Advanced Mobile Display System Architecture

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Abstract

This paper presents issues of display hardware architecture, relating to memory, display driver IC architecture, and chip-to-chip interface. To achieve a low power and low cost mobile phone, not only the display architecture must be carefully selected, but also the driver-ICs optimized to accommodate the different modes of operation found in typical handheld devices. The technique of forming a photo sensor in each pixel using TFT and display module architecture are developed to add multi functions in display such as fingerprint recognition, image scanning, and integrated touch screen. Detailed architectures of IC partitioning, high-speed serial interface, D/A converter, and multi functions such as fingerprint recognition and image scanning using photo sensors are important to a power optimized system.

1. Introduction

As mobile devices are becoming more usable anywhere and any time according to one's needs, their market share is increasing abruptly. Among all mobile devices, the mobile phone market share is increasing more rapidly than that of consumer electronics and computer. Mobile phones were originally voice oriented, but they are moving to multimedia centric such as color phone, camera phone, MP3 phone, and DMB (Digital Multimedia Broadcasting), as shown in Figure 1.

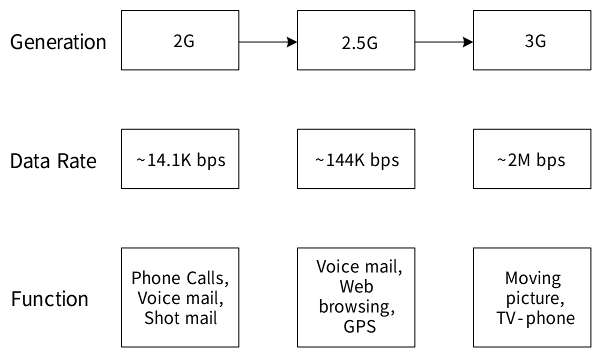

Figure 1. The trends of mobile phones

As processor power and wireless bandwidths increase, the need for displays with more colors and capability of video rate display increases. Because of the small size of mobile phones the batteries are limited in the amount of energy they can contain; therefore, it is imperative that the power consumed by the display module is minimized. At the same time, there are demands for full-color displays and multi-functionalities such as security, image scanner, integrated touch panel, etc. However, improving the performance to such a full-color display as well as more functional display is likely to raise manufacturing costs. Therefore, we must study the system architecture and driving circuit schemes to achieve good cost-performance. Moreover, having small number of parts and interconnect lines is important to improve form factor of the display system.

This paper presents the display system architecture design issues to obtain low power and low cost multi-functional mobile phones, relating to memory technology, display driver IC architecture, multi functions such fingerprint recognition and image scanning using photo sensor, and chip-to-chip interface.

2. Proposed mobile display system architecture

The mobile phone, in addition to digital camera function, is increasing the requirement for more multi functions such as fingerprint recognition, image scanning, and integrated touch screen. As processor power and wireless bandwidths increase, the power consumption increase and also EMI (Electromagnetic Interference) increase. Also, there are a lot of interconnection lines from LCD panel to Modem/AP (Application Processor) and LCD panel and camera module. To solve these problems, we propose the display system architecture for a mobile phone as shown in Figure 2.

The functional blocks are as followings: CIS (CMOS Image Sensor) generates the image digital data with camera sensor and sends the raw data to display module. Modem/AP (Application Processor) interfaces with display module and memory. Display module consists of driver ICs such as ISP, F/B, source driver, TCON, and photo sensor readout LSI and panel. It displays some information such as texts, still images, and moving pictures with full-color and high resolution, which are from CIS with raw data interface and Modem/AP with RGB-interface or Host-interface. ISP modifies, interpolates, and transforms the digital data to show images naturally with digital image signal processing algorithm, which are from the CIS or Modem/AP. Also, it is embedded photo sensor on the panel to implement multi functions such as fingerprint recognition and image scanning. Finally, memory stores the processed data from Modem/AP with SDRAM or NAND Flash.

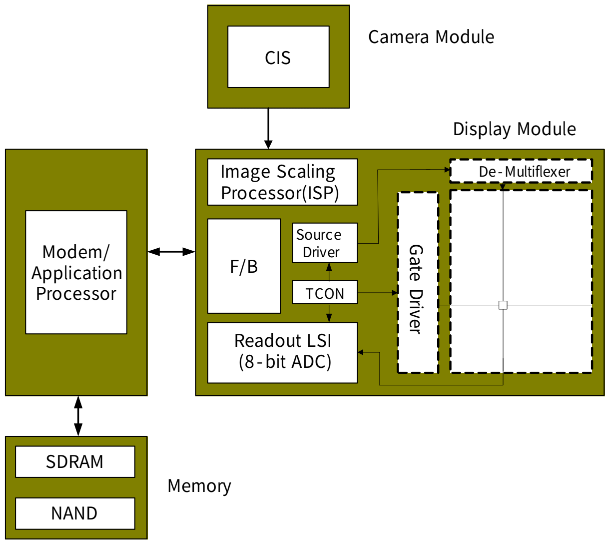

Figure 2. Block diagram of the proposed mobile display system architecture

The interfaces among Modem/AP and display module and display module and CIS are the same as SMIA [8] developed by Nokia and ST, which uses differential mini-LVDS signaling with maximum 208Mbps per channel throughput. It increases reliability and reduces power consumption in mobile phones by decreasing the number of wires that run across the handset's hinge to interconnect Modem/AP with the camera sensor and LCD display. This reduction of wires also allows handset to reduce development costs by simplifying mobile phone designs. Therefore, as mobile phones increase display resolution and multimedia functions, it is imperative that we should use high-speed serial interface to reduce power consumption, interconnection wires, and developing costs.

The display driver IC contains 5 main blocks, which are gate driver, source driver, timing controller, DC/DC converter, and memory. Most display driver systems under QVGA resolution use one chip driver. However, as resolution enhances, it is difficult to integrate single chip because the area of memory is larger. Almost all mobile phone in today's market use a 2-chip with QVGA resolution, as shown in Figure. 3.

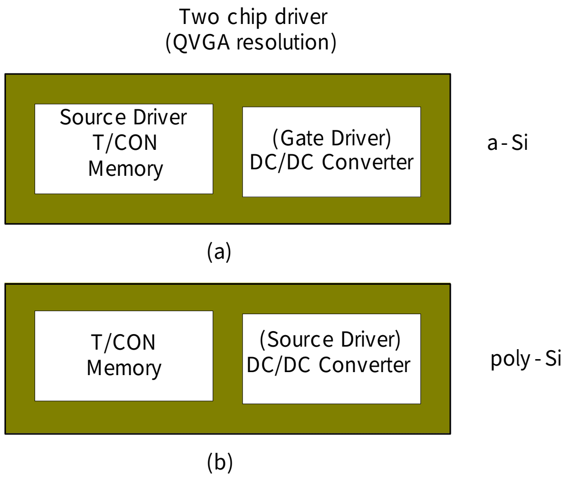

Figure 3. Block diagram of the display architecture of 2-chip solution (a) implemented in a-Si TFT-LCD panel and (b) implemented in LTPS TFT-LCD panel

Figure 3 (a) is partitioned according to process options, low voltage of chip 1 and high voltage of chip 2, which are developed by Renesas [7] and Philips [2]. The main benefits of this choice are the low assembly cost and the close link between the controller and RAM, which allows low-power stand-by and still-mode. This display driver is for a-Si panel, where gate driver may be integrated on panel.

Figure 3 (b) is for low-temperature poly-Si (LTPS) panel, which is developed by Sony [1] and Samsung [6] and offers high-speed switching than a-Si TFTs, and can form a driver circuit on the glass substrate [1]. Therefore, we can integrate the gate driver circuit and source driver or only de-multiplexer on a glass substrate. Here, the de-multiplexer allows the driver IC to have fewer pins by outputting time multiplexed signals. If LTPS process is stabilized enough with low variations of threshold voltage and mobility, DC/DC converter, TCON, and source driver can be integrated on LTPS panel.

The proposed architecture is as shown in Figure 2, in which graphic processor is integrated in display driver IC. Therefore, there is no memory redundancy and communication between Modem/AP and display module to transfer display data. But, it will be large IC chip size due to graphic processor and embedded memory; we need to use a 0.18um process or advanced CMOS process.

As mobile phones increase display resolution and multimedia functions such as camera, MP3, and DMB, the storage density and data bandwidths increase. Due to insufficient system area in a mobile phone, it needs a stacked package techniques such as MCP (Multi Chip Package) shown in Figure 4. Mobile memory needs to consume less power than normal synchronous DRAM by adopting low power circuit techniques and low power supply. Additionally, it needs to reduce the pin count by serializing the address and special functions such as PASR (Partial Array Self Refresh) and Internal TCSR (Automatic Temperature Compensated Self Refresh) which extend battery life both during operation and on standby mode.

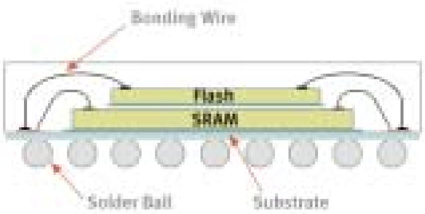

Figure 4. MCP stacked package technique [6]

3. Display driver IC design

In designing the driver IC, the choice of driving method is very important because it affects the power consumption, display quality, and costs. Several driving schemes have been proposed for TFT-LCDs [2-5]. Among these schemes, the Vcom modulation method has the advantage of lower source voltage amplitude. However, this scheme usually inverts the Vcom and Vsource signals every horizontal period in order to suppress flicker, so it usually has high power consumption which is solved by increasing inversion time and frame rate [3].

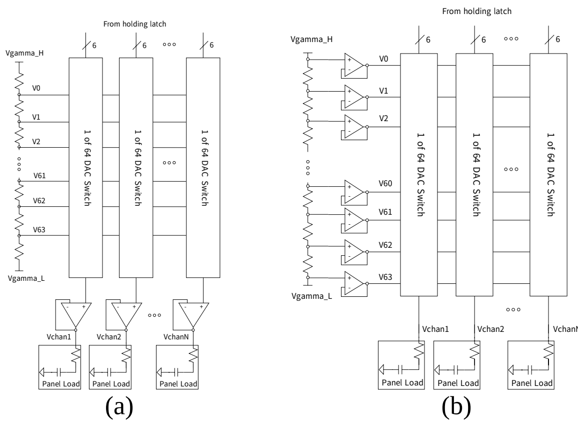

Figure 5. DAC architectures (a) for large size panels and (b) for small size panels

Next, we consider output circuit for the source voltage 262k color requires 64 levels of gray. So, a 64-level voltage generator and 1-of-64 selectors are necessary in the driver IC. Figure 5 shows the two types of circuits. The differences arise from where the buffers are located. The buffers of Figure 5 (a) are located at every output and those of Figure 5 (b) are in front of the selectors. Figure 5 (a) has higher drivability than Figure 5 (b) and it is widely used in the drivers of large size TFT-LCDs, but its circuit size and power consumption is larger because a large number of Op-amps are required. Figure 6 shows the simulation results of Figure 5, we find that Figure 5 (b) is superior to Figure 6 (a), when the panel size is 2.2 inches and resolution is QVGA (240x320-pixel).

Small color displays need a smart tuning capability aiming at adapting the power consumption of the display to the mode of operation of the device. Figure 5 (b) is easy to implement a smart power tuning scheme [2]. Three main modes of operation were identified for a mobile phone device and current consumption, as shown in Table 1. In standby mode, the information to be displayed is battery level, antenna sensitivity, etc. These items can be shown using 64 colors on a partial display. The 64-color display uses only 4 levels; the other levels are unnecessary. The still picture mode is when scrolling through text or web pages with a high information content rendering with acceptable color depth and response speed. The video mode is indeed only required for displaying moving pictures, and therefore a full-color is mandatory.

Table 1. Summary of mobile display modes of operation and current consumption of Figure 5 (b) for QVGA resolution

Mode	Description	Quiescent Current
Standby	64 colors	42uA
Stills	4096 colors	168uA
Video	262,144 colors	840uA

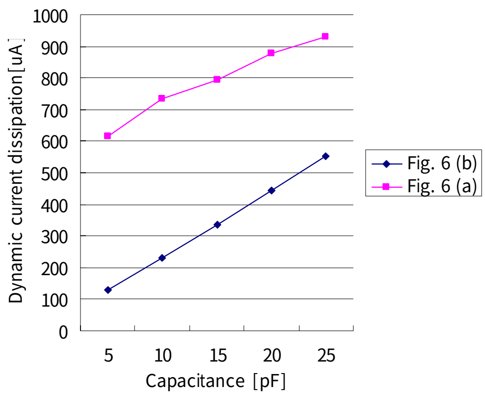

Figure 6. Dynamic current dissipation per output buffer as a function of capacitance per data-line

4. Driver ICs for multi-functions

A technique of forming a photo sensor in each pixel using a-Si or LPTS TFT was developed to add new functions in display such as fingerprint recognition, image scanning, and touch panel without additional screen on the display [9-10].

Figure 7 shows the proposed block diagram of the display module for image scanning, which electric charge is generated in the photo sensor depending on the intensity of incident light and stored in a capacitor formed in each pixel. Then the stored charge is readout by readout LSI having 8-bit ADC to be converted to grayscale digital image data. After that, ISP does image processing to detect the touched location. Finally, the data stored memory through the Modem/AP.

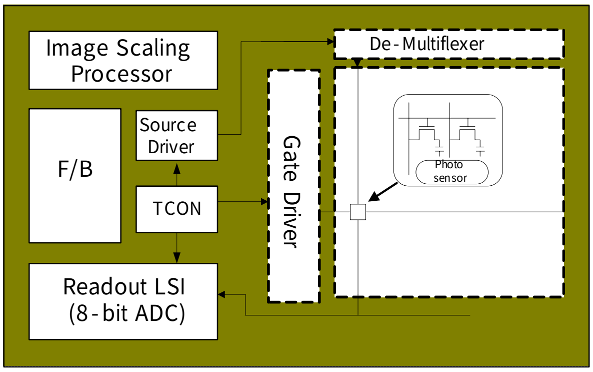

Figure 7. Block diagram of the display module with photo sensor for image scanning

5. Summary

The display hardware architecture issues for mobile phone relating to memory, display driver IC architecture, and high-speed serial interface were described. To achieve good cost-performance, a careful choice of the display system architecture as well as specific driver ICs is required. Highest integration while satisfying the tight mechanical constraints imposed by today's mobile phone's form factors can be obtained by IC partitioning, stacked package, and high-speed serial interface.

The D/A converter architecture with 1-buffer per gray level allows reduction the static power consumption with the required color resolution of the display and also allows to further tune the power consumption according to the various modes of operation found in mobile phones.

The technique of forming a photo sensor in each pixel using LPTS TFT and new display module architecture are developed to add new functions in display such as touch panel function, fingerprint recognition, and image scanner function without additional screen on the display

6. Acknowledgements

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