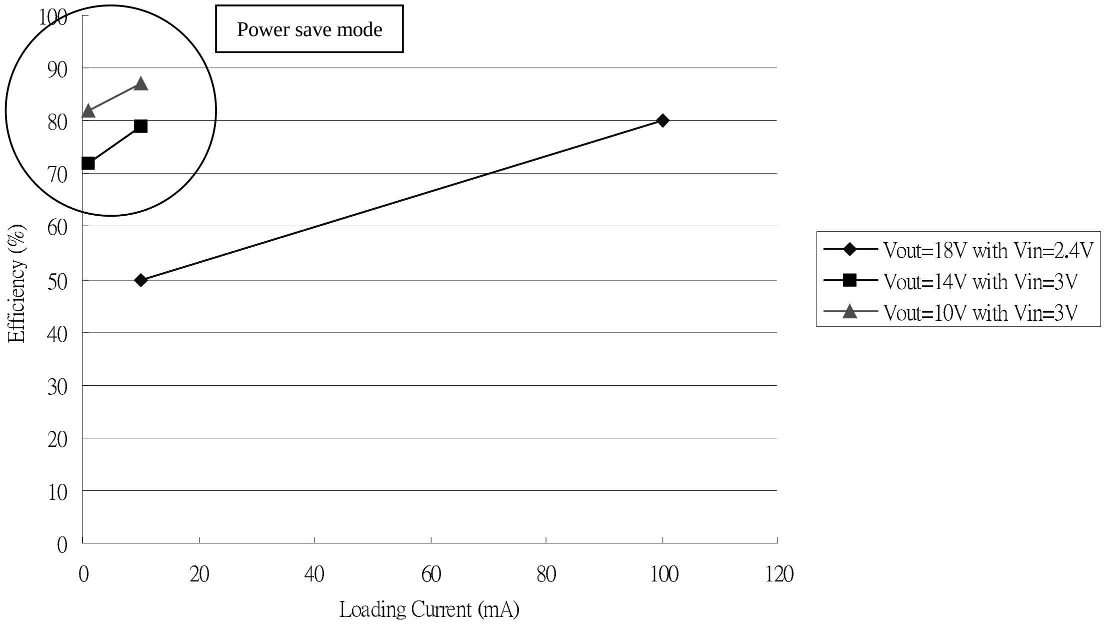

Figure 5: The efficiency at different V_{out} and V_{in}

VII. REFERENCES

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