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SYSTEM ON CHIP DESIGN: MASTER STUDIES EXPERIENCE AND PROSPECTIVE FOR PhD STUDIES IN MACEDONIA

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1. INTRODUCTION

Embedded systems give intelligence to many devices that we use in everyday life – they are found in everything from mobile phones and MP3 players, over cars and home appliances, to complex controllers. The continuous progress of semiconductor technology has made it possible to implement complex systems on a single chip, which has led to new challenges in design methodologies. Driven by these technological forces, the Faculty of Electrical Engineering and Information Technologies (FEIT) – Skopje with support from TEMPUS JEP_41107_2006 Project 0 has developed an interdisciplinary Master of Science Programme on System-on-Chip design, which couples hardware and embedded software design principles. The programme aims to provide students with competence and skills for designing, analyzing and verifying embedded systems. In this paper, we describe the process of developing the curriculum, the study programme plan, as well as our plans for developing PhD studies in System on Chip Design.

2. BACKGROUND AND IMPLEMENTATION

The Faculty of Electrical Engineering and Information Technologies in Skopje has reorganized the teaching process according to the Bologna declaration starting in 2004. The contents of the courses, as well as the teaching methodologies for both undergraduate and graduate programmes are therefore being restructured in order to meet the requirements of the Bologna declaration. The curriculum of System-on-Chip Design (SoCD), was developed as a master's Programme, with aims to provide students with practical knowledge through laboratory work and practical student projects. Being developed as a part of the TEMPUS Joint European Project sponsored by the European Commission, the Programme has had the support of the European Commission and the project's partner universities from the EU (School of Telecommunication Engineering at Technical University of Madrid, School of Electronics and Computer Science at University of Southampton and Elektronski Fakultet at University of Niš) throughout the entire process of the programme development and implementation. The support comes in terms of training teachers, equipping laboratories, student exchange possibilities and providing books for the university's library, as well as creating and publishing new textbooks and laboratory manuals.

The System-on-Chip Master's programme at FEIT has been developed with the awareness of the need for a cross-disciplinary educational approach, coupling microelectronics with computer science technologies. In order to create our master programme we started with analysis of more master programme form different universities across Europe [3] [4] [5] [6]. As result of this analysis we get draft master programme which was sent to our European partners for revision. Also, in our programme we include experiences and knowledge form our partner form University of Nis 0.

According to Macedonian's Low on Higher Education0: *The second cycle academic studies are conducted in the period of one to two years. After their conclusion the students earn 60 to 120 ECTS credits. The total credits that can be achieved during the first and the second cycle of university studies are 300 ECTS credits. The person that completed the studies with a total of 300 ECTS credits attains a master degree of studies in the given field.* At our university we chose the 4+1 study model, and according to that our master studies last for one year and had 60 ECTS.

Starting form this choice, the study plan includes a 20 ECTS compulsory block, which consists of both low-level and system-level design courses, as well as one compulsory non-technical course. The students also choose 4 out of eleven elective courses, two in each semester, which also comprise 20 ECTS in the study plan. Additionally, students can also choose 10% of their courses (in this case one course) form any other programme form our faculty. Finally, the master's thesis combines the acquired knowledge into an individual research project and totals the last 20 ECTS.

This solution is not completely according the last changes (form March 2008) in Macedonian's Low on Higher Education which state that: *The study programs are made up of compulsory and elective courses. The topics of the compulsory courses are from the suitable area of the University unit, i.e. internal organizational unit (institute, department, section). The contribution of the compulsory courses cannot be above 50% of the number of courses on the study program. The rest of the study program is made up of the elective courses from all of the courses given on the University unit. The students are free to select any of the available elective courses.* According of this, our compulsory courses are not above 50% which is complainant with the law, but we will need to change the status of elective course in suggested elective courses, and allow to a student to choose any other courses from our faculty/university.

3. STUDY PROGRAMME PLAN

The study plan is organised in two semesters. In the first semester of the programme, the student need to take four compulsory courses, as well as chose two electives. The second semester is reserved for the other two electives, as well as the preparation of the master's thesis. The table 1 shows a list of the courses, credits and how they are scheduled.

In order to make easily choosing and combining the courses and getting exactly the needed 60 ECTS we have standardized the number of credits per course to 5 ECTS. All courses (except the non-technical one) are organised with 2 hours lectures per week, 2 hours laboratory per week and 2 hours per week for student project work. For every course the student must complete a practical work, that enable him to apply the acquired knowledge and develops practical and research skills.

Table 1 – System on Chip Design Curriculum Structure

	Title	Semester		Credits		Classes
1	**System on chip design techniques**	IX		5		2+0+2+2
2	**Integrated circuits design**	IX		5		2+0+2+2
3	**Embedded computer systems software development**	IX		5		2+0+2+2
4	**Compulsory non-technical course**	IX		5		2+0+0+4
5	Specialization elective course	IX		5		2+0+2+2
6	Specialization elective course	IX		5		2+0+2+2
7	Specialization elective course		X		5	2+0+2+2
8	Specialization elective course		X		5	2+0+2+2
9	***Master's thesis***		X		20	
	Total			30	30	

The first course, *System on chip design techniques*, aims to provide students with conceptual knowledge about System-on-chip (SoC) design methodologies. The course introduces the basic principles and problems of designing complete SoCs, focusing on hardware, as well as embedded software design principles simultaneously. It also gives an introduction to hardware description languages (Verilog HDL, VHDL and system C), and addresses the problems of testing and verifying SoC designs. Students will also learn how to use Intellectual property (IP) cores for the purpose of designing SoCs. *Embedded computer systems software development* concentrates on tools and techniques for developing embedded systems software and introduces embedded operating systems. Students should acquire good programming practice in an embedded context, using the appropriate software techniques and tools, as well as hardware interfaces. The aim of the *Integrated circuits design course* is to provide students with the knowledge for analysing and designing integrated circuits in CMOS technology. It covers the basic characteristics of the CMOS technology and the principles of designing small digital systems.

The engineers of today are not only required to have professional technical knowledge, but also show some additional skills in order to be competitive for employers: whether it is about how to market a product or to write its technical description. Therefore, the last compulsory course in the SoC Master's programme is non-technical and two different courses are offered as an alternative for the students. The first alternative is *Project management*, where students learn to effectively plan and control projects, identify and deal with risks and write project documentation. *Technical writing and research methodologies* is the second alternative course and the objectives of the course are to prepare students for autonomous research and argumentative, persuasive writing of technical reports and documentation.

The electives courses give students the opportunity of customizing the study programme according to their interests. Therefore, the programme offers a broad spectrum of elective courses, either providing background for nanotechnology and digital system design, introducing cryptographic techniques or covering networking techniques and methods for network analysis. We present the full list of the elective courses, without additional course descriptions, which are beyond the scope of this paper:

- Wireless and ad hoc computer networks
- Contemporary methods for network analysis
- Digital system design using HDL
- System reliability
- Collaborative computer systems
- Digital electronic system design
- Custom purpose networks
- Cryptography
- Process computers
- Nanotechnology
- Analogue and mixed signals design

The studies from the second cycle are concluded by taking exams for every course and defending a master's thesis in accordance to the study program. The students can chose their supervisor for master thesis between professors form which they get at least one course. The defending of the master thesis is done in front of a commission made up of three members that have higher science degrees. Two of the members need to have science degrees in the appropriate subject matter that coincides with the topic of the master thesis.

Students that successfully graduate on the SoCD master's programme can find potential employers in Macedonia in a variety of industries. In addition, there are more companies that are involved in outsourcing embedded software development, and also in creating and developing new embedded devices and software. Alternatively, students can continue with doctoral studies in the same field at the home university.

4. PERSPECTIVES FOR PHD STUDIES IN SYSTEM ON CHIP

According to Macedonian's Low on Higher Education, The PhD studies of 180 ECTS credits are taken in the period of three years. With the public defense of the PhD thesis the candidate obtains the PhD degree (dr. sc.). The PhD studies can be started after finishing the second cycle of academic studies. The university legislates the acquisition of ECTS credits on the PhD studies with a general act and also prescribes the ECTS credits that are needed to supply an application for making a PhD thesis. The PhD studies are concluded by taking exams for every course and developing and defending the PhD thesis (dissertation). The defending of the PhD dissertation is done in front of a commission made up of five members with a respective science degree. Three of the commission members must have a science degree in the appropriate area that corresponds to the doctoral dissertation.

Based on this solution form the low, we are planning creation of ECTS based PhD studies that will begin form October 2009. Because, form beginning of this year we are part of integrated university, some parts of regulations will be common for all member faculties.

Our considerations about PhD studies organization are similar to a solution that is used by Faculty of Electrical Engineering and Computing at University of Zagreb. Our proposal is to have 36 ECTS form courses (6 courses with 6 ECTS), and other ECTS required the student must acquire trough research work. The PhD thesis it self can be 60 ECTS. The rest of 84 ECTS the student will need to take as reward for published research papers. In research work are included publication in domestic conferences (12 ECTS), domestic journals (18 ECTS), international conferences (24 ECTS) and international journal (48 ECTS).

5. CONCLUSIONS

In this paper the presentation of Master programme for System on Chip Design at Faculty of Electrical Engineering and Information Technologies – Skopje was given. The master programme was realized with help of TEMPUS JEP_41107_2006 Project. We also give short explanation of parts of Macedonian's Law on Higher Education that are connected with Master and PhD studies. The plans for creating three years PhD studies for SoCD are also presented.

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