Full Custom Design in VLSI

A Seminar paper on the Full Custom Design approach in VLSI

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***Abstract*—**

***Index Terms*—Full custom VLSI, Synthesis, Integrated Circuit, Design, Silicon**

I. Introduction

A tiny semiconductor-based electronic device made up of fabricated transistors, resistors, and capacitors is called an integrated circuit (IC). The fundamental components of the majority of electronic equipment and devices are integrated circuits. These ICs are part of almost every electronic device that we use today. Since the rise of digital technologies and digital computing, the core components used for building digital circuits, the transistors, have gotten smaller and smaller. While getting smaller and more efficient, building digital circuits also became more complex over time and different design approaches were sought after. The general process of designing an integrated circuit nowadays is called Very large scale integration (VLSI). It is important to note that VLSI is generally meant for circuits with 10.000- 100.000 transistors, however it is also used to describe designs that use far more transistors [1] [2].

For most circuits today, there are mostly 2 approaches for developing an ASIC:

1) semi custom design
2) Full custom design

Semi custom design aims to speed-up the design phase for circuits with high performance requirements. To achieve that, not everything is designed anew and common components like adders, memory elements or multiplexers are bought from vendors in the finished state. Therefore the design team only has to design the elements around the already bought components and therefore saves alot of time. Using FPGA functionalities to develop the intended system also falls under this category. While this approach can be fast and efficient alot of times, it might not be able to fulfill performance requirements every time. Full custom design avoids using bought components in the IC design. This is especially beneficial if the system has especially high performance requirements and needs to be adjusted to a very specific application. Every component is designed from the bottom up and can be perfectly adjusted to the customers or companys needs. While this process takes a significant amount of time, it usually provides a higher performance and more efficient hardware. This Paper focuses on Full Custom Design in VLSI while diving into VLSI itself and the differences from the semi custom design approach

A. History of VLSI

The integration of transistors on chips started in a small scale and continued growing due to moores law.

- Small-scale integration (SSI) technology emerged in 1960 and integrated 1-100 transistors on a single chip, e.g. Gates, flip-flops, op amps also seen in figure1 [2].
- Medium scale integration (MSI) developed in 1967 by integrating 100-1000 transistors on a chip, e.g Counters, MUX, 4-bit microprocessor also seen in figure 1 [2].
- Large scale integration (LSI) started in 1972 by integrating 1000-10000 transistors on one chip, e.g 8 bit microprocessors, ROM also seen in figure 1 [2].
- VLSI technology emerged in 1978 and integrates more than 10000 transistors on a single chip as mentioned earlier. It is the most common term used today even for chips with millions of transistors, although these also seperate terms. Examples are older microcomputers, peripherals and 16-32 bit microprocessors [3] [2].
- Ultra large scale integration (ULSI) technology integrates 1-10 million transistors on a single chip, e.g special purpose processors [2].
- Giant scale integration (GSI) integrates more than 10 million transistors on a single chip and is generally used for embedded systems or system on chip [2].

II. VLSI

The term VLSI refers to the amount of functionality integrable on a chip with current fabrication processes. As mentioned earlier, smaller scale chip designs used the lower grade terms such as SSI , MSI and LSI seen in Figure 1.

The engineering resources required to create a VLSI design depend on the complexity. However, determining the complexity of a VLSI design is a challenging task in project difficulty estimation. Insightful comparisons can be drawn between the resources required for earlier designs if a similar methodology was applied. The ability to reuse current physical and logical intellectual property is a key factor to

Table 2.
Components realizable at each level of circuit density.

	Combinational circuits	Sequential circuits
SSI	Gate	Flip-flop
MSI	Adder, multiplexer, encoder, decoder	Register, counter
LSI	ROM, PLA	RAM, PLA, microprocessor, PIO, USART
VLSI	ROM	Microcomputer, multifunctional devices

Fig. 1. Showcase of the used terms and their respective circuits in 1987 from [3].

take into account when creating a project plan [1].

Having done the complexity determination, different objectives exist for the design to fulfill. These are typically:

- Power (power dissipation value) for determining aspects like battery life, electrical delivery and cooling. To fulfill this objective, power calculation flows are used [1].
- Performance (Clock speeds) like clock frequency or periods as well as timing constraints [1].
- full-chip area (PPA targets) determining the the final product cost [1].

A. *VLSI Design Methodology*

There is more to the design methodology than just the steps that need to be taken. It also describes the model build configuration to represent the complete chip logical and physical definitions, as well as the policies in place for chip hierarchy data management. The use of electronic design automation (EDA) software tools at each stage, along with software for design data management and revision control, is a crucial component of the design methodology. Furthermore it is important to manage the output formats of the files in the design methodology to be ready to be submitted to the next tool in the design flow or if it is the final chip design, the submission for fabrication. While the design methodologies for VLSI have not changed substanntially over the years, specific tools and data model features have changed constantly.

III. Full Custom vs Semi Custom Design

Looking at ASIC development, the 2 different choosable approaches differ in alot of aspects.

A. *Semi Custom Design*

IV. Fundamentals of Full Custom Design in VLSI

V. A Full custom VLSI Design flow

As an example to demonstrate the design flow of a full custom VLSI system, a 32-bit micropocessor is used. This microprocessor was developed by the Toshiba corporation in 1989 with a total transistor count of 460 thousand. Further features of the system can be seen in figure 2 [4].

Target System	Controller
Performance	5MIPS
Clock Frequency	25MHz
Process Technology	1.0μm CMOS with two levels of metal
Number of Transistors	460K
Die Size	10.89mm × 10.27mm
Package	155 pin PGA
Number of Instructions	92

Table 1 Outine of TX1

Fig. 2. Features of the full-custom designed microprocessor

Using fully automatic design for control logics and manual design for datapaths effectively is the key to the design methodology used for this microprocessor. The overall design method can be seen in Figure 3 . First, the chip is broken down into four function modules and its specification is explained in plain language. Second, a register-transfer-level (RTL) language is used to describe each function module in accordance with the chip specification. The crucial step in RTL design is breaking down each function module into smaller building blocks that fall into one of three categories: control logics, datapaths, or macrocells like ROMs, RAMS, and PLAs. For control logics, an automatic logic synthesis tool converts the RTL description directly into a logic net, and an automatic standard cell placement and routing tool yields the corresponding layout. On the other hand, the layout and logic for datapaths are manually created on the Engineering Work Station (EWS) [5].

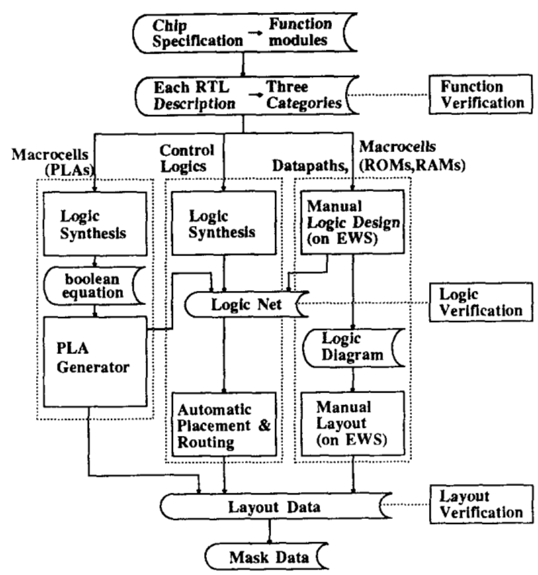

Fig. 3. Optimized design method for the microprocessor "TX1" [5]

VI. Conclusion

i have not finished yet

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Statement of authorship

Hereby, I declare that I have composed the presented paper independently on my own and without any other resources than the ones indicated. All thoughts taken directly or indirectly from external sources are properly denoted as such.

Lippstadt, December 21, 2023

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