Low Power Consumption Technology for Mobile Display

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Abstract

A variety of power reduction technologies is introduced and the benefits of the technologies are discussed. PenTile® DBLC (Dynamic Brightness LED Control) combined with SABC (Sensor-Based Adaptive Brightness Control) enables to achieve the average LED power consumption to one third. The panel power reduction of 25% can be achieved with low power driving technology, ALS (Active Level Shifter). MIP (Memory In Pixel) is expected to be useful in transflective display because the whole display area can be utilized in reflective mode with power consumption of 1mW.

1. Introduction

Mobile internet, TV, GPS, game and various multi-media functionalities has become the main stream trend of high-end mobile phone. In accordance, the mobile display size and resolution of such multimedia phones have increased, for example, from 2.2 inch 180 dpi QVGA to 3.3 inch 300 dpi WVGA, while white luminance has increased from 250 cd/m^2 to 400 cd/m^2. The trend poses a big burden on phone power architecture design, which has to guarantee proper batter hours by allocating power consumption budget for each device in the phone. For example, 3.3 inch WVGA TFT-LCD is now taking more than 65% of the total system power consumption when the phones are in gaming or multi-media playing mode. Power reduction technology for mobile display is now a critical issue as high resolution, large and bright display is required.

High speed serial interface (HSSI) is no longer option, but has become a requirement for high resolution display in order to reduce interface power consumption and EMI. Provided that HSSI is adopted, the LED power consumption accounts for almost 80% out of the total display power. Its reduction has been the highest priority because of its predominance. However, as the panel resolution increases, the portion of panel power consumption has increased and reached 20% for WVGA TFT-LCD. The portion of panel power consumption for QVGA is only 6%. Panel power consumption is no longer negligible.

This paper discusses what kind of power reduction technologies is available now and how the technologies will evolve to reduce display power consumption in the future.

2. LED Power Reduction Technology

Adaptive LED brightness control has been widely used to reduce LED power consumption [1, 2]. Both LED brightness and input data are dynamically changed to minimize LED power and to keep original image qualities. LED dimming is compensated by brightened image data. It has been known that it is a very effective technique for power reduction, especially with moving images. However, its power reduction performance is not satisfactory when internet is a primary use.

Another type of adaptive brightness control is PenTile® DBLC, which is expected to be the next generation RGBW rendering technology [3]. It is widely accepted that it fits best for 250 dpi display and higher in phone applications. It enables 1500 cd/m^2 for 300 dpi WVGA in outdoor mode and 50% power reduction in the average LED power consumption in indoor mode. In indoor mode, PenTile® DBLC algorithm utilizes white luminance gain to reduce LED power consumption, while the image quality can be kept intact for over 250 dpi display. The average 50% power consumption reduction can be realized even when regular web pages with white background images are on display, which cannot be achieved with existing adaptive brightness control based on RGB stripe. PenTile® DBLC algorithm is available for both frame buffer embedded and buffer less architecture. Both the frame buffer size and the number of source amplifier channels are only two thirds. PenTile® DBLC has a potential to increase color reproducibility without a sacrifice of white luminance in the future.

SABC (Sensor Based Adaptive Brightness Control) is one of the promising technologies as a candidate to reduce LED power consumption [4]. Photo sensor can be either integrated on panel or a discrete device. It can be implemented with either a-Si or LTPS device. LED luminance level is adaptively adjusted to provide both best readability and low LED power consumption. Integration of photo sensor on glass has been tried since the early 2000. The linearity error of integrated PIN diode needs improvement to compete with the discrete photo sensors.

PenTile® DBLC can be easily combined with SABC to provide the most efficient LED power reduction. PenTile® DBLC needs to distinguish whether the environment is either indoor or ourdoor, which SABC can provide. When a RGB stripe panel is given, panel luminance can be increased proportional to LED current. However, PenTile® DBLC can double the luminance only increasing the luminance gain of white sub-pixels at the same LED current.

3. Panel Power Reduction Technology

A variety of inversion technique has been used in TFT-LCD industry. Dot inversion, multi-dot inversion, column inversion and line inversion are being widely used for mobile TFT-LCD. DC common voltage for upper glass electrode is usually preferred to AC for mobile display. Since AC Vcom causes resonant vibration of display mechanical structure, audible noise has been one of display engineer's headache. In addition, integrated capacitive touch solution seems requiring DC Vcom in order to secure higher signal to noise ratio. One the other hand, dot inversion consumes the highest power and column inversion suffers from severe vertical crosstalk as display luminance increases. ALS (Active Level Shifter) can be a good candidate for DC inversion technique with low power consumption. Its source data is the same as line inversion, while upper glass common electrode is DC. Pixel storage line is boosted up and down alternately line by line so that both positive and negative gamma voltage are realized. This enables to reduce panel power consumption by 25% for both LTPS and a-Si. ALS technology is applicable very widely, ranging from QVGA to QHD. Since the border width of display becomes narrower, slim circuit integration is one of the future requirements.

As mobile phone requires low power consumption of TFT-LCD, the widely-accepted LTPS development trend in the middle of 2000, so called, SOG (Silicon on Glass) has been modified and redirected to optimum integration on glass for low power consumption and slim border width. As more circuit components are integrated on glass, TFT-LCD requires more power consumption, wider border width and even higher cost, ironically. Integration of DC-DC power has been effective in reducing the driver IC cost, but it is losing its position as slim peripheral width is generally required. It is regarded that SOG technology has to be reevaluated from the point of power consumption and panel slim design.

MIP (Memory in Pixel) has been one of the interesting topics in LTPS TFT-LCD [5, 6]. Every sub-pixel is supposed to have integrated memory-like pixel structure so that the written pixel data can be retained for a while with extremely low refresh rate. MIP display enables to reduce the frame rate to 1 Hz or even lower in eight color mode. It is critical to minimize static power consumption both in panel and driver IC. The whole display can be 24 hours on with power consumption of 1 mW. MIP is implemented in tranflective display and back light is turned off during MIP mode operation.

4. Summary

Low power consumption technologies for mobile display are introduced and the significance of each technology is discussed. As the portion of display power consumption increases, advanced power reduction technologies will be devised and adopted in future.

5. References

[1] L. Kerofsky, S. Daly, SID Technical Digest, pp1242-45(2006).

[2] S. Araki, R. Nonaka and et. al, SID Technical Digest, pp976-978(2008).

[3] B. Lee, C. Park, S. Kim, T. Kim, Y. Yang, J. Oh, J. Choi, M. Hong, D. Sakong, K. Chung, S. Lee, C. Kim, SID Technical Digest, pp1212-15(2003).

[4] S. Koide, S. Fujita, T. Ito, S. Fujikawa, T. Matsumoto, Proc. IDW '06, pp689-690(2006).

[5] Y. Nakajima, Y. Teranishi , Y. Kida, Y. Maki, SID Technical Digest, pp1185-88(2006).

[6] K. Yamashita, K. Hashimoto, A. Iwatsu, M. Yoshiga, J. R. Ayres, M. J. Edwards, H. Murai, SID Technical Digest, pp1096-99(2004).