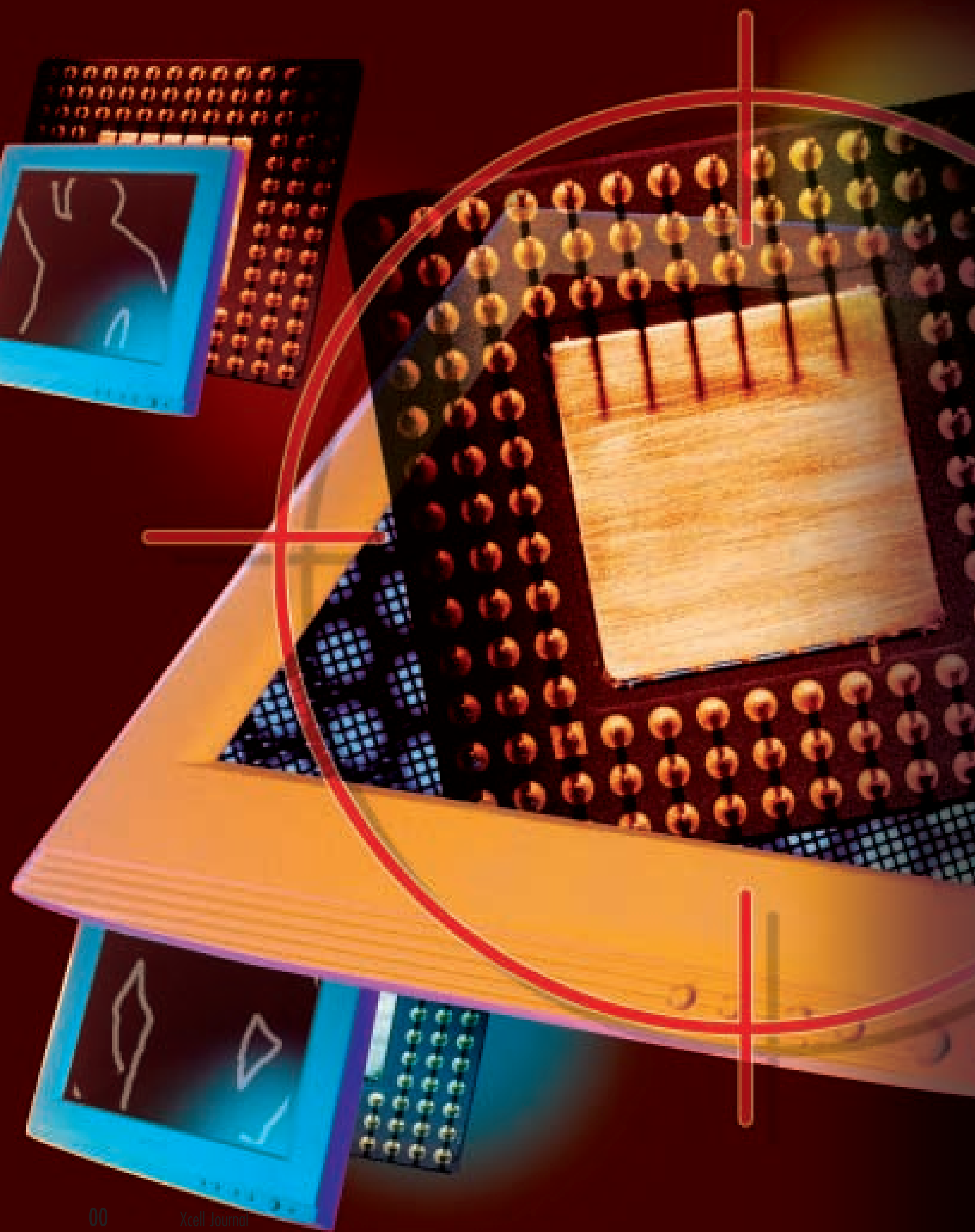
# Programmable Logic Enables Digital Displays

An overview of an important emerging market.



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DisplaySearch Inc. forecasts that by 2005, digital displays will eclipse conventional display technologies in market revenue. Digital liquid crystal displays (LCDs), digital plasma display panels (PDPs), digital light processors (DLPs), and many others are fast becoming the display technologies of choice.

This article will explain why this is happening and document the universe of complexity that has been spawned in the process. Next we will examine some of the unique challenges that digital display systems pose for you. Finally, we will review a representative case study to illustrate how programmable logic can be used to your advantage in developing digital display products.

## The Digitization of Display Technologies

What's driving the digital display transition? There are three basic answers to this question:

- Content has become digital
- Digital displays achieve superior quality
- Digital display technologies have enabled new and desirable form factors.

Content is king. Analog television became inexpensive because it served a huge content market: broadcast television. But things have changed. The emergence of commodity PCs, the Internet, digital cable and satellite TV, and consumer DVD have combined to establish a huge new universe of digital content. And, as the transition to digital broadcast television unfolds (SDTV and HDTV), virtually the entire display universe will have become natively digital.

With regard to quality, digital content has several advantages.

- Digital content can more effectively filter noise as illustrated by the lack of background hiss on an audio CD as compared to an analog cassette.
- Digital content enables digital manipulation of the content which means that you can effect highly specific enhancements. For example: shadow enhancement, sharpness control, and color manipulations commonly used in medical imaging.
- Digital content can be quickly and repeatedly replicated with precision and widely distributed much more efficiently than analog formats.

And then there is form factor. Without digital displays, products such as today's laptop computer would simply not be possible (remember the first Compaq CRT based portable PCs?). The same applies to wall mounted televisions, PDAs, seat back displays on airplanes, and the mini-displays on the back of digital cameras. The inherent flat panel nature of most digital display technologies is thus a key factor in their increasing success. These applications could not be fulfilled without them.

### The Opening of Pandora's Box

While the emergence of digital display technologies has been a good thing, the developments behind them have been the equivalent of opening Pandora's Box. In the frantic rush to digitization, technologies have been invented and re-invented on a multi-dimensional scale across diverse geographies, industries, and suppliers. The result is a multitude of standards, formats, regulations, specifications, and derivatives, all of which makes your job ever more challenging.

To illustrate the complexity that we have wrought, I have compiled a representative list of technologies, formats, and standards introduced as part of the mass digital emergence, in Table 1.

### Difficult Questions

While by no means complete, Table 1 nevertheless illustrates a foremost challenge facing you today: risk and complexity. Which are the correct features to support? How do they vary by market segment? How do they vary by geography? How are they evolving? How do you implement the mix of features you need quickly and efficiently? Can you effectively support a family of configurations to service multiple market segments? How do you get to market fast enough to gain market share?

Digital convergence is driving these technologies together, in new ways and in new products – and making that happen is your responsibility.

### Unique Challenges of Digital Display Design

Beyond the complexity of their world, environment digital displays also present some unique challenges to you. These include achieving the performance required for the target application, correcting for technology-specific display characteristics, and generating the drive signals for the target display.

Performance is particularly challenging in digital video display applications due to the tremendous computational loads involved.

- You require a high-bandwidth connection from the source.
- You need to perform a complex string of operations on the data. These can include decryption from a secure transmission format, decoding into pixel maps, and optimization of these pixel maps for display.
- You must use the resulting data to generate the driver signals for the display.
- Finally the display driver generates a family of signals that will be distributed to drive each individual pixel. The format of these signals varies with each technology, they have exacting timing requirements, and their specifications are often unique to each and every model.

To make things worse this must all be achieved in real time, and while transiting this pipeline the dataflow will expand from about 25 Mbps (streaming HDTV) to 1.5 Gbps (raw uncompressed 1080i HDTV display data).

The optimization stage of the pipeline is a challenge in and of itself. Here the digital

| Wired Connection Technologies | Broadband Access Technologies | Chip to Chip Technologies | LVDS Interconnect Technologies | Television Standards | Streaming Media Formats |
|---|---|---|---|---|---|
| | | LVTTL | LVDS | NTSC | MPEG-1 |
| IEEE 1394 | ISDN | LVCMOS | LVPECL | PAL | MPEG-2 |
| USB 2.0 | DSL | **Chip to Memory Technologies** | BLVDS | SECAM | MPEG-4 |
| Ethernet | Cable | | **PC Display Formats** | SDTV 480i | MJPEG |
| HomePNA | WCDMA | HSTL-I | | SDTV 480p | Real Networks |
| HomePlug | Chip to | HSTL-III | EGA | HDTV 720p | QuickTime |
| **Wireless Connection Technologies** | **Backplane Technologies** | HSTL-IV | VGA | HDTV 1080i | MS Media Player |
| | | SSTL-I | SVGA | **Digital Imaging File Formats** | **Encryption Standards** |
| | 5V PCI | SSTL-II | XGA | | |
| 802.11b | 3.3V PCI | SSTL2-I | SXGA | TIFF | DES |
| 802.11a | 3.3V PCI-X | SSTL2-II | UXGA | JPEG | 3DES |
| HiperLAN2 | GTL | SSTL3-I | WXGA | Scitex | AES |
| Bluetooth | GTL+ | SSTL3-II | | Targa | PKI |
| HomeRF | AGP | CTT | | GIF | |

*Table 1 - Standards and technologies spawned in the mass digital emergence*

image data must be adapted to the specific characteristics of the target display technology. This is necessary because while all displays operate on similar principles of color science, each has its own specific (and non-linear) behavioral characteristics. Thus, RGB data (which is most typically targeted for a CRT display) must be processed to display with acceptable results on an LCD, PDP, or other display technology. This processing can be as simple as color correction, or much more involved with algorithms applied for scaling, contrast, brightness, gradation smoothing, edge sharpness, shadow enhancement, and so on. Almost anything is possible, it simply takes adequate processing power.

### A Case Study

To illustrate the challenges of digital display design let's analyze a case study example for a digital projector. In the generic case such products traditionally accept analog RGB video input, perform some moderate processing on the data, and then drive the projection display. This is typically effected through a variety of analog (blue), digital (black), and control (green) components as illustrated in Figure 1.

With the advent of digital convergence, the next iteration of such a product may well be required to support some form, or forms, of direct digital input and include the ability to accept and display encoded file formats. In such a case, you face the dilemmas regarding which inputs and formats to support, and then you must select and integrate appropriate components to realize them in a design that meets performance requirements.

Figure 2 illustrates an example for such a design that would support a fast serial USB 2.0 connection as well as an 802.11 wireless LAN connection.

The simplicity of these illustrations belies the complexity of the task. How do you implement the new logic in the system controller to manage the new data flows? What interfaces and signaling standards are required in order to integrate the new components? What extensions to your user interface and control software need to be developed? And, if it is determined that you need to implement and support a variety of these technologies and options, your task becomes much more complex.

### The Value of Programmable Logic

Programmable logic is an ideal solution for addressing these challenges. By their nature these devices are flexible – the premium requirement for success in this

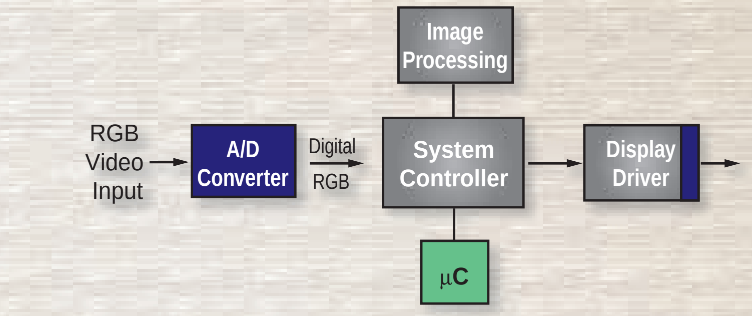



*Figure 1 - Generic projection display system design*

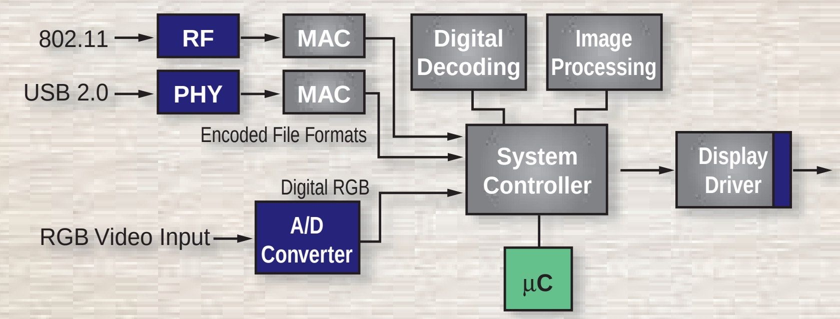



*Figure 2 - Digital convergence projection display system design*

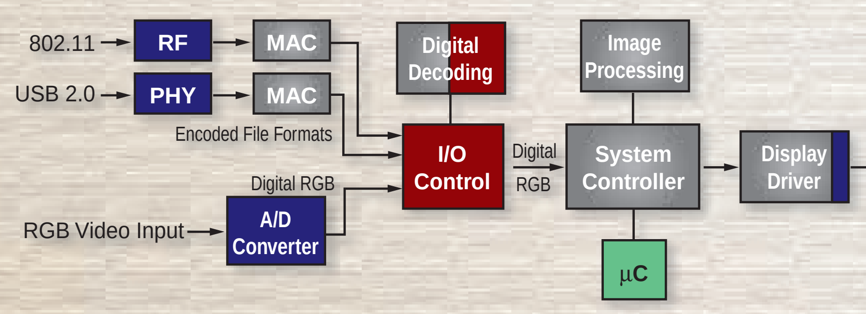
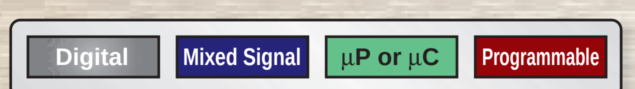



*Figure 3 - Programmable logic-based digital convergence*



endeavor. In addition FPGAs are fast and efficient development platforms, enabling rapid development cycles. Finally, modern FPGAs are extremely cost effective, and therefore viable production solutions for almost any application.

Figure 3 illustrates how an FPGA-based solution could be used to affect our digital convergence projector. As you can see this design inserts an FPGA (illustrated in red) and associated logic between the A/D converter and existing system controller. In this design the FPGA serves as the I/O arbiter, accepting input from all three sources.

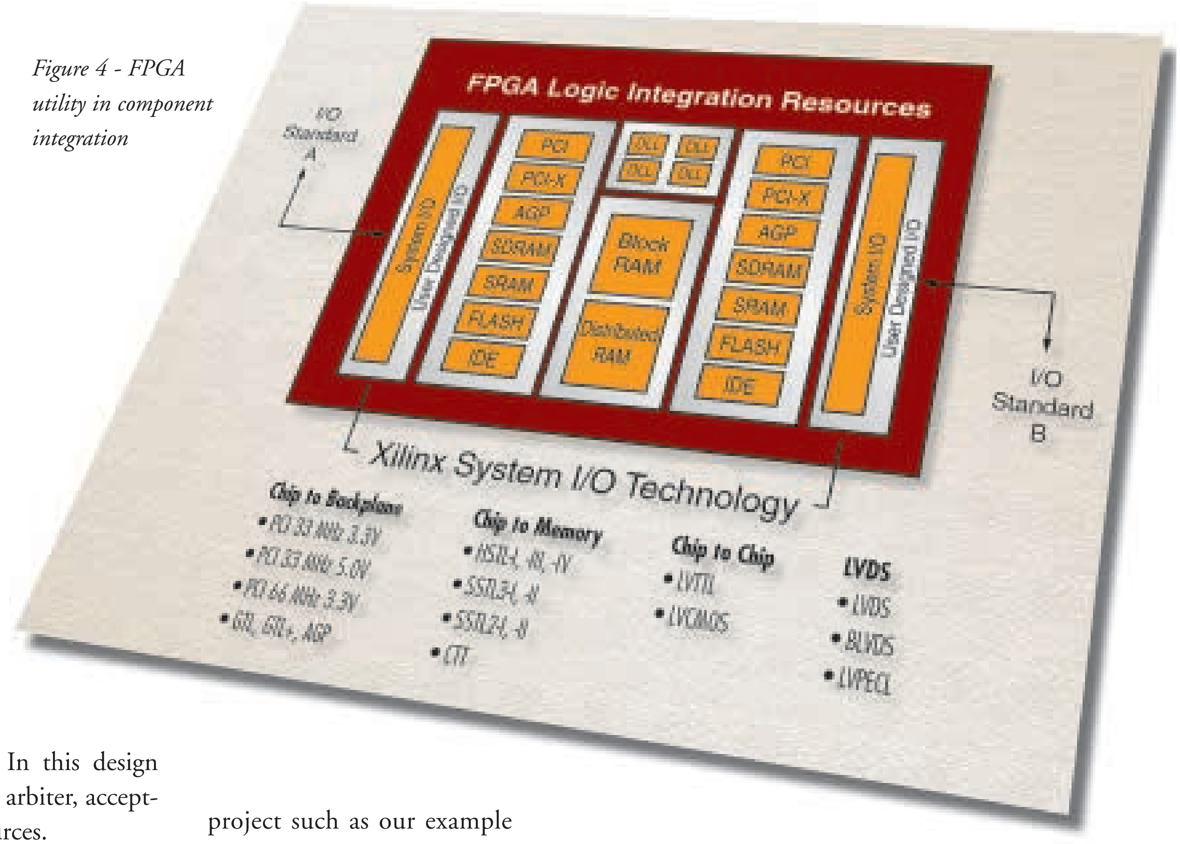
In operation the legacy digital RGB signal is simply passed through when this connection is active. In the case of USB 2.0 and 802.11 however, the FPGA serves to manage these new interfaces completely, as well as decode the incoming data stream into the legacy digital RGB format. Decoding can be accomplished entirely in the FPGA or with the assistance of an ASIC or ASSP as appropriate (illustrated by the combined black/red block).

This approach has several important advantages.

- It retains the existing backend of the legacy design essentially unchanged. This bounds development complexity and reduces risk.
- The programmable bridge imposes no schedule penalties for numerous iterations. This can be a significant advantage when you are tasked with integrating new and unfamiliar technologies.
- Upon completion the design can be released and in production very quickly.

How is all this possible? Figure 4 illustrates some of the standard features and IP available in Xilinx FPGAs that make a project such as our example relatively straightforward.

*Figure 4 - FPGA utility in component integration*




On the perimeter of Figure 4 is System I/O, which allows each and every I/O pin to be programmed to support any of 17 different signaling standards. But System I/O doesn't stop there. In addition to the basic signaling parameters it supports programmable drive strength and multiple slew rates too. These features make it easy to deal with unanticipated PCB behaviors (in those not so rare cases where fabrication reality doesn't match design theory) as illustrated in Figure 5.

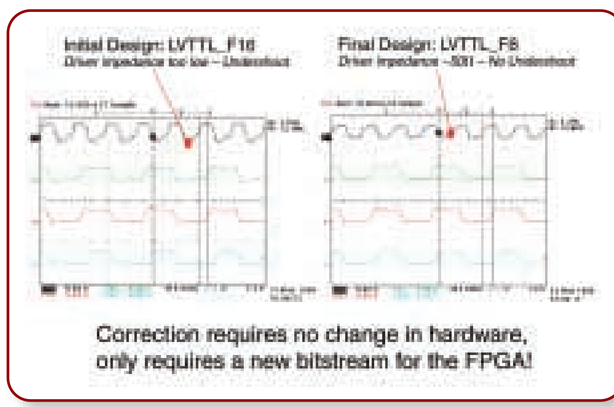



*Figure 5 - The benefit of programmable drive strength in System I/O*

Some FPGAs, such as the new Spartan™-IIE family from Xilinx, even go a step further including support for LVDS, BLVDS, and LVPECL differential signaling standards at up to 400 Mbps per pin pair. This enables very high-performance component interconnection without the need to resort to higher pin count and more expensive packaging. Further, it reduces system power, lowers EMI, and is much less sensitive to noise as illustrated in Figure 6.

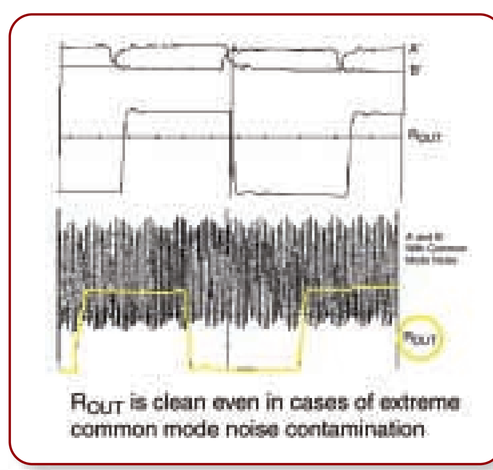



*Figure 6 - Noise immunity benefit of LVDS signaling*

Figure 4 also shows a representative sample of the standard controller IP modules available for FPGAs. These are commercial quality function blocks that are available to jump-start your design. Much can be accomplished with standard IP as solutions are available to address most of the topics listed in Table 1.

For buffers and FIFOs you have a variety of on-chip memory resources to choose from. These include 200 MHz flip-flops, true dual ported Block RAM, a Shift Register Mode (SRL16) capability in the FPGA's fabric Look-up Table (LUT) structures, and highly configurable Distributed RAM. These features provide high-performance and silicon-efficient solutions for almost any on-chip memory need.

For clock management Xilinx FPGAs feature four or more Delay-Locked Loops (DLL) per device. These provide the resources to synchronize and connect your system elements together and manage EMI. These DLLs exhibit superior noise immunity compared to PLLs, and they feature excellent jitter specifications, making your job easier. A few examples of their utility are illustrated in Figure 7.

Finally, an array of Configurable Logic Blocks (CLB) and internal interconnect resources tie everything together. These are illustrated in Figure 8 and are the underlying fabric that make an FPGA an FPGA.

### The FPGA Way

While the benefits of programmable logic are obvious as illustrated in our example, its value can be even greater when leveraged as a foundation element in your design. Figure 9 illustrates how our digital convergence projector might look if it were designed from scratch, only this time the FPGA way.

In this design the flexibility of FPGAs is being leveraged to maximum advantage. By designing the core logic of the system controller into an FPGA component you gain maximum flexibility in the selection of every other component you require – be they HSTL, SSTL, LVTTL, LVDS, or whatever, they can be quickly and efficiently integrated.

Another advantage in our example is the modular architecture for system input. In this design we could support a family of configurations to address a variety of geographic and application requirements. Further, there is no reason why these cannot be developed in a serial fashion, enabling the most important configurations to get to market first. And, all that would change from configuration to configuration in the core design is the bitstream program in the FPGA.

With programmable logic in the data path you have tremendous ability to tailor encoding/decoding, encryption/decryption, and image processing functionality to your precise needs. More importantly, you also have the flexibility to keep up with changes as these needs evolve over time. Take file decryption for streaming media as an example. Today there are no firmly established standards, and the standards that do exist vary widely by geography and content provider. And remember, Content is king, and that using a programmable device as the decryption engine could allow you to support whatever your customers require both today and tomorrow.

When used as the heart of the display driver circuit, programmable logic can give your design the ability to support two or more display options. This can be of tremendous value in managing the cost for this high dollar bill of materials component (more than paying for the FPGA in many cases) or to support a family of products based upon a common core design that increases your accessible market. In addition, you can use LVDS to route these signals around the board (which quite often involves traversing large tracts of real estate) and thus minimize system level EMI and the impact of noise on these critical signals.

FPGAs are also well suited for crafting a unique and attractive user interface for your design. They are the very definition of GPIO (General Purpose I/O) and can implement microcontrollers (or even a PowerPC microprocessor) for supervisory control. In today's competitive markets the user interface can be one of the most effective ways to differentiate your prod-

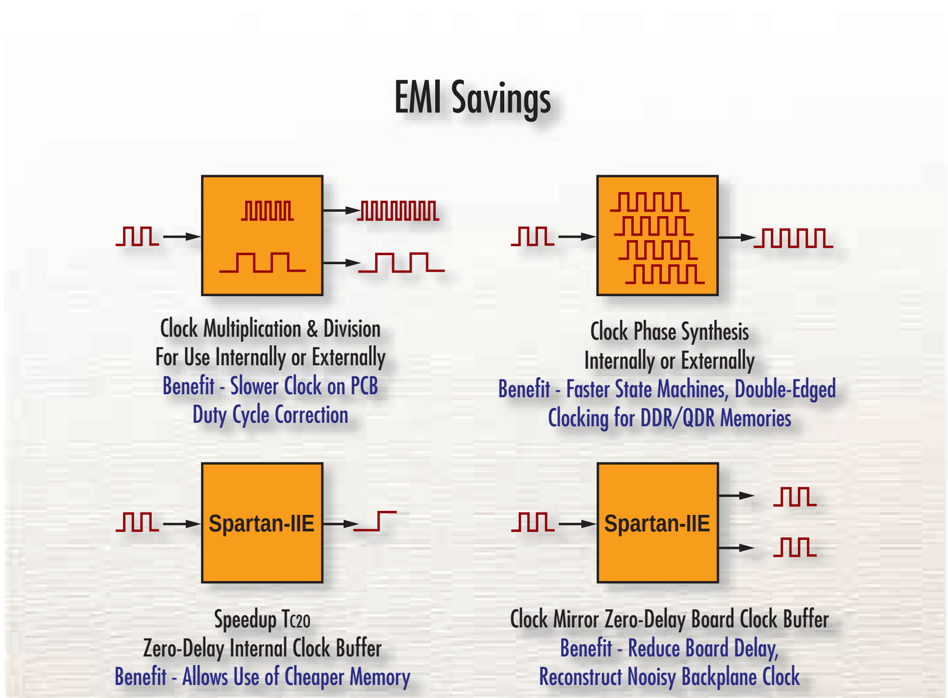



*Figure 7 - Some examples of DLL capabilities*

uct from that of your competition, and an FPGA gives you the maximum freedom to innovate.

Finally, your FPGA based solution is never frozen. If a customer comes to you requesting a new feature, a slightly different capability, or a new configuration, you have a platform to quickly and efficiently deliver it. When inevitable bugs and incompatibilities crop up you can not only fix them quickly, you can also update deployed systems in the field. This can greatly reduce support and service costs. And if you ever face a supply problem for a system component while in production, you have the flexibility to find and support an alternate solution to keep your factory running, your product shipping, and revenue coming in.

## Conclusion

The era of digital convergence is upon us. From pictures to e-mail, from music to news, the world has gone digital. And because of this digital explosion today's systems require ever more connectivity and intelligence. It is no longer good enough to have the best widget or display. Now you need a more digitally connected and data manipulating widget or display, one that supports the standards and formats in your

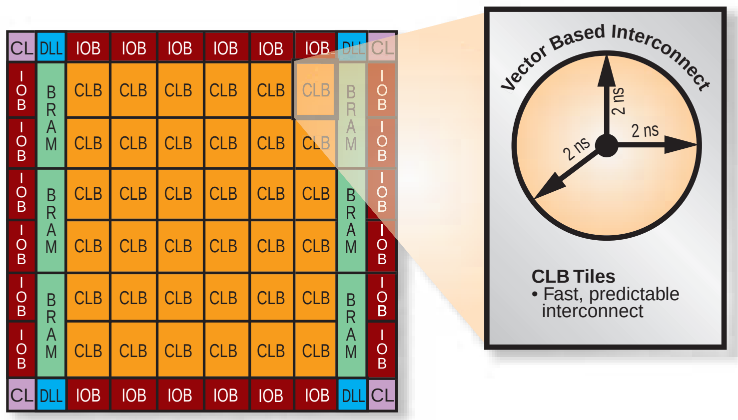



*Figure 8 - FPGA CLBs and interconnect resources*

target market and geography – and one that does it before your competition.

Programmable logic is an invaluable asset in confronting this challenge. Its inherent flexibility makes it an ideal mechanism for grafting new functionality into an existing design. Its rich features, efficient development flow, and extensive IP support will simplify your job and give you a chance to meet aggressive schedules. The newest generations of devices are cost efficient solutions for almost any design. And when made a fundamental part of your architecture from the beginning, this technology can be exploited to modularize your configurations, provide flexibility with critical and costly components, and tailor your product functionality to your exact needs.

To learn more about digital video and digital convergence technologies, and how FPGAs can help with them, visit the Emerging Standards and Protocols (eSP) Web portal at *www.xilinx.com/esp*. This website was developed by Xilinx as a resource for the digital system design community and is specifically targeted at dealing with these new and challenging technologies. To date, segments have been deployed for home networking, Bluetooth, and digital video technologies, and more are on the way.

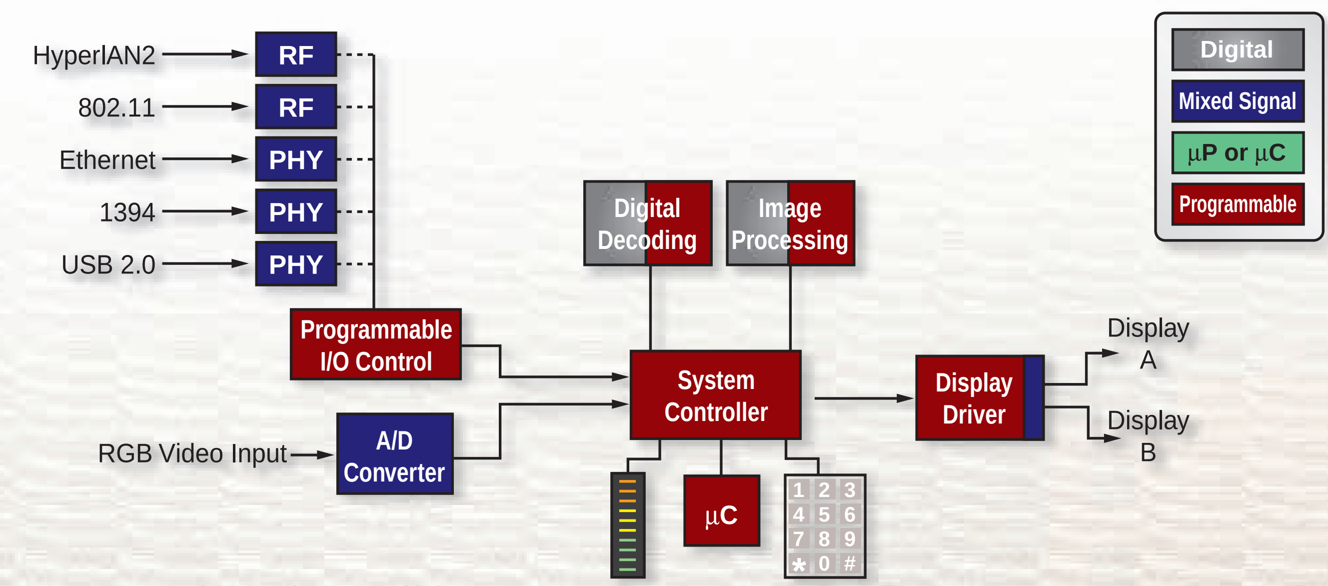



*Figure 9 - Maximizing the value of programmable logic*