FPGA Overview

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Abstract

This document is meant to give the history, and elaboration on the concept of field programmable gate arrays or FPGAs. It also details the structure of a field programmable gate array and the benefits of having such a structure. This document will also outline some of the applications field programmable gate arrays are being used in and how they have impacted the technology world.

Keywords – configurable, logic, gates, architecture, synchronous, asynchronous, computable, skew, schematic

Introduction

Field programmable gate arrays or FPGAs have changed the way integrated circuits can be used in today's world. An FPGA is an integrated circuit designed to be configured by the consumer after manufacturing; that is why they are considered field programmable. FPGAs configurations are generally specified using a hardware description language. The FPGA dynamically turns semiconductor switches on and off in accordance to the wiring list provided by the user, allowing it to be modified in the field. It was not until the 1980s when we first see the FPGA, but once it was successfully created, it did not take long to begin perfecting the FPGA and mass producing it. Due to its moderate cost, software-controlled reconfigurability, and high operating speed the FPGA is the fastest-growing way to implement digital hardware. FPGA technology is used across the industry. Every product that uses computing power most likely also uses FPGAs to complete those computations in a quicker, more versatile way. This technique has boosted not only technological advancements, but advancements in countless other fields. It is hard to say where the world would be without FPGA technology because of how much of an impact the technology has had. The best part is, FPGAs are very accessible and are created at such a low cost that anyone can purchase and behave like a circuit from whoever designs it. Here we will briefly talk about all the historical aspects of FPGA technology and how it can be utilized in everyday life and expanded to help the ever-growing technology industry speed towards a faster processing world.

Historical Developments

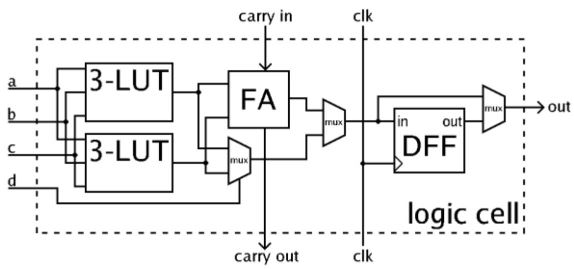
FPGA technology can be traced to programmable read-only memory (PROM) and programmable logic devices (PLD). Both PROMs and PLDs could be programmed in a factory, or out in the field, but they were hard-wired between logic gates. The Naval Surface Warfare Center funded an experiment by Steve Casselman to develop a computer with 600,000 reprogrammable gates in the late 1980s. This experiment was successful and led to a patent in 1992. During this time, Altera was founded in 1983 and produced the industry's first reprogrammable logic device in 1984 called the EP300. Xilinx co-founders Ross Freeman and Bernard Vonderschmitt created the first commercially viable field-programmable gate array in 1985 named the XC2064. The XC2064 had programmable gates and programmable interconnects between gates and had 64 configurable logic blocks. Ross Freeman was entered in to the National Inventors Hall of Fame for his work on FPGA technology. This was the beginning of a new technology and market. The 1990s were a time of rapid growth for FPGA technology. Altera and Xilinx were the forerunners of the market. By 2013, Xilinx served for 36 percent, Altera 31 percent, and Actel 10 percent, for a combining 77 percent of the market.

FPGA Structure

The most common FPGA architecture is logic blocks. This consists of an array of configurable logic blocks, input/output pads, and routing channels. A logic block consists of a few logical cells with 4-input LUTs (lookup tables), a full adder and a D flip-flop. In normal mode, the 4-input LUT will go

Figure 1

through the mux, and in arithmetic mode it will go through the full adder. The output can be either



synchronous or asynchronous. Figure 1 shows a simplified version of a logic cell block.

The next type of architecture is hard blocks. Modern FPGA families expand above the capabilities of just logic blocks. These include higher functionality built in to the silicon. Having common functions embedded in to the silicon reduces the area in which the FPGA takes up also increases the speed of those functions like embedded memories for example. Some of the higher-end FPGAs have hard IP processors, which are built out of transistors instead of LUTs, so they have ASIC level performance but take up less fabric resource space, leaving room for other application-specific logic.

Most of the circuitry inside of an FPGA is synchronous so it needs a clock signal. FPGAs contain global and regional routing networks for clock and reset so those signals can be delivered with minimum skew. Complex designs can use multiple clock signals. This shows that you can use FPGA technology in real-time systems such as cars, cell phones and PCs.

One of the most notable types of architecture in recent years is 3D architecture. Also referred to as Stacked architecture, 3D architecture, was designed by Xilinx to help shrink the size of FPGAs and decrease the power consumption. Xilinx’s approach is the have three or four active FPGAs stacked on top of one and other on a piece of silicon that carries a passive interconnect.

The Programmability Technology

To program an FPGA, one must use the correct programming language. FPGA technology uses Hardware Descriptive Language(HDL) to implement the design of the FPGA specified by a user. This is different than most software programming languages like Java, Python, C++ for example. Advanced software programming languages like the examples given can be more abstract and indirect with their programs and they do not need specific names for their variables. With hardware descriptive languages you can be very specific with structures and defining them numerically. Another major difference between software programming languages and hardware descriptive languages is that hardware descriptive languages use the notion of time. Time and time constraints are critical in hardware design. When it comes to hardware descriptive languages, you are literally describing how the hardware circuit should execute. This is called a schematic; when you create a design or diagram that represents the elements of a system.

One of the most common Hardware Descriptive Languages is VHDL or VHSIC Hardware Description Language. This language is used to describe digital and mixed-signal systems such as Field Programmable Gate Arrays. VHDL was created first back in 1983 by the U.S. Department of Defense. The original version of VHDL, designed to IEEE standard, included a wide range of data types like numerical, logical, character, time and arrays. Throughout the years VHDL has been modified and expanded to have capabilities for more signals. There are other hardware descriptive languages like Verilog that one can use, but for the purposes of this class we will mainly be using VHDL for our hardware designs.

Major Industrial Players

Xilinx and Altera were the market leaders for FPGA technology in 2016. Together they controlled 90 percent of the market. Other manufacturers include: Microsemi which was formally Actel, Lattice Semiconductor, SiliconBlue Technologies, QuickLogic, Atmel, and Achronix. On June 1, 2015, Intel announced it would acquire Altera for approximately $16.7 billion and completed the acquisition on December 30, 2015. The industry really has blossomed in a short amount of time. That is usually how the technology industry progresses; exponentially. Roughly twenty years prior, there was no industry for FPGA technology. But as soon as it was first created, it was able to be built more efficiently and then mass produced. Soon enough, other major industries found uses for field programmable gate arrays and now you cannot find many industries that do not implement FPGA technology. It is hard to predict if any company will become a front-runner for FPGA technology, Xilinx and Altera have had a solid hold on the market for numerous decades. Field Programmable Gate Arrays will most likely always have their uses in the world, so it is hard to see this industry ever decline. It may eventually level-off and no longer grow exponentially like it once did, but FPGA technology will always remain relevant and stay with us in the industry for many years to come.

Areas of Application

A field programmable gate array is used today in a wide variety of industries. An FPGA can be used to solve any problem which is computable. Computable problems are either decision problems which are problems that have an instance to decide on an output given the input data or function problems which are problems with a function that computes an input with the corresponding function for the output. With that type of power and manipulation, it is clear to see how an FPGA can be used in numerous applications. A few fields that use field programmable gate arrays are automotive, industrial, medical, security, wired and wireless communications. As seen, these are major industries that serve the entire world in everyday life. FPGA technology certainly has changed the way products work now in a more efficient manner.

These industries where FPGA technology is applied certainly are used in everyday life. Not only that, but some of these equipment in which FPGA technology is applied, they are critical to be able to perform efficiently and with quick response time. For example, in the medical field there is zero room for error or delay. In life or death surgeries, the technology the surgeons use need to be efficient and respond in real-time for the surgeon to complete a successful surgery. FPGA technology allows other technicians and engineers to modify the FPGA and implement them in to their designs and tools to have their products run at the most effective rate. The same can be said for the automotive industry; where safety is the most important, and in today's world there are numerous safety features that vehicles have and utilize. These features need to be able to run in the most effective manner to ensure the safety of all passengers. Alike, FPGA technology can also be beneficial in other areas of application, not just critical situations. FPGA technology can overall be found in every modern-day piece of technology. From cameras to security systems to even portable devices that we carry every day, FPGA technology has changed the course of the technology industry for the better.

Conclusion

Overall, just like the rest of the technology world, FPGA technology has increased exponentially. Since it was first created till today, every industry has found significant value of the FPGA. It is astonishing to think of how little a piece of equipment can be and it leave such a big impact on everyday life. Society will continue to go about life and many will have no knowledge of the power of the FPGA and how it has made technology faster and more efficient. If FPGA technology never existed, it is hard to think of how far back that would push the technology revolution. Where would we be? What kind of technology would be available to us?

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