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Sailing through the Silicon Maze: FPGA versus ASIC

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Introduction: Field Programmable Gate Arrays (FPGAs) and Application Specific Integrated Circuits (ASICs**)** provide different values to designers and they must be carefully evaluated before choosing any one over the other. FPGA is an integrated circuit and designed by ASIC design engineer Field Programmable Gate Arrays (FPGAs) are semiconductor devices that are based around a matrix of Configurable Logic Blocks (CLBs) connected via programmable interconnects. FPGAs can be reprogrammed to desired application or functionality requirements after manufacturing. This feature distinguishes FPGAs from Application Specific Integrated Circuits (ASICs), which are custom manufactured for specific design tasks. Application specific integrated circuits (ASICs) typically conjure up the notion of massively complex logic chips containing tens or hundreds of thousands (even millions) of transistors configured to solve a customer's unique set of problems. Unlike multi-function standard product ICs such as a micro-controller that can find its way into a

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wide variety of applications, ASICs are designed for one specific application and generally for one specific product or product family.

Field-programmable gate arrays (FPGAs) are reprogrammable silicon chips. Reprogrammable silicon also has the same flexibility of software running on a processor-based system, but it is not limited by the number of processing cores available. Unlike processors, FPGAs are truly parallel in nature, so different processing operations do not have to compete for the same resources. Each independent processing task is assigned to a dedicated section of the chip, and can function autonomously without any influence from other logic blocks. As a result, the performance of one part of the application is not affected when you add more processing.

In FPGA Design the design is ported on an FPGA which consists of Random Logic. Hence the tools that use this design flow have a priori information about where a certain logic cell is present and how the routing can be done to another logic cell. This in a way has greater optimization. But the offshoot is that certain designs may use more than required amount of logic cells.

The first Digital ASICs were built using a standard cell library consisting of fixed-height, variable-width ‘tiles’ containing the digital logic functions discussed above. The ability to reuse these blocks over and over saved time and money when designing a custom logic IC. Analog ICs were initially comprised of a pair of matched transistors and soon expanded to include rudimentary op amps, voltage regulators, comparators, timers and much more.

In ASIC Design the implementation of logic is based on the functionality i.e. if a Multiplier is required then a multiplier block is inserted. In most cases the logic is provided by Standard Cells as ASIC design is Cell Based Design.

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Applications of FPGA and ASIC:

FPGAs are an ideal fit for many different markets due to their programmable nature, e.g. Aerospace & Defense, ASIC Prototyping, Automotive, Consumer Electronics, High Performance Computing and Data Storage, Medical, Security And Image Processing, Wired and Wireless Communications, Broadcast Targeted Design and Video & Image Processing.

ASICs play a critical role in our lives. Without them, none of the portable electronic devices in our daily lives would exist. Imagine a world without cell phones, MP3 players and navigation systems. Building them with standard products would make them prohibitively expensive and physically impossible to carry in our purses or pockets. Every automobile contains dozens of ASIC chips for everything from climate control to airbag deployment; suspension control to entertainment systems. ASICs also play important roles in applications for hospital medical equipment, Electronic Meters, Home Appliances such as washers and dryers, scuba gear, hearing aids and much more.

FPGA VS ASIC Design Flow

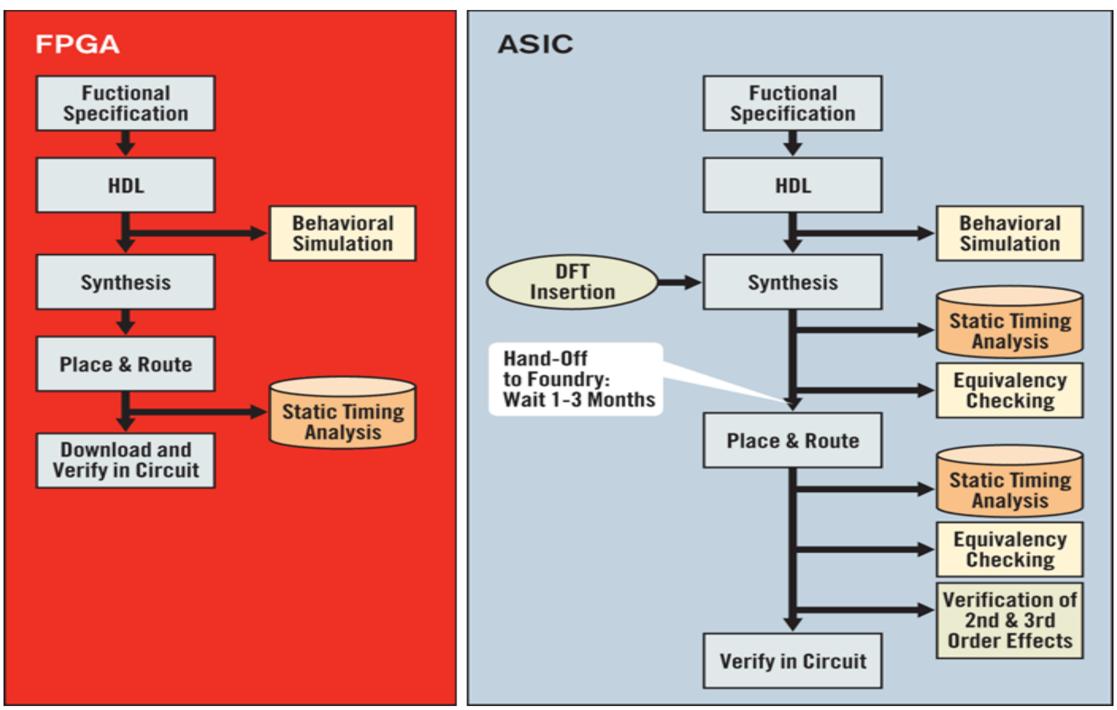

Figure1: benefits of FPGAs over processor-based systems

Advantages of FPGA Design

Faster Time-to-market: No layout masks or other manufacturing steps are needed for FPGA design. Readymade FPGA is available and HDL code can be burnt to FPGA.

No NRE (Non Recurring Expenses): This cost is typically associated with an ASIC design. FPGA tools are cheap. Only cost is to buy an FPGA.

Simpler Design Cycle: This is due to software that handles much of the routing, placement, and timing. Manual intervention is less. FPGA design flow eliminates the complex and time-consuming floor planning, place and route, timing analysis.

More Predictable Project Cycle: The FPGA design flow eliminates potential re-spins, wafer capacities etc of the project since the design logic is already synthesized and verified in FPGA device.

Field Reprogram ability: A new bit stream (program) can be uploaded remotely, instantly. FPGA can be reprogrammed in a snap while an ASIC can take $50,000 and more than 4-6 weeks to make the same changes. FPGA costs start from a couple of dollars to several hundred or more depending on the hardware features.

Reusability: Reusability of FPGA is the main advantage. Prototype of the design can be implemented on FPGA which could be verified for almost accurate results so that it can be implemented on an ASIC. If design has faults change the HDL code, generate bit stream, program to FPGA and test again. Modern FPGAs are reconfigurable both partially and dynamically.

Speed and Complexity: Generally FPGAs are used for lower speed, lower complexity and lower volume designs. But today's FPGAs even run at 500 MHz with superior performance. With unprecedented logic density increases and a host of other features, such as embedded processors, DSP blocks, clocking, and high-speed serial at ever lower price, FPGAs are suitable for almost any type of design.

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Special hardware: Unlike ASICs, FPGA's have special hard wares such as Block-RAM, DCM modules, MACs, Memories and High-speed I/O, embedded CPU etc in built, which can be used to get better performance. Advanced FPGAs usually come with Phase-Locked Loops, Low-Voltage Differential Signal, Clock Data Recovery, More Internal Routing, High Speed,. There are FPGAs available now with built in Analog to Digital Converter. Using all these features designers can build a system on a chip.

Synthesis & Floor Planning: FPGA synthesis is much more easier than ASIC and No floor-planning is required.

Figure 2 shows one of the benefits of FPGAs over processor-based systems is that the application logic is implemented in hardware circuits rather than executing on top of an OS, drivers, and application software.

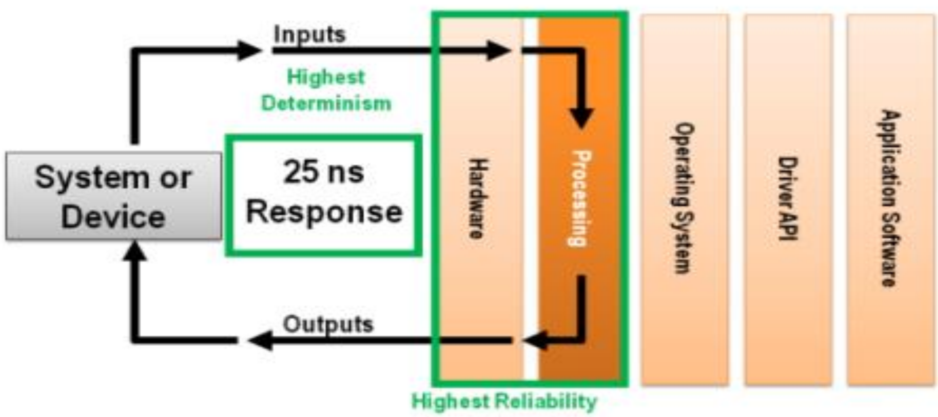

Figure 2: benefits of FPGAs over processor-based systems

FPGA Design Disadvantages

Power Consumption: Power consumption in FPGA is more. There is no control over the power optimization. This is where ASIC wins the race.

Limited Design Size: Resources available in the FPGA can only be used. Thus FPGA limits the design size.

Cost Per Product: Good for low quantity production. As quantity increases cost per product increases compared to the ASIC implementation. Thus FPGAs are good limited production.

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ASIC Design Advantages

Lower unit costs: For very high volume designs costs comes out to be very less. Larger volumes of ASIC design prove to be cheaper than implementing design using FPGA.

Speed: ASICs are faster than FPGA. ASIC gives design flexibility. This gives enormous opportunity for speed optimizations.

Low power: ASIC can be optimized for required low power. There are several low power techniques such as power gating, clock gating, multi threshold voltage cell libraries, pipelining etc are available to achieve the power target. This is where FPGA fails badly In ASIC you can implement analog circuit, mixed signal designs. This is generally not possible in FPGA.

ASIC Design Disadvantages

Time-to-market: Some large ASICs can take a year or more to design. A good way to shorten development time is to make prototypes using FPGAs and then switch to an ASIC.

Design Issues: Design for Manufacturing issues and Signal Integrity issues are to be taken care of by an ASIC designer. A design has to go through various tests e.g. Built in self test and Boundary scan.

Expensive Tools: ASIC design tools are very much expensive basically, a large amount of Non Recurring Expenses are to be spent.

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