FPGAs NOT JUST LOGIC GATES ANY MORE!

While the debate on ASIC versus FPGA continues, today's FPGAs with integrated functional blocks like high-speed transceivers, DSP blocks, hard IPs like PCIexpress and Ethernet MAC, and DDR3 memory controllers have surpassed ASICs in many embedded applications. These have now become designers' choice in communication, defence, medical, consumer electronics and many more devices

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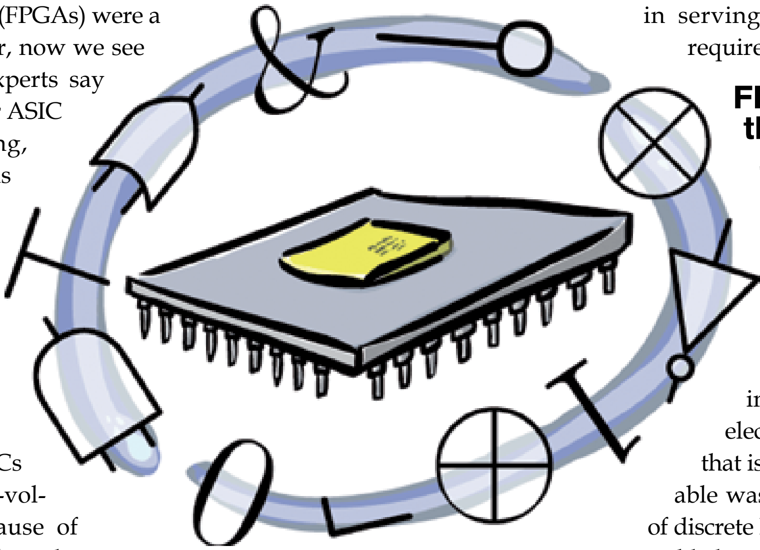
Earlier, if we were to summarise the ASIC versus FPGA battle for cost and performance, ASICs had a greater penetration because there was demand for high-volume applications in which application-specific integrated circuits (ASICs) provided a cost-effective solution and field-programmable gate arrays (FPGAs) were a costlier affair. However, now we see a reversal in trend. Experts say that the cost of entry for ASIC design is skyrocketing, which has made FPGAs a natural choice. Apart from the cost, the reduced time-to-market and design flexibility have made FPGAs relevant for more and more embedded applications.

Traditionally, ASICs were preferred in high-volume applications because of the overall low cost of production. "Today, the demand for ultra-high-volume products is reducing and so is the demand for ASICs," shares Neeraj Varma, country manager, Xilinx India. "Last year use of ASICs declined by 21 per cent for the simple reason of exorbitant cost associated with them," says Varma. Market segments like communication (routers, switches, back-haul equipment, and wireless pico and femto cells) and high-end consumer electronics (flat-panel plasma TVs) centre around FPGAs. Medical, industrial, defence, security and surveillance related applications are also designed using FPGAs.

"Use of FPGAs offers great flexibility, scalability/reprogrammability and almost zero non-recurring engineering (NRE) cost," explains Apurva Prabhakar, senior design engineer,



embedded group, KritiKal Solutions. She adds, "For designing with FPGAs, you have easy-to-use and less complex design tools. For simple designs, a single integrated tool for simulation, synthesis, place-and-route and binary file generation can be used."

Adding to the benefits, Barry Tso, regional manager, Avnet Electronics Marketing Asia, says, "FPGA is a standard product and easily available off-the-shelf. With an extensive library of intellectual property (IP) available for use, you can change design in hours."

Prashant Aggarwal, vice president-technology, VirtualWire Technologies, comments, "The design and development cycle for an ASIC design is 2-3 years, while with FPGA it's few months to about a year." This helps in serving the constantly changing requirement of the market.

FPGAs aren't just the logic gates

The first FPGA from XC2064 had 64 configurable logic blocks and two 3-input look-up tables (LUTs). Today, we have FPGAs with millions of logic cells and many integrated blocks in a very tiny area. In the electronics industry, something that is programmable and switchable was always available in terms of discrete logic components, programmable logic devices (PLDs), etc.

Varma comments, "The whole idea was to replace or integrate the logic components (what we refer to as glue logic) into a single component." As the silicon technology developed, the number of logic cells, capabilities and the speed of FPGAs increased.

When FPAGs were introduced, these were blank hardware chips. "With advancements in technology, FPGAs included more and more

India: A potential market with competitive advantages

There is tremendous opportunity for programmable technology in India, especially with rapidly growing new markets in diverse domains like communication, industrial, medical, defence and military. Gangatharan Gopal, country manager for Altera India, says, "There are new innovative products designed by Indian companies like fuel-dispenser systems used at petrol stations, thermal printer designs used in shopping malls for printing the receipts, LED-based outdoor display boards, railway passenger information displays, patient monitoring systems and many more. Programmable hardware like FPGAs have become heart of the system."

However, Shah feels that India is yet to explore the FPGA market to the same extent as rest of the world. There are customised products that can be designed using FPGAs especially for the Indian market at effectively low cost. "The new products today differ only in terms of looks and some add-on features from their previous version or release. As the product shelf life is shortening, you have to lower your initial investment cost. This kind of market will drive the use of FPGAs as you can get the flexibility of using the same device, re-programming it and providing new solution," suggests Shah. With FPGA usage, you can have low investment cost and low volume catering to the Indian market.

Many vendors like Lattice Semiconductor and Altera are coming up with low-cost FPGAs targeted at the Indian market. With in-built IP cores dedicated to Indian applications, the sales of these low-cost solutions will soon pick up in India.

features on chip, like RAM and digital signal processing (DSP) blocks, memory controller, high-speed serial input/output transceiver and hard intellectual property (IP) for PCIE and Ethernet MAC," informs Tso. "There is an extensive library of IP available to use and as the technology improves, there would be more and more features adding to it," Varma adds.

FPGAs with embedded DSP blocks

Digital signal processing is required in every embedded application starting from audio-video devices to defence equipment. Any digital signal processing algorithm can be broken into the simplest architecture of multiply-and-accumulate function. Integrating these multipliers and accumulators on board with FPGAs serves a high-end alternative for DSP-intensive applications.

The natural question that arises is whether you can replace a DSP processor with an FPGA having a DSP block. The answer is both 'yes' and 'no.' "The difference between a DSP processor and a DSP-implemented FPGA is the same as between a software and a hardware. DSP is still a programmable processor and you write software programs that it runs," says Varma. He adds, "FPGA is a programmable hardware where everything runs concurrently. If you were to design a 256-tap filter, in DSP you will have to run the filter 256 times as it runs the program sequentially. In FPGA, as it is hardware, the 256-times run happens simultaneously in a single clock cycle." FPGAs are uniquely suitable for repetitive DSP tasks as they operate in parallel. However, dedicated DSPs are sometimes preferred because of their low cost in applications that do not demand repetitive and high performance.

Telecom technology is one of the early adopters of FPGA for high-performance DSP applications. With the versatility of FPGAs, you are able to provide support for multiple platforms leading to a universal handset for different technologies (GSM, CDMA, 3G and 4G). FPGAs are also used in networking devices like wireless base stations, modems, switches and routers.

"After evaluating the pros and cons of DSPs and FPGAs, we found that FPGAs are the most suitable for our multiple-input multiple-output (MIMO) system design. Our latest design of digital baseband for 4×4 MIMO system supports 180 MHz on FPGA with 60 per cent utilisation, which is very good," informs Aggarwal.

With high-definition images and 3-D rolling, and growth in consumer electronics devices like the plasma TVs and digital cameras, there is a need for image processing algorithms that produce high-quality image. Image processing operations are simple and repetitive, so these can be best implemented using FPGAs with DSP block. But in image pipelining where 'blobs' and 'region of interest' in an object are inspected, a DSP may be preferred because of the varying sizes of blobs and subsequent processing required.

There are certain scenarios where you will see a DSP and an FPGA being used together. Here, the algorithms are divided in computing-intensive tasks for FPGAs and others for the processor. This is called 'hardware exploration,' shares Varma.

Xilinx' Virtex-5, Virtex-6, Spartan-6 and Extended Spartan-3A, Actel's RTAX, Altera's Cyclone and Stratix are some of the FPGA families with embedded multiplier of varying bit-length used for digital signal processing applications.

High-speed serial I/O technology

The data throughput requirements and chip-level functionality are increasing as high-speed communications start using FPGAs. This has compelled the industry to migrate from lower-data-rate parallel connections to higher-speed serial connections. This concept of SerDes (serialiser-deserialiser) introduced by Lattice involves transmitting serialised data over high-speed, differential pairs rather than lower-speed parallel buses, facilitating higher data rates with fewer pins.

Shakeel Peera, director of marketing for high-density solutions, Lattice Semiconductors, shares, "There was an increasing need for low-cost FPGAs. However, these did not have high-speed interfaces. Through the concept of SerDes, we were able to provide low-cost FPGAs with high-speed serial interface." SerDes serves a wide market, including wired and wireless communications (like microwave radio link), automotive, broadcasting video, industrial automation, printers and medical imaging applications.

Serial standards and protocols like PCI Express, serial rapid I/O and SerialLite are accepted in high-speed serial transceivers. "These high-speed serial transceivers supporting speed of up to 10.3125 Gbps (also called 'multi-gigabit transceivers') are now integrated in high-end FPGAs offering the benefits of less board space and increased flexibility and eliminating the interfacing issues for the board designers," shares Varma. High-speed serial solutions are applicable in next-generation telecommunication, networking and storage applications.

Fusion mixed-signal FPGAs

There is a common understanding that FPGAs are only digital devices. However, there are certain mixed-signal field-programmable gate arrays that integrate programmable analogue fabric and digital fabric. Such mixed-signal FPGAs find applications in power management, smart battery charging, clock generation and management, and motor control, which are still served by discrete analogue components, mixed-signal ASICs or microcontroller units with embedded analogue-to-digital converters (ADCs). An MCU with embedded ADC has limitation on the number of analogue inputs and the speed at which it operates is relatively low.

Analogue control can be differentiated from digital control by a simple example of the dimming light application. Analogue signals process the output continuously as opposed to digital control of the dimming in steps. In short, real-world applications are more associated with the analogue domain, while digital comes in when you need to store and process the data.

The Fusion family from Actel is claimed to be the first embodiment of mixed-signal FPGAs. The architecture supports a 12-bit internal ADC at a sampling speed of 600 kSa/s, eliminating the need for external mixed-signal support ICs. It can take 30 high-voltage-tolerant analogue inputs. Fusion devices eliminate the need for multi-voltage and power-up sequencers. These operate off a single 3.3V supply. The combination of single-voltage operation and power management makes them ideal for system/board management applications.

Selection criteria for FPGAs for your application

(Based on collective opinion of contributors)

- Number of logic cells
- In-built memory requirement
- In-built processor
- Number of inputs/outputs required
- Does your application need high performance and repetitive DSP
- IP cores needed for your application
- Tools and support from the vendor
- Expertise and experience of senior engineers in your organisation
- Power requirement of your application
- Cost

FPGAs with embedded processor cores

Inclusion of memory and other blocks on FPGAs have made them suitable for implementing the entire system-on-a-chip with in-built processor core. The advantage of implementing processor and its mix in the programmable logic fabric is the immense hardware-software flexibility. There are two approaches provided by major FPGA vendors for the embedded processor core. The hard-core processor has dedicated silicon on the FPGA chip, while you can implement soft-core entirely using the hardware descriptive language (HDL). As hard core is fixed on the chip, it does not provide the flexibility of soft cores.

The first processor core designed by ARM along with Actel specifically for implementation in FPGAs is 32-bit Cortex M1. The ARM Cortex M1 de-

Comparison of Programmable FPGA Technologies

FPGA	Advantages	Disadvantages
Antifuse-based FPGAs	Very low power consumption, instant-'on' when powered up, radiation-tolerant, highly secure (which makes it hard to reverse engineer the design)	One-time programmable
Flash-based FPGAs	Low power consumption, instant-'on,' radiation-tolerant, reprogrammable	Additional fabrication required on top of the standard CMOS process, low gate count
SRAM-based FPGAs	Based on the standard CMOS process, reprogrammable, available in large gate counts	Volatile (reconfiguration required on power-up), higher power consumption

velopment kit for Altera's Cyclone III FPGAs provides soft-core implementation. Xilinx' Microblaze, Altera's Nios II, and Lattice Mico 8 and Mico 32 are also soft-core implementations. The concept of multi-core processors and parallel computing can be extended to FPGAs in order to perform more complex embedded tasks.

New concept: PSoC

Cypress Semiconductors has introduced a new concept of programmable system-on-a-chip (PSoC). Rajeev Mehtani, senior vice president, Cypress Semiconductor, explains, "PSoC devices encapsulate features of a microcontroller with flexibility and programmability of FPGAs and a configurable analogue sub-system." "Our chip comes with a sophisticated software that allows the users to program the digital and analogue sub-systems to their specific application, giving them ultimate control of the system design process," he adds.

Scope for improvement

"FPGA as a technology has evolved, and has started developing a lot of eco-system around it," says Rahul V. Shah, director, custom solutions, eInfochips. "The ecosystem means FPGAs with different features, different IP cores, tools, evaluation board, reference design from the vendor and ultimately vendor support." With all this, time-to-market is another challenge before the vendors and designers.

FPGA vendors are providing newer FPGA chips with more and more functionality in sync with the market demand. However, in the race, the chips are not tested and verified thoroughly. ""There is no chip which is bug-free" has now become applicable to FPGAs, which are coming with added complexities," says Shah. If the new chip is a derivative device, i.e., a variant of the already existing FPGA chip, it has the least probability of having a bug.

There are still certain application areas where ultra-low-power ASIC chips are preferred to FPGAs; e.g., in handheld devices. "FPGA technology has not reached a point so far where it will find its application in ultra-low-power devices. However, for a few handheld devices where performance is needed, such as the man-pack radio carried by soldiers for highly sophisticated wireless communication, FPGAs are preferred," shares Varma.

FPGAs sometimes show erratic behaviour beyond certain temperature. "You cannot select an FPGA for your thermal requirement with just one parameter. You have to do a comparative study to determine whether the FPGA works fine at a particular temperature or at a particular frequency on a specific board," comments Shah.

Aggarwal adds, "As long as you are working with the vendor's board, the specifications are well-mentioned. But for a custom-made board, these are not well documented." The vendor documentation does not give you the exact details of the required cooling fan, kind of cooling, temperature and even the weight of the fan—things that affect the device design.

Software tools for FPGA are still a problem for designers. Aggarwal says, "The tools are locked to a particular vendor and designers need to pay for the FPGA device as well as tools to the vendor."

Prabhakar adds, "Every FPGA has its proprietary tool, so changing FPGAs in subsequent projects requires learning of a new design tool suite altogether." There is a need for platform-independent tools for FPGA designers.

Despite technological advancement, FPGAs are still high on bill-of-material (BOM) price. "In most cases, the most expensive chip in a typical board BOM comes out to be an FPGA," says Prabhakar.

In a nutshell

FPGAs have moved from 130nm to 28nm process today. There is a lot of development and innovation happening to support additional features, programmability and flexibility. Also, the industry is extending support in terms of training the users on basic architecture, providing reference designs and helping them in custom designs.

"The bulk of the revenue for FPGAs comes from wireless and wired communications. This is the fastest growing segment across the globe. Display and security and surveillance are the other fast-growing applications based on FPGAs. These are the areas where we see India as a huge market," informs Peera.

"FPGAs are the best choice when volumes are of the order of a few hundreds per annum. These are also the best choice while designing prototypes or proof-of-concept products as well as stepping stone towards ASIC design. All this is possible as FPGAs are reprogrammable, field-upgradable and easy to design. With all the new developments, FPGAs are preferred in applications that are complex and performance-intensive," says Prabhakar. ●

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