

QuickLogic X/Y Swap Design for Simultaneous LCD and TV-Out Display in Handheld Electronic Devices



••••• QuickLogic® White Paper

Introduction

Handheld devices are becoming more advanced and handling more multi-media applications than ever before. A mobile application that in the past was only able to run on a high-end laptop personal computer (PC) can now be easily implemented on a personal digital assistant (PDA) device or Smartphone device. It's also clear that handheld products are converging in capability, blurring the lines between one's mobile phone, PDA, digital still camera (DSC), video camera and audio/video personal media player (PMP). As handheld devices continue to advance in sophistication, their capabilities and features will continue to become more like PCs or laptop PCs. With larger, more colorful, high resolution displays, high speed connectivity, an abundance of non-volatile storage and QWERTY keyboards, these devices, which also in many cases run a mobile version of the Windows® operating system, will soon make the need for carrying a laptop PC diminish. A capability that is also starting to emerge in these handheld devices is the ability to drive an external monitor, projector or television. This capability is commonly known as video graphics array (VGA) or TV-out functionality. It is predicted that greater than 40% of all Smartphones will include TV-out functionality as a de-facto feature by 2010.

While adding a feature such as VGA or TV-out may seem as simple as adding the appropriate connector, its addition presents many system design challenges in the areas of power management, device interoperability, and user interaction. This paper will discuss these issues and present a solution to these technical system design challenges based on QuickLogic's programmable solution platform.

The Challenge

Adding the ability to drive an external display from a handheld device presents the following system challenges:

- **Power Management:** Full speed (60 frames per second (fps) VGA or 30 fps NTSC) video requires the inclusion of additional power-hungry components such as extra memory devices for frame buffering, graphics processors, video digital to analog converters (DACs) and NTSC (National Television System Committee) /PAL (Phase Alternating Line) encoders. Combined, these extra components can add a serious drain to the system's power budget, affecting the overall energy consumed by the device, which in turn diminishes battery life. When these components are added, their power must be managed properly so as to consume the least amount of power when operational, and to consume very little to no power when unused.
- **Interoperability:** Adding the feature and capability to drive an external display device gives the user the ability to connect the system to any display brand or technology of any geographical region or age. Thus, it becomes important to provide flexibility in output video timing and resolution to match the majority of common worldwide standards. Furthermore, the timing and resolution of the native display internal to the device may not match the requirements of the display externally connected to the device. Thus the VGA or TV-out subsystem must include features such as frame rate conversion and video scaling/cropping. Also, adjusting the parameters provided by these features must be intuitive and easy for the user to manage.

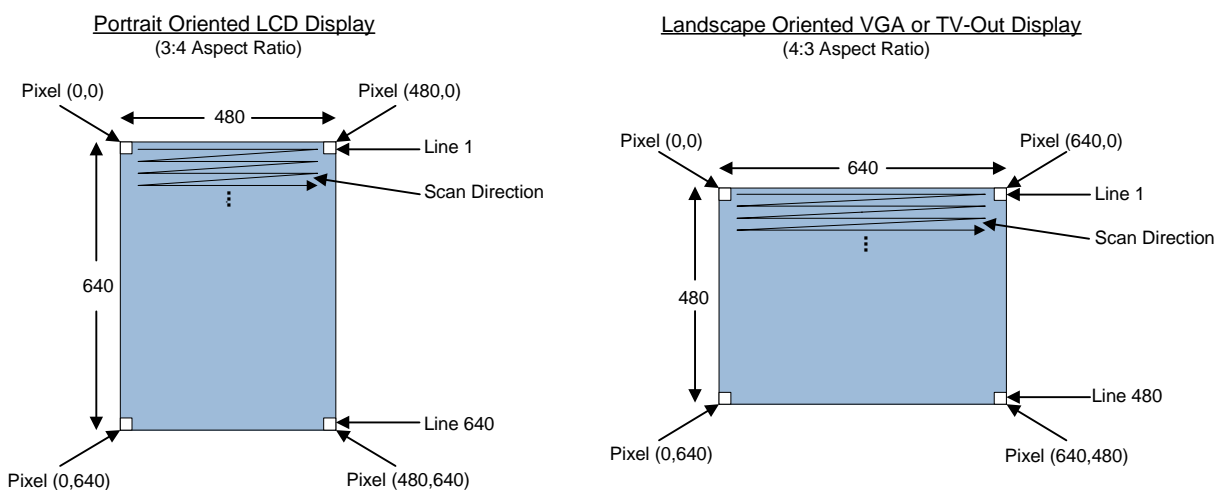
- User Interaction:** Aside from the requirement of the external display subsystem being easy to manage, the user must also be able to provide tactile input to the device when using the external display. Many PDA or Smartphone devices have liquid crystal display (LCD) touch screens that act as the main interface to the user, and thus must continue to accept user input when an externally connected display is in use. It is not acceptable for the user to use an LCD touchscreen for input to the device if the respective display beneath the touch sensor matrix is not operational. This means that the external display and internal native display must operate at the same time (i.e., simul-scan). While this may seem simple enough, it can be quite a challenge if the internal and external displays differ in aspect ratio, video timing (frame rate) and resolution.

Handheld Device Example

In a specific handheld device example, the device includes a native VGA (480x640) resolution color active matrix LCD display oriented in “portrait” mode. Portrait type displays (instead of landscape displays) are common in handheld devices since they match the native shape of the device and also resemble an 8½ x 11 sheet of paper or portrait-style photograph. Advanced handheld devices include the ability to rotate the image 90 degrees based upon the user’s orientation of the device, such as when displaying video versus static images or using a QWERTY keyboard for user input. While the image can be easily rotated 90 degrees by the graphics processor, the scan direction is fixed with respect to the native display device.

For a portrait type LCD display, as shown in **Figure 1**, the LCD’s scan direction is from left to right, top to bottom with the display’s short side oriented at the top. This is a 3:4 aspect ratio screen, but differs in scan direction by 90 degrees from a typical 4:3 (640x480) VGA display. Thus, as **Figure 1** shows, an X/Y swap operation is required to display the same image on both display devices simultaneously. While the frame rate (vertical sync) timing in these two cases *could* be kept constant between the two displays, the number of lines and line rate (horizontal sync) timing will differ.

Figure 1: VGA Resolution 3:4 Portrait and 4:3 Landscape Display Examples with Opposing Scan Directions



With respect to the display image, the native display is written to line-by-line and the simultaneous external display is written to column-by-column. Since an entire frame of lines must be available to construct one image column, a full frame buffer is required to successfully perform the X/Y swap operation.

Taking this example a bit further, if the native portrait VGA LCD display must be locked to a 60 Hz frame rate and is to be used simultaneously with an external PAL (50 Hz frame rate) or NTSC (59.94 Hz frame rate) display, then the frame rate (vertical sync) timing will also differ between the two displays.

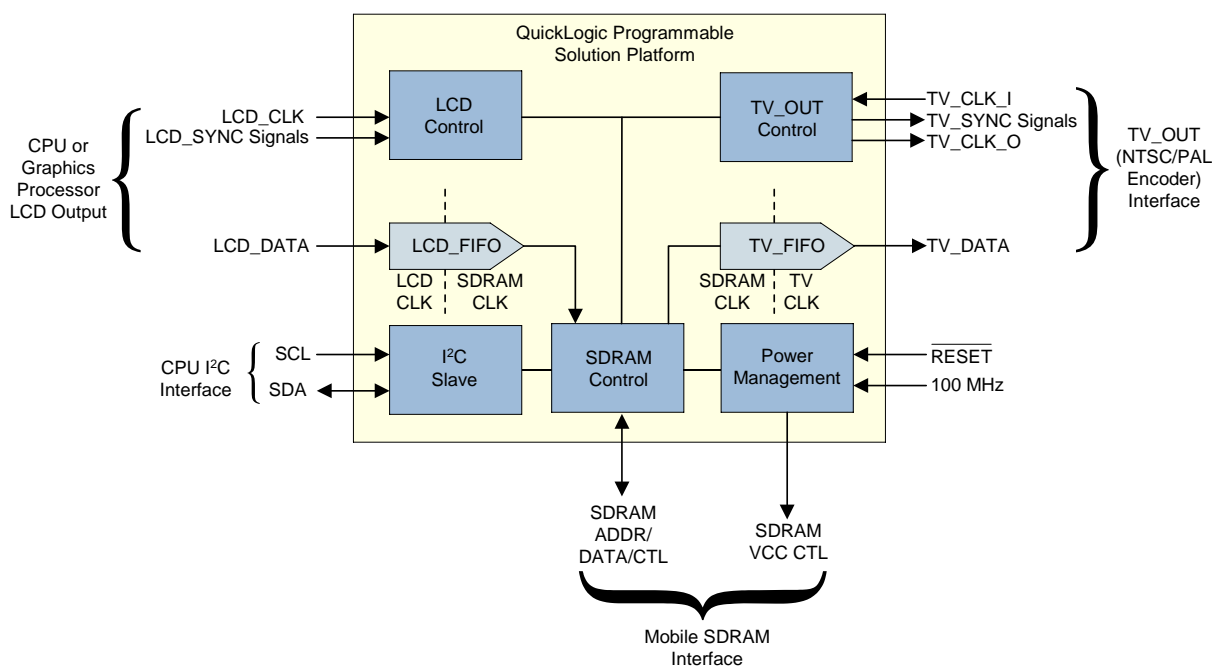
Differing frame rates for the native display and the external display means that the X/Y swap image buffer must also handle a different write versus read rate, and thus must be able to accommodate different pixel clock rates as well as incorporate the ability to manage (dynamically drop or re-use) multiple temporal frame buffers.

The X/Y swap and frame rate conversion operations must occur in real time, consume as little power as possible and require as few components and the least amount of printed circuit board (PCB) area as possible. All these technical requirements must be met while keeping bill of materials (BOM) cost to a minimum.

Handheld Device Example: QuickLogic Solution Platform

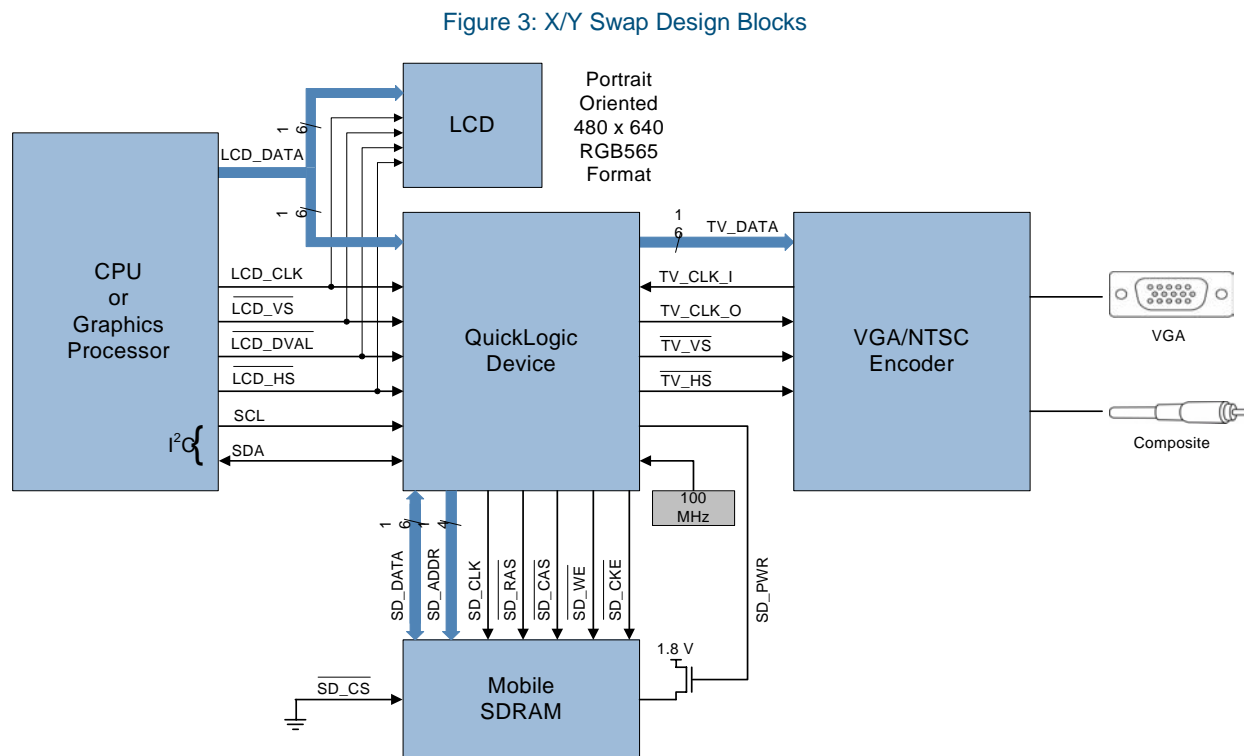
While the previous problem description presents a significant digital design challenge, it is perfect for a QuickLogic low power solution platform containing embedded FIFOs and that is capable of interfacing to multiple external high-speed components at varying I/O voltages. **Figure 2** shows a system diagram of the X/Y swap solution.

Figure 2: X/Y Swap Display Subsystem Solution



For this solution a QuickLogic PolarPro™ programmable solution platform has been chosen in an 8 mm x 8 mm 132-ball BGA package. The frame buffer is implemented using a single x16 mobile (1.8 V) SDRAM device. The video encoder function is implemented using a Chrontel VGA/NTSC/PAL encoder device. This entire video subsystem is driven by a graphics processor, which drives the QuickLogic device and the internal portrait LCD display simultaneously with the same data and timing (480x640 resolution, 60 Hz frame rate, progressive scanned, RGB565 (16-bit) format).

Figure 3 shows the internal blocks of the QuickLogic X/Y swap design.



The QuickLogic PolarPro device is responsible for the following system functions:

- X/Y Swap Operation:** This function is implemented simply in how the external SDRAM memory is written to and read from with regards to the implemented addressing scheme. Incoming video is written to the PolarPro device's input FIFO which decouples the LCD pixel clock frequency from the SDRAM clock frequency. The SDRAM clock frequency is fixed at a rate derived from the incoming 100 MHz master clock. Data is read from the input FIFO and written to the SDRAM memory on a line-by-line per single column basis with respect to the output image orientation. Data is then read from the SDRAM memory in a column-by-column per single line format with respect to the output image orientation. This data is moved through the output FIFO which decouples the SDRAM clock from the TV-output clock. The output FIFO directly drives the VGA/NTSC/PAL encoder device. All SDRAM accesses are performed as burst operations to maximize bus efficiency.
- Frame Rate Conversion:** This function manages the multiple frame buffers in SDRAM to allow a 60 Hz input frame rate with an output frame rate of 60 Hz for VGA, 59.94 Hz for NTSC or 50 Hz for PAL. While the VGA/NTSC/PAL encoder chip can provide an appropriate pixel clock frequency for these three output modes, it expects the 640x480 progressive scanned landscape data and vertical and horizontal synchronization timing presented to it to be compliant with the chosen output standard. Thus, the PolarPro device is responsible for generating the output VSYNC and HSYNC timing based upon the chosen mode, given the output pixel clock as a reference. Multiple frame buffers are stored and managed in SDRAM to properly construct an output image of a differing frame rate from the incoming image. Dropping or re-use of frames stored in SDRAM is automatically employed by the PolarPro device based upon the timing differences between the incoming and outgoing frame rates. Furthermore, frame rate conversion is achieved with standard SDRAM devices and a single 16-bit bi-directional data bus. No dual-port, dual-bus or "ping-pong" device approach is used to manage the SDRAM frame buffer.

- **Power Management:** The design within the PolarPro device includes the ability to selectively stop all display subsystem clocks and shut down the attached SDRAM device to conserve battery capacity in the system. The PolarPro device also natively includes a mode entitled Very Low Power (VLP) in which the device can be commanded to enter a low power quiescent state, drawing as low as 2.2 μA at 1.8 V. In VLP mode, all internal register and FIFO bits are retained, and the device can be “woken up” at the command of the system CPU within 250 μs . In operational mode, the PolarPro device draws less than 30 mA at 1.8 V while actively performing all dynamic operations.
- **Configuration:** The host CPU in the system communicates with the PolarPro device by means of the Inter-Integrated Circuit (I²C) bus. Using this interface, the CPU is able to configure the design with the proper output timing and format, and configure the power management features.
- **Voltage Level Translation:** The PolarPro device provides up to four I/O voltage domains. The incoming LCD interface, the SDRAM interface and the outgoing TV-out interface can all operate at differing I/O voltage levels. This is of particular importance when reducing power is a key system goal – mobile (1.8 V) SDRAM can be used simultaneously in the system while the Graphics Processor and LCD Encoder devices can also operate at their higher (>1.8 V) required I/O voltages.

It is important to note that while the design discussed previously solves the X/Y swap challenge with this specific particular design implementation, the PolarPro platform is inherently programmable. Thus, it is a simple task to modify the design to support additional power management features, decrease or increase the supported display resolution or increase the color depth supported in the design.

Conclusion

For a handheld device with TV-out functionality, if the internal, native portrait display is to be simul-scanned with the externally attached display device, a video subsystem design comprising of a device capable of X/Y Swap operation and frame rate conversion must be employed. As discussed previously, to properly solve this problem, the chosen device must consume very little static and dynamic power, contain embedded FIFOs for clock domain crossing, and have the flexibility to interface to external devices with various I/O voltages.

QuickLogic has solved this system problem using the PolarPro programmable solution platform, which consumes minimal system power, minimizes BOM cost, and conserves PCB area. Furthermore, this design is available today and has been proven in actual hardware. In the fast moving world of handheld consumer electronics design, time-to-market is absolutely critical. QuickLogic’s programmable solution for simultaneous display X/Y Swap as well as its line of programmable CPU companion devices for connectivity solutions gets designers and system integrators to market faster with the low power characteristics of an ASIC.

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A	July 2007	Judd Heape and Kathleen Murchek
B	November 2008	Kathleen Murchek

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