Clock Around Embedded Systems and Reconfigurable Systems

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Abstract: The influence of Von Neumann computer model [4] and the second EDVAC computer built by the Moore School deeply influenced the last 50 years of computer sciences and embedded systems. The FPGA (Field Programmable Gate) technology brings another possibility to the field as introduced the reconfigurable computing concept. The paper gives one possible view of this research field.

Keywords: microprocessors, microcontrollers, FPGA, reconfigurable systems, embedded systems

1. Introduction

Semiconductor industry shows sinusoidal development wave as Tsugio Makomoto stated in his paper [1]. Figure 1 presents the technological periods as stated Makimoto. These periods the positive and negative waves of the sine wave in the figure are noted as standardization and customization. Standard circuits take from “the shelf” speed up system design while custom circuits which are optimised solution for a specific product. Makimoto also predicted in the mentioned paper the convergence of several technologies and circuit types into one single chip system. This chip is called today System on Chip (SOC) or if network is targeted then is called Network on Chip (NOC).

Certainly, customer designed chips called ASIC (Application Specific Integrated Circuits) are power, speed and functionally optimized, but using them the embedded system design cycle is longer then the one of standard ICs.

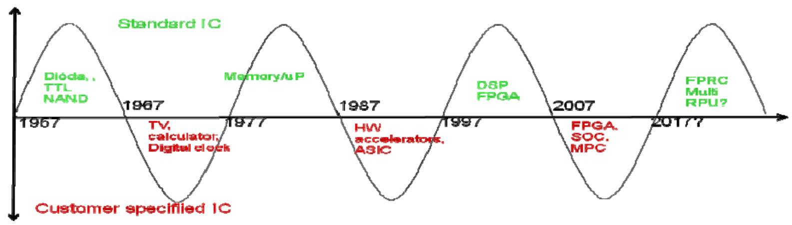

Figure 1: Makimoto's wave

After the Personal Computer (PC) was introduced, a software-hardware revolution started. The microprocessor built based on von Neumann model [4] became the central motor of every computing system. The first 8 bit, microprocessor designed by Intel the Complex Instruction Set Computer (CISC) era begun. The X86 family became the main microprocessor for every day computers.

From the beginning, system designers realized several problems of the von Neumann model. The problems (not treated in the paper) resulted in several improvements during the past 40 years. The major problems persist against the last technological advances: common code and data memory and power dissipation. Looking at the improvements proposed by companies and academia resulted in huge number of papers but also in hardware implementations, just to mention the Cache memories, pipeline code execution, and external memory amount. In the mean time another computer model - the so called Harvard architecture - was gaining field. On the other hand, the Reduced Instruction Set Computing (RISC) was also overcome to the variable instruction set and huge number of microprocessor instructions.

The paper treats the relationship of technological advances, and the reinvention of some previously introduced chips and their influence on the embedded system market.

2. Microprocessors, Microcontrollers and FPGAs

The huge number of applications using microprocessors resulted in the development of microcontroller and created a new industry called embedded systems. Embedded system key technologies are processor-, integrated circuit- and design technologies. Processor technologies refer to the general-purpose processors (microprocessors), application specific processors (microcontrollers) and single purpose processors (ASIC) [3]. Integrated circuit technologies are referred here to standard ICs, PLDs and ASICs. Design technologies are the design methods for system integration [3]. In this paper only the first two technologies are treated.

A. Microprocessors and Microcontrollers

Today microprocessors are used mainly in computer systems and embedded systems. They are as mentioned before CISC and RISC types. The improvements made, during the past years were done mainly for improve their computing speed, have advantages and disadvantages also.

Data format: Soon, the data size stored in memory became from 8 bit to 16 bit (half word), 32 bit (word) and today is 64 bit (double word). This generated a new problem called memory size in word dimension and the amount of stored data. Data dimension problem was the adjusting the data/code storage to address alignment. The addressable memory amount increased with the stored data dimension. This created another problem the memory access time. As Carvalho stated in [6] the gap between memory access time and processor clock cycle increased. For this reason, the memory access time became a gap of the increasing execution speed. Cache memories do not bring the expected solution. Increasing cache memory dimensions without any limit were not the good the solution. Increasing cache memory can improve cache performance but after an amount of cache memory dimension this performance result in cache miss rate.

Decreasing the gap between microprocessors and memories resulted in bus controllers, different memory types (DDRx, EDORAM, etc) and memory management as presented in [6]. Another solution was to increase the number of processors per chip and decreasing processor clock frequency. This improvement decreased somehow the dissipated power and the processor execution speed, but the processor core processing load became a new problem.

B. FPGA and System on Chip

Field Programmable Arrays since their introduction in 1985 became more and more an important technology in embedded systems. Unlike microprocessors because of their internal structure can implement data processing algorithms in parallel. Using lower clock frequencies, their power dissipation is lower then the microprocessor’s one. Their flexibility and continuously improvement due to the technology advancement made possible to incorporate not only logic resources but also memory blocks, and microprocessor cores. The first dynamically and partially reconfigurable FPGA made by Algotronix resulted in the new research area the reconfigurable computing. The offered Intellectual Property (IP) cores permitted their application in various fields where previously microprocessors, microcontrollers, digital signal processors (DSP) were dominant.

The soft and hard processor core integrated in the FPGAs permitted for the first time the use of multicore processors. FPGA resources allow the design of a complete system in the FPGA chip. This possibility appeared in 1998 with the introduction of the first System on Chip solution (SOC) introduced by Triscend. The first two processing elements integrated together with the FPGA fabric together with the memory management system, were the 8032 and ARM processors together with their specific peripherals. The SOC was at that time (1998) the best chip for a huge embedded system application with the possibility of dynamically reconfiguration. After Xilinx acquisitioned Triscend, they stopped the production of Triscend SOC. By that time (2000), the ARM as processor or microcontroller was “just another” microprocessor, its advantages against the X86 architecture and DSP was recognized by only a few [7]. Altera and Xilinx reintroduced the SOC with ARM solution again only recently. Today ARM became the major processor for embedded applications.

3. Conclusion

System on chip solution with integrated ARM processor, memory and DSP blocks will dominate the next few years of embedded system applications. The gap between memories and microprocessors, against multicore processor chips will not solve this processor problem. The power dissipation generated heat increase and is still problem which must be solved.

New ideas like dynamically partial reconfiguration and SOC with ARM cores, which were, introduce almost ten years ago became embedded industry motors only in our days. Applications which use dynamic reconfiguration are only a few known or not know or are kept in secret.

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