



DESIGN CHALLENGES OF HUMAN MACHINE INTERFACES

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Lattice Semiconductor
5555 Northeast Moore Ct.
Hillsboro, Oregon 97124 USA
Telephone: (503) 268-8000
www.latticesemi.com

Introduction

Human productivity is increasingly dependent on interaction between persons and equipment. Human Machine Interfaces (HMI) enable workers to work with automation equipment via an interface rather than switches and levers. HMI is the convergence of visual computing and automation control systems.

HMI Applications

- Industrial automation HMI systems consist of console-mounted LCD panels with touch-screen capability.
- Building Automation HMI comprises touch-screen operator panels for HVAC control, lighting and temperature control and elevator monitoring and safety.
- New generations of innovative, free-standing automated vending machines now incorporate colorful displays, with on-screen text, touch-screen “buttons” for product selection and overlaid video advertising.
- Automotive and Marine reconfigurable instrument clusters – essentially, dynamically changing instrument panels, highlighting particular instruments based on the driver’s immediate need – are becoming baseline requirements.
- Building Automation and Automotive/Marine HMI applications also need to display overlaid video from external sources, such as images of the road ahead, often from low-light video cameras at night, to alert motorists of obstacles, or radar navigation images and video overlays from integrated marine camera equipment.
- Household appliances like washers now sport color touch-screen graphic LCD displays, which, besides assuming the functions of electro-mechanical pushbuttons, also instruct consumers visually in methods of loading and wash program selection for different fabrics and garments. Refrigerators have begun to appear with large graphic LCD screens offering features once considered esoteric, such as entertainment (TV, DVD), home control integration, videophone integration, digital picture frame applications and even web browsing.

HMI Needs and Challenges

- Manufacturers of Industrial and Building Automation HMI systems face the challenges of creating scalable HMI product families with varying performance levels: scaled, for example, from 200MHz up to 1GHz processors. Manufacturers also need scalable graphic resolution from QVGA (320x240) up to UXGA (1600x1200) with integrated touch-screen controllers and the ability to provide support for Real-Time Industrial Ethernet, Serial and CAN bus communication ports.
- Automotive and Marine HMI manufacturers -- in addition to many of the requirements common to Industrial and Building Automation -- require video overlay capability, often from more than one video source.
- Vending Machine and White Goods manufacturers can have product lines that range from very low cost machines with character-based or “text” LCD displays, to ultra high-end machines with large TFT LCD screens. The machines typically are based on microcontrollers for simple I/O. A major design goal is to keep the same controller for all display types. One requirement that typically conflicts with the very low cost points of vending machines is that they also must permit video advertising.

All HMI applications require standard graphic functions such as lines, rectangles and polygon fills. All can benefit from a layered video architecture and advanced graphic functions such as alpha blending and PIP (Picture-in-Picture) support and graphics acceleration functions. Video input and layering capability are important to a significant portion of the marketplace.

While it is obvious that most of the requirements listed above can be met by relatively low-cost PC graphics cards, it is not so obvious that low cost PC graphics cards are designed neither to support a wide range of display resolutions and types nor to work with embedded 8051 class, or even lower, processors. They are also not designed, except in more expensive tablet PCs, to work with a touch-screen and cannot provide functionality like overlaid video, multiple video streams, multi-depth blending, etc., without the luxury of being serviced by an underlying operating system and driver

software. Operating systems also impose restrictions of cost, complexity and low reliability not tolerated by HMI. PC graphics cards also offer no way to integrate support for communications protocols like Industrial Ethernet.

Other methods of addressing HMI display control needs, such as using custom ASICs, are expensive and rarely justified unless deployment volumes are extremely large. ASSPs, while inexpensive and often quite powerful, are usually designed for the mobile marketplace, can interface to only a very small number of display types, often lack the system peripherals needed by HMI manufacturers and, due to rapid product obsolescence, present challenges for Industrial and Building Automation manufacturers with 10-year product life cycles. Table 1 lists the features most frequently requested by designers of LCD touch-screen-based HMI systems, and why those features are needed.

Summary of Features requested			Why these features are needed
Graphics Primitives (Lines, rectangles, Solid Fill, Pattern Fill)			Draw lines, buttons, icons
Flexible Video controller able to drive different TFT sizes from 5.7 inch to 19 inch TFT (1280x1024)			Support many different LCD Panels
Scalable graphic resolution from QVGA(320x240) up to UXGA (1600x1200)			Support many different Panel Resolutions
Integrated Touch Screen Controller for analog resistive touch screens			Implement Touch-Screen functionality
Video Input capability			Overlay video from camera or other source
Ability to accept different Video Input sources type: Camera, DVI from Radar and Navigation System, in a single video input module			Display multiple types of video simultaneously
Ability to drive external Monitor connected with DVI port			View panel data also on a other monitors
Video Layers architecture, Advanced Graphics Support	PIP	Overlay independent picture sources.	E.g. To show navigation data over video. Text over video. Menu over image etc
	Smooth Scrolling	Allows a “window” to be quickly and smoothly moved over a larger image in the memory.	Allows for scrolling backgrounds, tickers or maps
	Chroma keying	Also called color-keyed transparency. Enables replacing image backgrounds with other images	Typically used to insert a computer-generated image behind a camera image of a person in TV productions. Useful in graphics and ad creations for vending machines/kiosks

	Alpha Blending	Widely applied graphics technique allowing multiple degrees of transparency by combining each pixel with its underlying pixel	Enables translucency effects in image overlaying, smooth bitmaps transitions and antialiasing of image objects
	Multi-depth Blending	Overlays of different color depths can be combined in the resulting image	Enables a low-cost, low performance microcontroller or CPU to render a simple image combined with a high-depth image.
	Alpha Masking	Attaching transparency information to objects which are not transparent themselves, such as video frames from a camera. E.g. parts of a image can be 'alpha-masked' before overlay. Unmasked portions are treated as transparent.	Only information relevant to the user can be taken from a image or video frame and then displayed as overlaid on another image
BITBLT acceleration functions			Graphics Accelerate all the above functions
Initial Splash Image rendition			Hold a start screen image without compute
OSD (On Screen Display) overlay controlled by external microcontroller			Graphics accelerate in LCD-Pro but let control info come from another embedded application
Multilanguage			Self-explanatory
Simulated Video via animated image rendering			Render very low-cost video without video hardware
Ability to display all information on the same LCD			Integrate multiple layers of graphics and video information
Embedded I/F scalable from low-cost 200MHz up to 1Ghz processor			Support connection to different classes of processors depending on performance requirements of the embedded application.
Support for Real-Time Industrial Ethernet, Serial and CAN bus communication ports			Support connection to real-world via application domain specific interfaces.

Table 1

FPGA-based LCD Controller Platforms for HMI

FPGAs are the ideal vehicles for implementing cost-effective HMI platforms. FPGAs offer the benefits of flexibility and scalability to meet the cost needs of various applications. By being programmable they offer the ability to keep up with changing needs in the marketplace. FPGAS meet manufacturers' needs for field upgradability to

keep installed equipment current, and typically do not suffer from product obsolescence and end-of-life issues.

The primary difference among the different FPGA-based solutions available for HMI is the quality of available Intellectual Property (IP) for HMI applications.

The Lattice LCD-Pro Advanced Touch-Screen Video Graphics Controller

The Lattice LCD-Pro Advanced Touch-Screen Video Graphics Controller provides HMI manufacturers with ready to use, out-of-the-box, state-of-the-art display driving capability in a fully configurable FPGA video system based on the LatticeECP2 FPGA family. The LCD-Pro implements a powerful, fully configurable 16bpp LCD video controller with display support ranging from 2 inches, 4:3 aspect ratio to 23 inches with resolutions from QVGA (320x240) to high resolution 1366x768 16:9 widescreen TFT displays.

LCD-Pro implements state-of-the-art display control functions such as multiple video layers, layer overlay, picture-in-picture, smooth scrolling color-keyed transparency, alpha blending and alpha masking. It supports scaling, cropping and positioning of real-time video, supporting both video in and video out.

The video controller is supported by a powerful graphics accelerator that performs BITBLT and ROP operations such as solid fill, bitmap copying, raster operations to support advanced alpha blending supporting Porter-Duff alpha blending rules, generic bitmap copying and others. It supports variable memory organization for efficient memory use. LCD-Pro also features a powerful, field-proven memory controller with several commercially available memories.

Touch-screen and Backlight Control interfaces

Lattice LCD-Pro features an integrated touch controller that provides additional control signals that are ready to connect to external analog resistive touch-screens. The A/D-D/A controller is fully programmable, offering 12 bit A/D and D/A conversion at 4 KSPS.

The D/A channels can be used to support backlight and contrast control of TFT screens, while A/D channels can be used to read output of ambient light sensors, allowing for adaptation of backlight.

Field Proven IP with Versatile AMBA Interconnect

Lattice LCD-Pro provides users with a powerful library of field-proven IP for rapid time-to-market. The FPGA implementation employs a core-interconnect scheme based on the industry standard ARM AMBA AHB/APB. This totally eliminates problematic and time-consuming interconnect debug that can slow the delivery of high-speed system solutions. The IP can also connect easily to any external CPU or embedded processor such as the LatticeMico32 via an AMBA bus wrapper. A multilayer architecture is optionally available for multiprocessor systems.

A SPI master is included, supporting interfaces to external SPI devices such as Flash memory, and is useful for storing FPGA configuration, display settings and splash image data. Also included is a SPI slave, allowing access from an external microcontroller for control of LCD-Pro via an inexpensive serial bus.

The Lattice LCD-Pro IP is fully parameterized and configurable to enable customizable, economical core footprints for optimized resource usage for different applications.

Lattice LCD-Pro Evaluation Platform

The Lattice LCD-Pro Evaluation Platform is designed to provide HMI manufacturers the dual benefits of rapid prototyping and accelerated product development. All the required hardware, intellectual property and software are available in a self contained, easy to use kit. The Lattice LCD-Pro Evaluation Platform ships complete with the Lattice LCD-Pro Advanced Touch-Screen Video Graphics Controller system, 7" WVGA 840x480 color touch-screen display, color video camera, power supply, and cables and a demo for a complete out-of-the box experience. Lattice LCD-Pro Configurator software is included, and, in addition to running LCD-Pro plug-ins, enables transparent access to all FPGA resources. Figure 1 shows the block diagram of the LCD-Pro Evaluation Platform.

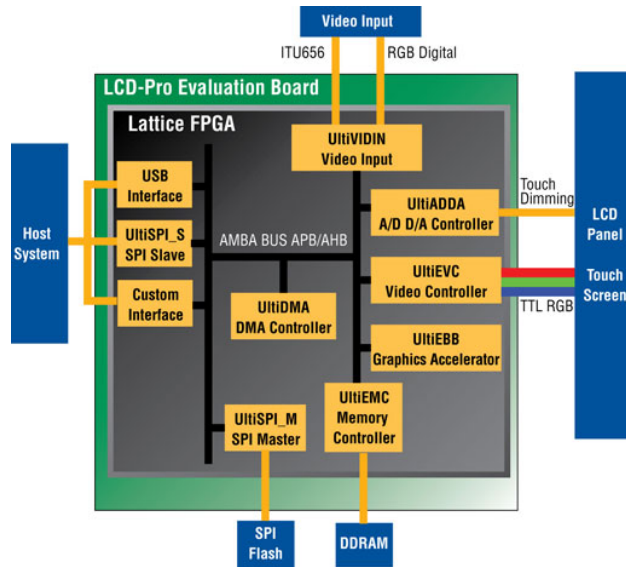


Figure 1

Table 2 shows the resource utilization within Lattice FPGAs for LCD-Pro IP.

LCD-Pro IP Bundle	Device	Slices	LUT-4s	Registers	EBRs	PLLs/ DLLs	External Pins	DSP Sites	Multipliers
Base: Enhanced Video Controller module	ECP2-20-5	8358	13288	9326	4	1/1	118	4	4
Base plus 2D Graphics Accelerator module	ECP2-35-5	13553	21370	14994	7	1/1	118	34	25
Base plus 2D Graphics Accelerator plus Video Input module	ECP2-50-5	16334	25057	18156	12	1/1	146	72	49

Table 2

The above resource-usage is for a 4-layer -- all layers are 24-bit -- video controller. Implementations with less resource-usage are possible by using a smaller number of layers and/or fewer IP features.

Lattice LCD-Pro Advantages

The Lattice LCD-Pro provides several advantages.

- *Comprehensive Advanced Graphics IP Library:* LCD-Pro provides a complete state of the art library of IP for advanced LCD display control, graphics and video, supporting touch-screen functionality. The IP is field proven, and employs the industry standard AMBA AHB/APB scheme for IP interconnect and connection to external processors, either natively or via wrappers.
- *Multiple Display Support:* State of the art LCD controller IP allows advanced graphics functions to be implemented entirely within the FPGA. Built-in support for over 30 commercially available displays, with touch-screen support, enables interfacing to a wide range of displays with no additional effort.
- *Field-proven, configurable IP:* Field-proven IP with a common AMBA interconnect framework significantly speeds time-to-market and virtually eliminates interconnect debug. Configurable IP cores offer optimization of internal pipelines to scale IP core footprints according to application needs to fit the optimum device for the application.
- *External IP Integration:* Industry standard AMBA architecture takes the guesswork out of integrating the customers' own or third party IP cores into the system.
- *Multiprocessor support:* An optional multilayer architecture is available for multi-processor system support.
- *System Expansion:* A high-performance 32-bit bus architecture is available to further extend system communication, peripherals and I/O. The system is expandable using static and Flash memory, uses an I2C system bus for plug and play detection of software drivers and graphic page creator software.

System-on-Module for Platform to Product

A unique and very important advantage offered by the Lattice LCD-Pro Evaluation Platform is the ability to go straight from platform to product. One can potentially use the Evaluation Platform's single-power-supply, 3.3V FPGA Module to develop the HMI application and then simply unplug it and plug it in as a System-on-Module HMI engine into the end product. Figure 2 shows how the FPGA module from the Lattice LCD-Pro Evaluation Platform can be directly used inside the customer's product.

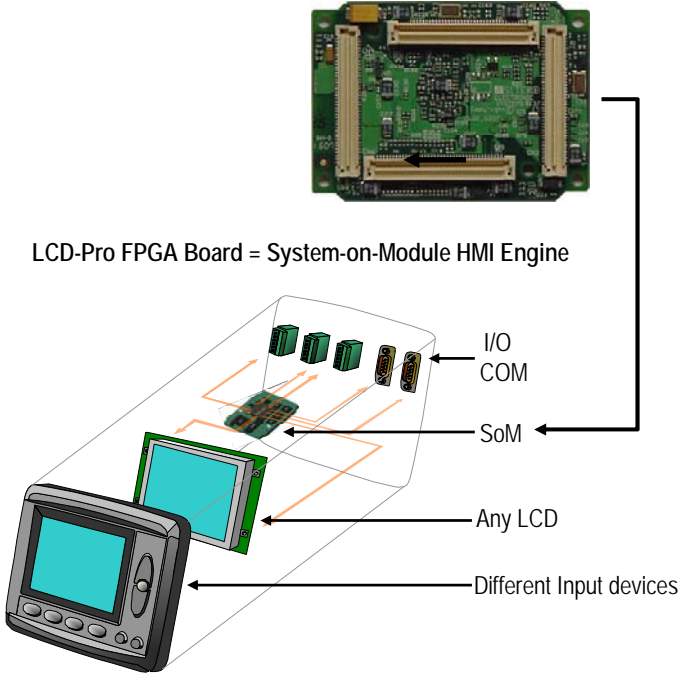


Figure 2

Using the System-on-Module approach, product development can proceed while the HMI is being developed, and the HMI engine simply plugged in to complete the product. For leapfrogging time-to-market obstacles, it does not get any better than the LCD-Pro Evaluation Platform.

Summary

Designing Human Machine Interfaces (HMI) with touch-screen LCD displays requires manufacturers to support a wide range of TFT displays. Graphics requirements like multiple layers, layer overlay, picture-in-picture, smooth scrolling color-keyed transparency, alpha blending, alpha masking, real-time video overlay, etc. add to the complexity of IP that needs to be developed for truly differentiated applications.

The Lattice LCD-Pro Evaluation Platform is a configurable advanced touch-screen video graphics controller for HMI manufacturers in Industrial, Building Automation, Vending Machines, Household Appliances, Automotive and Marine Control Panels, Medical Devices and Gaming. Lattice LCD-Pro comes pre-configured with FPGA IP that enables HMI manufacturers to meet increasingly sophisticated graphics demands in their markets, with the dual benefits of rapid prototyping and accelerated product development.

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