A New Master's Program in Integrated Electronic System Design

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ABSTRACT

We present the formation of a new Master's program in Integrated Electronic System Design (IESD). The main ideas behind the program are; 1) Two parallel introductory courses in the first study quarter: One rather practical top-down VHDL-oriented course, and one more theoretical bottom-up silicon-oriented digital VLSI design course. 2) A new broad course focusing on design methodologies from Electronic System Level (ESL) to VLSI, with hands-on emphasis on ASIC backend methodologies. 3) A large project during the first year spring semester in which the knowledge gained during the fall is utilized in design and verification using several complementing technology platforms. 4) Re-use of existing advanced specialist courses (formal methods, computer architecture, and analog VLSI design).

1. INTRODUCTION

The rapid development of best design practices for complex industrial electronic systems calls for engineers with a broad implementation technology competence. This competence ranges from "soft" systems to "hard" circuits, and includes a strong proficiency in a wide range of design and verification methodologies. In the context of current and future requirements in industry and academia, the aim of the Master's program in Integrated Electronic System Design (IESD) is to educate highly qualified electronic system designers [1].

Future electronic system designers must have the competence to efficiently design advanced electronic systems including both software and hardware components. They must have the capability to work vertically from system specification to physical implementation and test, under strict constraints on time-to-market, computational performance, power dissipation and reliability. The engineering role targeted for the student graduating from the IESD program is that of an *electronic system architect*.

2. PROGRAM STRUCTURE AND CURRICULUM

The curriculum of the program has been developed so that the IESD graduate shall be able to accept the entire design challenge - from formulating the specification and collecting the constraints at the system level, down to evaluating the technology platform and designing at the physical level. One important pedagogical principle is that cost/performance trade-offs between different technology platforms and between software and hardware are exposed.

With reference to Table 1, in the first study quarter of the first year, the course *Introduction to electronic system design* applies a top-down view to a practical system design example, through system modeling and component refinement. System design using Matlab and FPGA co-design exemplifies a system-oriented methodology. Since the course also serves as a gate for new students, RTL coding using VHDL is an important part of the content.

Simultaneously, and in parallel to the introduction course, *Digital integrated circuit design* offers a traditional VLSI bottom-up view of a similar system design example, where the influence of quantum-mechanical and electro-magnetic effects in transistors and wires propagate up the abstraction levels, making cost and performance for different styles of implementation and different technology platforms tangible. Here the students are, for the first time, enrolled in hands-on training on custom integrated circuit design, which is forming a foundation for further, advanced custom ASIC training in *Analog integrated circuit design* and in the spring semester project. The special measures that have been taken to increase the examination rate by use of weekly home assignments will be reported separately at this conference [2].

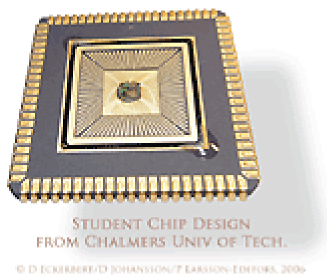

Figure 1. Student project chip design.

Table 1: Courses in the Integrated Electronic System Design Program, year 1.

Fall semester, year 1		Spring semester, year 1	
Study quarter 1	**Study quarter 2**	**Study quarter 3**	**Study quarter 4**
Introduction to Electronic System Design	Computer Architecture OR Analog Integrated Circuit Design	Electronic System Design Project	
Digital Integrated Circuit Design	Methods for Electronic System Design and Verification	*Elective courses*	*Elective courses*

In the second study quarter, the student has a choice to specialize towards higher or lower abstraction levels of design:

1. In *Computer architecture* design issues at the interface between software and hardware are considered, especially in the context of general-purpose processors. A small project assignment revolving around the exploration of processor design space at the architecture level enables hands-on training.
2. The course in *Analog integrated circuit design* focuses on transistor-level design considerations for basic analog IC building blocks, such as amplifiers. The course promotes design proficiency through a series of hands-on laboratory exercises, for which the pre-lab home assignments offer training in hand calculations and the post-lab reports encourage students to reflect on simulation outcomes.

In parallel to the courses above, the IESD program recently launched a new compulsory course called *Methods for electronic system design and verification* [3]: Given that we can integrate billions of complicated transistors and wires on one chip, designers are forced to make extensive use of software tools. It has become a methodological challenge rivaling traditional design challenges intrinsic to logic and circuit design, to apply the right software tools in the right context and in the right sequence. This course aims at conveying an understanding of the electronic system design phases that available CAD-tools are good at handling, and the phases they are not that good at handling. A key feature of this course is a set of new laboratory exercises, involving industrial synthesis and P&R tools, which highlights RTL coding and its relation to physical layout as well as to performance parameters such as timing and power.

During the spring semester, in the comprehensive design project, the theory of the fall courses is applied in the design of a complex prototype electronic system having several different technology platforms; analog ASIC circuits, digital ASIC circuits and digital programmable circuits. In this project all students of the IESD program work towards a common technical goal, but thanks to the differentiation of technology platforms within the prototype system, students have a chance to concentrate on higher or lower abstraction levels, according to previous specializations of their own choice.

During the fall semester of the second year, the students will have the option to choose among a number of elective courses from other related Master's programs. Finally, the program is concluded during the spring semester with the Master's thesis work. The program curriculum was specially structured to take advantage of such synergistic effects involving other master's programs at Chalmers and industry. A new "IMPACT" project (CollabIESD) is currently under way with the aim of supporting such collaborative efforts by gathering teachers, students, researchers, and industry people in one-day workshops with this in focus.

3. Learning Outcome

The new Master's program is a result of the Bologna Declaration that initiated a revision of the undergraduate education at Chalmers University of Technology. Starting from this academic year, 07/08, our education system has been changed from a one-tier integrated Master's education into a two-tier Bachelor/Master education. To achieve this goal, already in 2006 a process was initiated to actively move away from lecture-based teaching to student-oriented learning with clearly formulated learning objectives of the knowledge and skills students were expected to acquire during each course.

Great attention has been paid to formulating the learning outcomes of this Master's program. We will in the following give some examples of learning outcomes expected at the completion of our two-year Master's program:

An IESD graduate will:

- be able to carry out basic design, implementation, and verification of complex integrated electronic systems; from embedded software to analog transistor circuits.
- have specialized in a technical sub-area for which the graduate will be able to analyze new technical challenges and to generate technical advancements - either at higher abstraction levels (predominantly with digital features) or at lower abstraction levels (predominantly with analog features).
- be able to describe the main technology platforms, their characteristics and the development trends that can be expected in the near future.
- be able to describe the prevalent design methodologies, their characteristics and the development trends that can be expected in the near future.
- be able to take design decisions based on their awareness of fundamental …
  - methodological limitations and possibilities of the design flows that represent current best practice.
  - electrical limitations and possibilities of the technology platforms that represent current best practice.
- be able to apply suitable methods to carry out qualified tasks within given constraints where in an industrial context technical parameters must be secondary to constraints associated with economy and environment.
- have skills in applying industrially accepted computer-aided design (CAD) software.

A matrix for mapping the program learning outcome to course outcomes was developed to ensure that the program aims are treated consistently with the overall aims, in the individual courses.

4. Conclusion

The program started this fall (2007) and the first student generation is under way in the program. Our main conclusions regarding the new features introduced so far are as follows: 1) the students need co-designed courses as in Q1 where a bottom-up and a top-down course that meet in the middle not only allow for a motivating design case, but also emulate the complexity of real designs, 2) the new course on methodologies in Q2 connects algorithm theory and hands-on ASIC backend methodology, illustrating the vertical dimension of design (RTL to layout), and providing stimulating and relevant training.

References

[1] http://www.ce.chalmers.se/iesd/

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[3] http://www.ce.chalmers.se/edu/course/DAT110/