Digital Consumer Convergence Demands Reprogrammability

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Seventeen years ago, Xilinx developed the industry's first Field Programmable Gate Array (FPGA). The concept was quite simple – using Static Random Access Memory (SRAM) as the basis of the logic fabric, you could instantly develop integrated logic circuits directly on your desktop. The benefits were far reaching, because this technology did away with the risk and delay typically associated with designing custom Application Specific Integrated Circuits (ASICs).

While the concept of "user programmable" logic was perhaps first pioneered by enterprising engineers who used Programmable Read Only Memories (PROMs) as a "programmable ASIC", this solution was able to achieve only small levels of integration. The cost efficiency and logic density achieved by using PROMs as custom logic was extremely poor compared to ASICs. Interestingly, however, the concept of using look-up tables to implement logic functions is actually a basic technology used in today's multi-million gate FPGAs.

> Not long ago, the idea of creating an ASIC on the desktop was considered a novel concept.

Today, FPGAs have evolved into a mainstream technology because their current densities and performance compete with custom ASICs. Additionally, designing for an FPGA is almost exactly the same as an ASIC – your circuit can be described either by schematic, or by a high-level hardware description language such as VHDL or Verilog. This description is then synthesized for the FPGA with the final result being a configuration bitstream that ultimately programs device look-up tables that are interconnected by programmable wires. Just like the look-up tables, the configuration bitstream also determines the connectivity for the programmable wires.

Because the programmability is based upon volatile, SRAM technology, there is a requirement to "re-write" the configuration bit stream every time power is removed and re-applied to the FPGA. This configuration bit stream is usually contained in an external, memory which is dedicated for configuration, or by reserving a portion of a main system memory with the FPGA configuration information.

When FPGAs were first introduced, the fact that they required programming from an external memory source, and that they lost their configuration once power was removed, was generally considered a liability. Fixed ASICs had none of these requirements or added complexities. And for the most part, ASICs were still significantly cheaper than FPGAs – at least on a unit cost basis.

However, for applications that shipped a relatively low number of units, it could be shown that the high non-recurring charges for the ASIC more than offset the higher unit costs of the FPGA. Because of these cost constraints, the use of FPGAs was historically relegated to the lower volume, less cost sensitive applications that had large-scale integration requirements.

Over time, the additional benefits of being first to market and the ability to fix bugs or accommodate late specification changes rose in importance, and the decision to select an FPGA over an ASIC became common. This proved to be true even in cases where it could be demonstrated that an ASIC solution provided a lower overall solution cost than the FPGA. However, there were practical limits to how great the unit volumes or disparity in price would become before a design would transition from FPGA to ASIC.

These fundamental benefits of being first to market and of risk aversion have proven to be especially important to the networking and communications industries – as demonstrated by the fact that currently 70% of the $5 billion market for programmable logic is consumed by networking and communications applications. FPGAs have been particularly important in these markets because they have been able to keep up with the pace and innovation in those markets and accommodate the wide range of new standards that continuously emerge.

Flexibility for the Masses

Moore's Law, which says that transistor density of an ASIC will double every 18 months due to advances in semiconductor technology, has played a key role in driving larger density FPGAs with greater features and performance. This has in turn continued to fuel the increased demand and consumption of FPGAs in networking and communications applications.

The advances in semiconductor technology have not only yielded larger and faster FPGAs, they have also yielded FPGAs that are 10,000% cheaper than they were five years ago! The result is that FPGAs, which were previously practical only for prototyping or low volume, high-end applications, are now appearing in some of the hottest, newest high-volume consumer electronics.

Four years ago, Xilinx developed the Spartan series family of FPGAs that were optimized for low-cost, high-volume applications. The results are impressive; from MP3 players, to DVD writers, digital cameras, digital modems, and a host of other consumer electronics – FPGAs have rapidly become a key driver behind the digital consumer revolution.

And reprogrammability, which used to be considered a liability, is now clearly seen as a key benefit in not only getting a product to market sooner, but keeping it longer in the market by providing the ability to upgrade it and add new features once it's in the field. But how and why programmable logic is being used is sometimes just as interesting as where it's being used.

ReplayTV – Personal Video Recorder

Personal video recorders (PVRs) are perhaps one of the most exciting consumer products to offer new features and capabilities made possible only by the combination of digital technologies and FPGAs. With a PVR, traditional analog video programming is converted to digital using MPEG 2 encoding and stored directly to a hard drive – enabling instant search access and high quality video imaging.

PVRs represent a quantum leap in capability and quality compared to traditional videocassette recorders (VCRs). For example, a PVR such as ReplayTV's can store as much as 60 hours of programming, allowing viewers to watch programming on their personal schedules instead of those set by broadcasters.

The ReplayTV also contains an integrated 56K-baud modem, which is used to download the equivalent of a TV guide that can be searched, sorted, and grouped like traditional database programs. This allows for easy recording setup and unique programming search capabilities. This modem connection also enables additional unique capabilities – such as reconfig-

uring the FPGA. The reprogrammable logic is updated simply by downloading a new bitstream. If the unit is already installed in a customer's home, the bitstream is downloaded from ReplayTV's Internet server. This allows bugs to be fixed even after the customer takes the unit home, and lets ReplayTV add new features as necessary. Obviously, this extends the life of the product too, because rather than having to replace it as market requirements change; the customer simply has the unit's logic reprogrammed via the modem.

ReplayTV reprogramming takes place in the background: each evening the PVR automatically downloads TV schedule information from the company server, along with any bug fixes, operating system updates, or program modifications. The customer's unit is improved as he sleeps without intervention on his part. End users are typically never made aware of changes or fixes to their systems unless the functionality of the PVR changes as new features are added.

In one case, ReplayTV found itself forced to deal with a condition that caused degraded video quality in a few systems already in homes – one of the chips in the system had an undocumented clock threshold switching problem that varied as a function of lot processing. Because the control signals for this device were generated in the FPGA, it was possible to eliminate the problem by changing the timing of the FPGA-generated signal.

The company responded with a software change that was uploaded to all ReplayTV systems in the field as soon as it was debugged and certified. Most customers never realized that the change had been made; though some may have noticed improved video quality. A revolutionary capability enabled by FPGA programmable technology!

KB Gear – JAMCAM 3.0 Digital Camera

Perhaps one of the least likely places one would expect to find an FPGA would be in a toy digital camera. But time to market pressures and the risk of missing the narrow Christmas window of opportunity drove KB Gear Interactive, a manufacturer of Internet communications products and interactive gear for young computer trekkers, to chose the low cost Spartan™ FPGA because of its affordability and design flexibility.

As a testament to the viability of FPGAs in such a cost sensitive consumer product – the JAMCAM 3.0, which cost just $99, was sold in over 14,000 retail outlets including Best Buy, Target, K-Mart, WalMart, Circuit City, and a host of other highly recognizable consumer retail outlets. Because KB Gear had designed a toy that had broad appeal and used a Spartan FPGA, they were able to deliver one of the "must have" toys for the 2000 Christmas season on the shelves in time for the Christmas season. Years ago, the thoughts of an FPGA in a $99 kid's toy would have seemed impossible.

Conclusion

Seventeen years ago the idea of creating an ASIC on the desktop was considered a novel concept; they were primarily limited to prototyping and low volume production. The fact that the FPGAs needed to be programmed every time they were powered up was considered both a liability and a risk. Today, because of their lower cost and high flexibility, FPGAs have found a home in a wide range of applications. Xilinx FPGAs are now used in a wide range of high-volume, cost sensitive applications, especially those that require reprogrammability to meet the continuously changing standards and demands of the new digital consumer markets.