SELECTING RIGHT FPGA FOR THE RIGHT APPLICATION: A TECHNICAL SURVEY FOR XILINX FPGAS

Abdul Rafay Khatri[1], Nasreen Nizamani[1], Ehsan Ali[1], Abdul Sattar Saand[2]

[1]Deparements of Electronic Engineering, QUEST, Nawabshah, Pakistan.
[2]Deparements of Electrical Engineering, Technology, QUEST, Nawabshah, Pakistan.

ABSTRACT

Nowadays, the Field Programmable Gate Array (FPGA) is one of the most widely used components in the field of embedded system designs. Owing to its diverse advantages, it is used in the development of system on chip (SoC), Application Specified Integrated Circuits (ASICs), Reconfigurable ICs and Digital Signal Processors (DSPs). There are many vendors, which provide the FPGA with different capacities and functionalities. Xilinx Corporation is one of the major providers of FPGAs. The major families of Xilinx FPGA include Spartan, Virtex, Artix and Kintex. Each member of their family is different based on the capacity, features and capability to perform certain functions. In this paper, a technical survey about the Xilinx FPGA families is presented along with the technical analysis, which includes growth in capacity, clock rate, the suitability of an FPGA for a particular application. In the end, Open RISC-1200's ALU circuit is implemented on the Spartan-3E family of FPGA and simulated using Xilinx ISE, to give an idea of implementation of the circuit on FPGA.

Keywords: FPGA, Xilinx ISE, Look-up table, Spartan, Virtex.

I.INTRODUCTION

Field Programmable Gate Array is a breakthrough technology nowadays in the field of embedded system design. Owing to its remarkable features such as higher speed, parallelism, self-healing capabilities, cost effectiveness and reconfigurable capabilities [1], the FPGA becomes a heart of many embedded applications like aerospace, biomedical instrumentation, safety critical systems, satellite & communication applications and wireless sensor network applications during the last decade. It is also used as a processing element in many digital signal processing (DSP) applications. The FPGA is a fast growing field in order to implement embedded systems on a single FPGA chips i.e. System on Chip (SoC) design during the last decade. There are many vendors, which are working on this technology and produces different FPGAs for different applications, namely, Xilinx, Altera, Micro semi, lattice semiconductor to name a few. Xilinx Inc is one of the major providers, which produces various families of FPGAs. The major families are Spartan, Virtex, Artix and Kintex. Each new generation of FPGA devices have more density, faster speed large memory resources and compatible interfaces. The architecture of each FPGA families contains some common elements. The generic structure is described in Section II.

This paper gives the information about the most common parameter which one must consider while selecting the FPGA for a particular FPGA. We have considered the major FPGA provider i.e. Xilinx for the survey. The organization of this paper is as follows: The generic architecture and configuration technologies are presented in Section II. Section III gives the overview of FPGA vendors along with detailed introduction of Xilinx FPGA and their families. Section IV shows the implementation and simulation of OR1200 ALU on the Spartan FPGA. In the end, Section V concludes the paper.

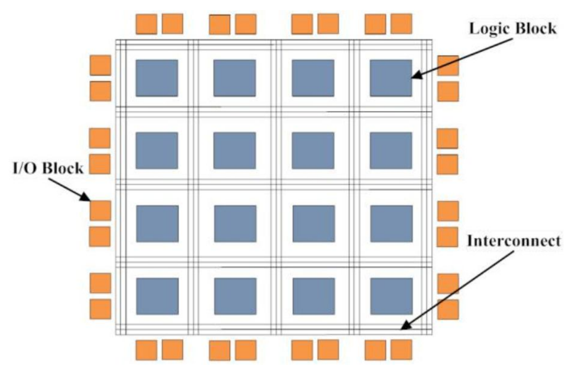

Figure 1. Simplified generic fabric of FPGA

II. FPGA ARCHITECTURE AND CONFIGURATION TECHNOLOGIES

The basic structure of the FPGA is known as fabrics. The architecture of the FPGA is divided into three main types, namely, Combinational Logic Blocks (CLBs) or Logic Elements (LEs), Routing channels or Interconnects and In-put/output Blocks (IOBs) [2]. The generic FPGA fabric is shown in Figure 1. Logic elements or CLBs are the smaller units consist of Look-Up Table (LUT) which,

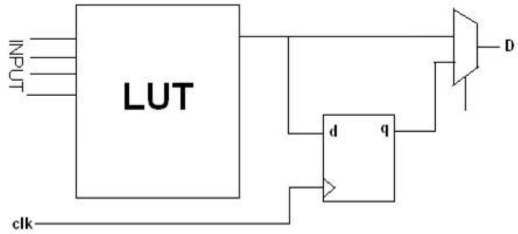

Figure. 2. Simplified structure of the FPGA LUT.

when combined, usually forms the functions of most logic circuits and designs as shown in Figure 2. CLB consists of four slices, state machine elements, combinatorial logic, controllers, and sequential circuits. The LEs are connected through interconnects that can be programmed. The FPGA has different types of interconnect depending in the distance between the logic elements to be connected [2]. The third element IOBs connects the design to the outside world. figured. There are three methods to configure the FPGAs,

1) SRAM based FPGAs
2) Flash
3) Antifuse

SRAM based FPGAs uses static memory to program or configure the FPGAs. This method is used for temporary configuration and needs to be programmed each time when power is on. The other two methods are used for permanent configuration of FPGAs. Modern FPGAs have some additional blocks that make the design easy, fast and efficient. In those FPGAs, embedded memories and embedded logic blocks are built-in to make easy interface and to perform arithmetic calculation, respectively [3]. Memory comes in different forms in new modern FPGA generation as, distributed memory is used for LUTs, FIFOs, single- and dual-port RAMs, and shift registers etc [4].

III. FPGA VENDORS AND THEIR FAMILIES

There are many vendors which provide FPGA integrated ICs, such as Xilinx, Altera, Micro-semi, Lattice semiconductor and many others. In this paper, the FPGAs from Xilinx and their families have been discussed.

Table. 1: XILINX FPGA SPARTAN FAMILY

Family	Members	# of Devices /member	System Gates	CLBs	IOBs/User IO	Block RAM bits	# of DCMs	Features/ Applications
SPARTAN	Spartan 2	6	15K-200K	96 - 1176	86-284	16K-56K	-	• Micro and Pico blaze embedded processor • Very low cost & high performance • High volume • Complete Xilinx ISE and web pack support
	Spartan 3	8	50K-5M	192-8320	124-633	72K-1872K	2-4	
	Spartan 3A	5	50K-1400K	176-2816	144-502	54K-576K	2-8	
	Spartan 3A DSP	2	1800K-3400K	4160-5968	469-519	1512K-2268K	8	
	Spartan 3AN	5	50K-1400K	176-2816	108-502	54K-576K	2-8	
	Spartan 3E	5	100K-1600K	240-3688	108-376	72K-648K	2-8	

Table.2: XILINX FPGA VIRTEX FAMILY

Family	Members	# of Devices /member	Logic cells	CLBs	IOBs/User IO	Block RAM bits	# of DCMs	Features/ Applications
Virtex	Virtex 2	6	-	-	-	-	-	• Micro and Pico blaze embedded processor • high performance • logic intensive applications • IP cores and SoC designs
	Virtex 4	17	12312-142128	-	320-896	648K-9936K	4-20	
	Virtex 5	26	-	-	172-1200	936K-18576K	2-12	
	Virtex 6	13	74496-758784	-	320-1200	5616K-39304K	-	
	Virtex 7	11	326400-1954560	-	300-1200	27M-67.68M	11	
	Virtex 7 3D	5		-	-	-	-	

A. *Xilinx*

Xilinx Inc, an American company, is known for developing and providing FPGA in a large scale. It is one of the major providers in this field. Xilinx FPGA products can be categorized into families, according to the different features each family provides. The main families are Spartan, Virtex, Kintex, Artix and Zynq series (SoC) [5].

1) Xilinx FPGA Spartan Family: The basic purpose of the Spartan family of FPGAs is cost sensitive in consumer electronics, high data volume applications and I/O intensive electronic applications. Each family is divided into members such as Spartan II family, Spartan 3, Spartan 3A, Spartan 3AN, Spartan 3A DSP, Spartan 3E and Spartan 6 etc. Each member consists of a number of devices with various features like number of logic cells, system gates and different features [6]–[10]. Table 1 shows the different parameters contained by each member in the family. Most application need to know the amount of LUT, system gates, CLBs, User I/O for their implementation.

2) Xilinx FPGA Virtex Family: Xilinx produces another family of FPGAs known as Virtex family. It is very well established and most widely used family from Xilinx. The Virtex family contains different members such as Virtex-II, Virtex-4, Virtex-5, Virtex-6 and Virtex-7 (Also Virtex-7 3D). Like Spartan, each member of the Virtex family consists of different devices and also sub families. Virtex 5 is the only family which is divided into 5 sub-families; remaining families are mostly divided into three sub families. This family is specifically designed for use in high performance FPGA applications. These family members are further divided based on the different platform used such as LXT, FXT, TXT, FXT etc [11]–[13]. Most of the members contain some special features such as, implementation of Power PC, High speed clock management circuitry, fast Ethernet to name a few. Table II shows the various features of Xilinx Virtex FPGA family members. The information of CLBs in Virtex family FPGAs is not directly seen but it is combined effect of slices and distributed RAM.

3) Xilinx FPGA Artix and Kintex Family*:* The basic purpose of these families is to apply these FPGAs in low cost (Artix) and mid range (Kintex) applications, respectively. These families contain only one member in each, e.g. Artix-7 and Kintex-7. Artix-7 contains 5 devices whereas Kintex-7 contains 7 devices [14].

IV. IMPLEMENTATION & SIMULATION OF OR1200 ALU ON FPGA

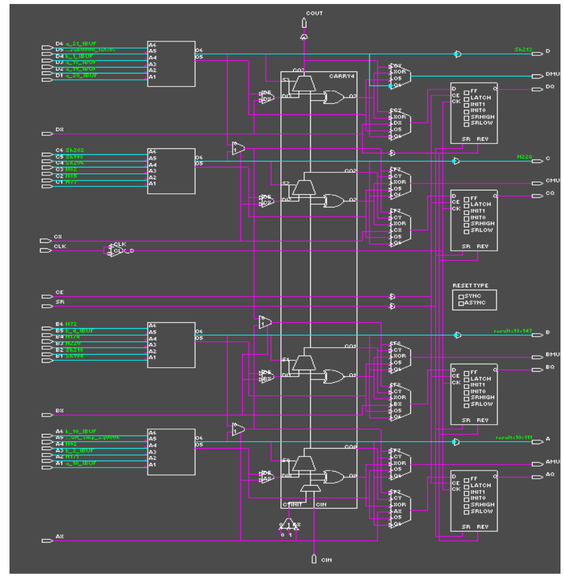

Figure. 3. Development of OR1200 ALU (FPGA editor).

The FPGA is configured and programmed into Hardware Description Languages (HDLs). The main HDL languages are Verilog and VHDL. When a program is written in these languages, number of steps are required to develop the de-signed for FPGA, such as synthesis which creates the netlist, translate, mapping on the particular device, place & route and bit file generation. A separate tool is required to do the specific task. All these tools are also provided by Xilinx, named as Xilinx ISE for these families of FPGAs [15]. Finally, IMPACT tool is used to download bit file into the target FPGA. User Constraint File (UCF) contains the information about the IOBs and the pins available on the FPGA chips. It connects the design with the outside connections. In this paper, a simple ALU from opencores.org for Open-RISC1200 processor is used and implemented on the one of the Xilinx FPGA from Spartan-3E family. This processor is written in the Verilog HDL. Using FPGA Editor tool, also provided in the Xilinx ISE, is used to visualize the implemented circuit under test as shown in Figure 3,whereas device utilization summary is shown in Table-3 for Spartan 3E 1600 device.

Table 3. Device utilization summary of circuit under test.

Logic Utilization	Used	Available	utilization
No. of slices	580	14752	3%
No. of 4 input LUTs	1046	29504	3%
No. of bonded IOBs	156	250	62%

In Table-3, the information about available device parameters and how much is used in the development and realization of a particular circuit is given. OpenRISC 1200 arithmetic and logic unit performs several operations. In this paper, some of the operations are simulated on the Xilinx ISIM simulator. The two 32-bit numbers are added (e.g. a +b) and subtracted (a-b) in this simulation. Results are shown in the Figure 4.

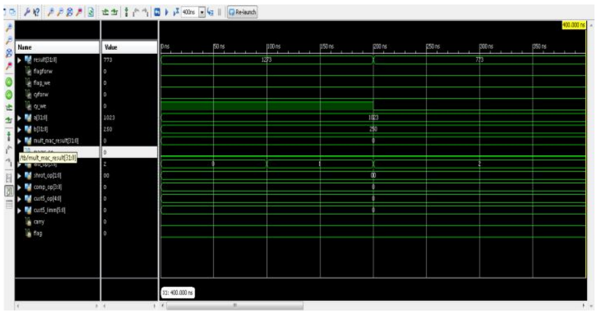

Figure 4: Simulation results for ADD/SUB commands

V. CONCLUSION

This paper presents the technical survey about the fast growing field in the development of embedded system design i.e. FPGA. It is used in the development of System on Chip designs. There are many manufacturers who are dealing with this field and provide us many types of FPGAs for various applications. The question is raised here, how do we select right FPGA for right applications? In this survey, we tried to find the answer about the Xilinx FPGAs. Xilinx is one of the biggest manufacturers of FPGAs and provides many families of FPGA for different purposes and applications. In the end, a simple design of the ALU is presented, implemented and simulated with the Xilinx tools. In this survey, various user guides and data sheets are studied from *www.xilinx.com* for each device mentioned here.

REFERENCES

[1] G. Corradi, R. Girardey, and J. Becker, “Xilinx tools facilitate development of FPGA applications for IEC61508,” in 2012 NASA/ESA Conference on Adaptive Hardware and Systems (AHS), (Erlangen, Germany), pp. 54–61, IEEE, June 2012.

[2] Wayne Wolf, “FPGA Fabrics,” in FPGA Based System design, ch. 3, pp. 105–164.

[3] C. Baumann, “Field Programmable Gate Array (FPGA),” in Embedded System Architecture, (Innsbruck), pp. 1–6, 2010.

[4] Pentek, “Selecting the right fpga for your application,” 2016.

[5] Xilinx, “Xilinx fpga families,” 2016.

[6] Xilinx, “Block in Virtex-5 FPGAs,” 2010.

[7] Xilinx, “Device Package User Guide,” 2010.

[8] Xilinx, “Spartan-3A DSP FPGA Family Data Sheet,” pp. 1–101, 2010.

[9] Xilinx, “Spartan-3A FPGA Family,” Xilinx, pp. 1–132, 2010.

[10] Xilinx Corporation, “Spartan-II FPGA Family Data Sheet,” tech. rep., 2008.

[11] Xilinx Inc, “Summary of Virtex-4 Family Features System Blocks Common to All Virtex-4 Families,” tech. rep., 2010.

[12] Xilinx Inc, “Summary of Virtex-5 FPGA Features,” tech. rep., Xilinx, 2015.

[13] D. S. August, “Virtex-6 Family Overview Summary of Virtex-6 FPGA Features,” tech. rep., Xilinx Inc, 2015.

[14] Xilinx Inc., “7 Series FPGAs Overview,” tech. rep., 2015.

[15] A. R. Khatri, A. Hayek, and J. Borcsoek, “ATPG Method with a Hybrid Compaction Technique for Combinational Digital Systems,” in IEEE SAI Computing Conference, (London, UK), July 2016.