APPLICATIONS FOR EMBEDDED COMESH

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ADVANTAGES

The advantages of an embedded reconfigurable component are processing speed and reconfigurability. Speed is an advantage for applications that require programmability (such as microprocessors and DSPs) since they can run at ASIC speeds. Reconfigurability is an advantage for applications that require speed since they can avoid the rigidity of the ASIC architecture. Thus the most desirable applications for embedded CoMesh are those that require dynamic functional changes in processing while maintaining a faster processing speed. Embedded reconfigurable components provide advantages for the entire ASIC design flow, as well as for specific commercial applications.

Until the CoMesh product, the primary disadvantage of embedded reconfigurable components was their cost in silicon area, which may be 50-100X more than an ASIC with equivalent functionality. Existing competing embedded reconfigurables suffer from poor gate densities and from irregular timing due to the indeterminacy of layout. CoMesh addresses and solves both of these problems. The layout stability and speed of the CoMesh architecture assures that the embedded component can maintain a high degree of integration with the performance of the ASIC components. The density of the CoMesh architecture assures that the embedded component can maintain the economic advantage of the ASIC architecture.

The standard method of achieving programmability is through the instruction set architecture used in microprocessors, microcontrollers and DSPs. Compared to a reprogrammable silicon component, these architectures may be 50-100X slower. Thus, these processors pay a large price in speed for their programmability. A CoMesh embedded component may run at 60-70% of the speed of an ASIC. The second major disadvantage of instruction set architectures is that their software programming is exceedingly difficult to verify. CoMesh hardware assures error-free, rock-solid, verified performance. Thus, all applications that currently use instruction set architectures and require greater speed benefit from an embedded CoMesh component. A primary application win here is the DSP.

Reprogramability can be achieved through brute force using ASICs. For example, a function that requires eight different configuration settings can be achieved using eight replications of an ASIC components, together with a small control unit. Thus the density of embedded reconfigurables must be great enough to justify their inclusion. Current reconfigurables may be 20-200X less dense that an ASIC, undermining their reconfigurable advantage. A CoMesh embedded component requires about 5X as much silicon area than does an equivalent ASIC, making the cost of reconfigurability far more palatable.

Current embedded reconfigurables constitute perhaps 1% of an ASIC chip, due to their density disadvantage. Current Xilinx embedded configurable cores range from 10K to 40K ASIC gates. CoMesh densities permit a far greater utilization of reconfigurables in an embedded environment.

A Xilinx whitepaper argues in favor of embedded reconfigurable components as a design win. [Xilinx whitepaper WP164: "Until now, designers had two choices: very dense standard cell technology, with its superior performance, integration, and lowest possible production price; or FPGA technology which offered flexibility and system-level features but at significantly higher prices per gate, and with a larger footprint. Combining these two technologies gives designers the best of both worlds..."] The CoMesh architecture furthers this argument by significantly reducing the performance consistency and density disadvantages of embedded reconfigurable gates.

APPLICATIONS

Flexible Design: CoMesh permits design change late in the design cycle, after many other components are frozen. Here reconfigurability is used to provide flexibility for ASIC design, particularly for design components that require definition or integration late in the chip design cycle. A late stage new chip prototype can cost half a million dollars and several months of development time. With embedded CoMesh, designers could change, refine, and integrate new design components immediately, eliminating the need of restarting the entire design cycle. Late stage changes can come about due to dynamic performance specifications, design refinements, discovered bugs, wider applications, and market shifts.

Reconfigurable Design: After a chip has be fabricated, the functionality of a product can be changed when CoMesh is on the chip. New performance requirements, new functionalities, changing protocols, changing interface specifications, and changing application environments can be incorporated while avoiding the fixed shelf life of rigid ASIC designs. Cell phones, printers, set-top boxes, and many other consumer products can benefit from reconfigurability.

More Reliable Design: CoMesh embedded components can be used for specific design steps, such as self-testing, validation, and multi-chip module integration. ASIC boundary scan, for example, can be included in the reconfigurable component, later to be removed, freeing the reconfigurable component for other uses. The formal verification built into CoMesh configuration provides performance insurance that can avoid very costly product recalls. Difficult and error prone design aspects can be placed in the reconfigurable component, leading to first-time-correct designs. Design flows between fixed and flexible logic can be partitioned for more modular design. Applications that benefit from more reliable design include mission critical components of military defense systems, medical instrumentation, automobile and airplane components, and buried components that are costly to replace.

Reusable Design: Product shelf-life is increased by being able to reconfigure selected components of a design with CoMesh. Reconfigurability is used here as a hedge against the rigidity of an ASIC design in a changing application environment. Markets with changing standards, with rapidly time-to-market challenges, and with different geographical requirements can be addressed with efficiency and low cost.

Elimination of chips: An embedded reconfigurable component can permit a higher degree of integration by allowing several separate ships to be combined into one. Embedded reconfigurable components can reduce chip boundary crossings and provide a closer interaction between fixed and reconfigurable logic. As ASIC applications grow in size due to shrinking geometries, such as the System-on-a-Chip application, more reconfigurable and "late configurable" components are required. Thus as the size of ASICs grow, so does the need for embedded reconfigurable blocks.

IP Cores: Very generally, any IP core that is included in a conventional FPGA can be an embedded application. Rather than paying for flexibility with an entire FPGA chip, that flexibility can be added to the ASIC chip directly. This enhances chip set integration, creating significant savings through System-on-a-Chip architectures. Specific applications include DSP functions, microprocessors, bus interfaces, memory interfaces, encoders and decoders for networking and communications, and specific mathematical and special purpose computational functions.

Configurable Products: Many product components, such as voice recognition, trainable filters, dynamically configurable data channels, and time-varying functions cannot be achieved solely using ASIC technology. CoMesh can provide the capability for real-time modification of microprocessor instruction sets, dynamic control of power usage, customized on-demand accelerators, smart interfaces, tunable algorithms, and adaptable communication protocols. Remotely loaded dynamic logic can reduce power needs by eliminating idle fixed logic. Dynamic logic can also reduce cost by eliminating silicon functionality that is not in continuous use. Networked appliances with CoMesh can provide the capability of downloaded new services and performance upgrades, dynamic software capabilities using JAVA technology, and modifiable security.

Less Expensive Product Families: Products that share a significant portion of functionality can be varied using the CoMesh embedded components. Re-purposing CoMesh components provides product differentiation without sacrificing time-to-market. Thus family lines can be manufactured and diversified more cheaply, of value in office equipment, consumer electronics, and telecommunications markets. Example benefits include less inventory tracking, single chip design, lower NRE, significant reduction of time-to-market when new features or product variations are added, and the ability to update shipped chips in the field, which leads to increased shelf life, lower inventory costs, and on-demand product availability.

APPLICATION EXAMPLES

Microprocessor Alternative

98% of the microprocessor market is in embedded systems, primarily relatively small 8-bit and 16-bit systems. The microprocessor is the primary way to achieve silicon programmability. However, fixed bit-width microprocessors are a poor forced choice for a wide range of applications. CoMesh can solve many problems with the out-dated microprocessor approach. Microprocessors are found in almost all consumer electronic, instrumentation, communications, and storage products.

The primary advantages of a microprocessor, other than programmability, is the huge installed base, the large base of skilled software programmers, and the sophisticated software tools that have evolved for programming microprocessor functionality. Due to the formal simplicity of CoMesh, industry-standard C programs can be converted directly and automatically into CoMesh configurations, requiring no new programmer skills and no change to programming methodologies. This solves an outstanding need of having a direct path between software specification and hardware configuration.

Microprocessors are good for sequential tasks, computationally intensive tasks, and tasks that are not time critical. CoMesh also excels at sequential, computationally intensive tasks, while providing an added bonus of processing speed that can eliminate common problems with system bus interfaces.

The functional overhead of microprocessors is huge, and includes

- fetching and decoding overhead
- instruction set overhead
- instruction set variability
- slow bus interface
- ALU operations that cannot be customized
- fixed and often wasteful bit-width
- no parallelism
- cannot integrate peripheral processing
- 2-5% efficiency of ASICs

Microprocessors provide very inefficient resource usage since most microprocessor logic elements are idle most of the time. For example, adding two numbers uses 2% of CPU while the rest of the CPU is idle but still consuming power. The cost of a microprocessor is not only in manufacturing and chip territory, but also in failure modes due to software instruction sets. Writing secure test protocols for software that is inherently not verifiable imposes a huge design risk relative to the reliability of a silicon implementation. Some more subtle difficulties with software that CoMesh solves include confounding functional logic with system and other high-priority interrupts; the CPU model limits i/o interaction; instruction sets themselves are rigid; and many subroutines can be run in parallel in silicon.

In sum, CoMesh offers all the benefits of a microprocessor with none of the overhead. This cost-benefit particularly strong for products with fixed function small microprocessors. Chips, for example, may be most expensive component of a home appliance, costing $1-2 each, mainly because of the silicon overhead imposed by microprocessors. The impact of cutting chip price in half while greatly improving reliability and power consumption might be around about $1 per appliance. The saving offered by CoMesh is even greater for industrial applications, where the stability of silicon performance can reduce maintenance, replacement, and re-purposing overheads.

Inside the Set-top Box

The modern set-top appliance provides essential services of program delivery, remote purchasing, home entertainment integration, digital sound and video, and internet activity. Inside the set-top box are literally dozens of functional units requiring configuration and integration. These include

- Viterbi and reed/Solomon decoders
- descramblers
- MPEG1 and MPEG2 decoders
- Dolby and digital audio enhancement
- RF modulator
- NTSC and video encoder
- satellite QPSK demodulator
- cable 64QAM demodulator
- phone ADSL demodulator
- CD/DVD/digital-audio decoders and filters
- screen display
- coordinating CPU

These well-defined functions are usually embedded in ASICs, and require substantial integration and coordination. However, each can have changing standards, different geographical requirements, and wasted cycles when not in use. Together, these impose a large cost overhead in a market driven by cost, time-to-market, and product features. The System-on-a-Chip movement is driven economically by applications such as the set-top box. CoMesh can provide reconfigurable and low-power disconnect capabilities for each functionality independently; CoMesh can be used for communication and coordination between functionalities; and CoMesh can assure product differentiation with low design and reuse overheads.

Smart Card Readers

The smart ATM and credit card reader is a product of relatively high silicon sophistication that will see very wide-spread usage in the future. Smart cards are credit/debit cards that carry user information in embedded memory. Smart card readers are used increasingly in restaurants, gas stations, taxis, buses, department stores, and in homes for online internet transactions. They are integrated into personal computers, cash registers, vending machines, pay phones, set-top boxes, ATMs, mobile phones, utility meters, and any other venue requiring authentication and economic transactions. Smart card readers can be used for cashless transactions, store purchase incentives and bonuses, access control, medical records, identity cards and driver's licenses.

Smart card readers consist of several silicon components that require communication and integration. These include

16-32bit microprocessor
ROM boot code
security/encryption logic
card reader interface
keypad PIN reader
LCD driver
modem interface with cellular/wireless/radio.

Due to the diversity of applications, and the diversity of uses made by each individual, smart card readers must be both complex and economic, both fast and low power, both secure and ubiquitous, both reconfigurable and small. Current FPGAs fail for this application, since FPGAs are insufficiently complex for the required price range; they are insufficiently low power and too wasteful of silicon area; and they are volatile, requiring reloading of functionality and compromising design security. FPGAs provide the field reconfiguration required by smart card readers, but fail to provide low power, low cost, small silicon size, high computational performance, and internal design security.

CoMesh provides several of the required key features for this application, including high silicon density leading to low cost, high performance computational capabilities, and rapid reconfigurability for diverse computational tasks. The CoMesh architectural design can be further refined for specific performance qualities such as ultra-low power, internal security, and dynamic customization.