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Computer Engineering Laboratory Course: E2LP Platform Experience

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Abstract – In this paper, the preliminary results of E2LP Base Board platform introduction to students of Faculty of EE and Computing - master programme enrolled in Laboratory of Computer Engineering 2 course are presented and discussed. The aim of introduction of new hardware unified platform was to improve practical skills and experience in embedded system design. The students embraced the new platform with enthusiasm and were eager to give the feedback in order to point out the strengths and weaknesses of this platform. The collected information will be a valuable asset for future improvement of the platform.

Keywords **– course development; hardware platform, Computer Engineering Laborator*y***

I. INTRODUCTION

EMBEDDED systems design is a rapidly expanding field growing more diverse as new technologies emerge. While this is an interesting discipline attracting more and more students each year, at the same time rising complexity is rather difficult to master. The working environment is dissimilar from the one peer students enrolled in computer science and engineering programmes encounter (PC and laptop computers). Embedded system design requires comprehensive knowledge and skill for dealing with a wide range of different hardware and software architectures . What is more, because these area is highly related to high-tech industry, the knowledge passed on from teachers to students must be in line with the current standards [2][5].

The goal of Faculty of EE and Computing (University of Zagreb, Croatia) is to provide the students with relevant knowledge and practice in the field of interest. Since the Faculty is one of the E2LP project partners, in academic year 2013/2014 the E2LP platform has been introduced in several courses as a pilot project for testing the new learning platform. In this paper the results of introducing the platform to students enrolled in master programme course Laboratory of Computer Engineering 2 are presented and discussed.

The rest of this paper is organized as follows: Chapter 2 provides general information about the Computer Engineering Laboratory course and the students enrolled in the course; in Chapter 3 the details about laboratory exercises and working environment are given; Chapter 4 discusses the results scored by students together with their feedback and in the final chapter the overall conclusion is given.

II. COMPUTER ENGINNERING LABORATORY COURSE

Computer Engineering Master programme [1] embodies research, design and implementation of computers, computer systems and related software. It includes in-depth knowledge of theory and practical aspects of the design and implementation of computers, computer based systems, mobile and embedded devices/computers, communication systems and other systems that incorporate computers as well as software design with emphasis on applications that require knowledge of the complete system. Computer engineering program provides system based approach to the design of computers, communication system and software as a whole. This program offers core, advanced and forefront knowledge required to creatively envision, conceptualize and design innovative, from simple to complex computers, computer based systems and applications running on those platforms.

The Laboratory of Computer Engineering 2 is a second semester course consisting entirely of laboratory assignments aiming to give the students the chance to put to practice the theoretical knowledge obtained through the study [3][4]. This course is intended to provide practical skills complimentary to theoretical knowledge for students enrolled in two of the following four courses: Computer Systems Reliability, Digital System Design, Real-time Operating Systems and Formal Methods in Computing Systems Design. The exercises try to cover the areas of digital system design, real-time systems, reliability analysis and testing.

A. Students partaking the course

In the summer semester of academic year 2013/2014 twenty five students were enrolled in the Laboratory of Computer Engineering 2 course. The students come with a very diverse background knowledge with respect to embedded system design, which was the core of the Laboratory of Computer Engineering Course 2 in summer semester 2014. The only course which all students have taken is Embedded Systems during third year of Bachelor programme. The majority of students have taken the course Tools for Digital Design and some have taken the course Embedded System Design. The diverse range of prerequisite knowledge about embedded systems the students have, makes designing laboratory task targeting that matter quite a challenge. What is more, the students themselves are not very confident in the knowledge and skills they poses. In the initial questionnaire, given to students before the course started, on the scale from 1 to 5 they have graded their knowledge of VHDL with 2.4 and skill using Xilinx tools 2.3. However, they have demonstrated the eagerness to learn something new and different in hope it will help them improve their knowledge and skills and possibly prove as an asset in the future development of their careers.

III. Exercise Overview

As mentioned earlier, the Laboratory of Computer Engineering 2 consists only of laboratory exercises. Throughout the semester students are given several problem solving exercises or small projects to gain knowledge and practical skills related to embedded system design.

In summer semester of 2014 the E2LP platform [6][7] was introduced to the course for the first time. The entire set of exercises was written from scratch to focus more on embedded system design and better suit the platform capabilities.

In the rest of this chapter a more detailed insight into the matter covered by the exercises and working environment will be given.

A. Details about exercises

During the semester students did four problem solving exercises on E2LP platform, which were designed to help students gain practical skill and experience in embedded system design.

In the first exercise students were given the task to design their own UART controller for E2LP Base Board platform using VHDL and Xilinx ISE tools [8][9]. This task was intended as an introduction aiming to help students refresh the previously acquired knowledge about basic digital system design.

The following three exercises were more challenging, focusing on designing a more complex system comprising programmable processor, dedicated hardware accelerators and peripheral controllers. Along with the hardware platform, application software was developed too. The idea behind these exercises was to give students a complete overview of embedded system design process – from hardware platform to OS and application software. Higher complexity of these tasks required using more advanced design tools like Xilinx EDK [10][11].

In the second exercise students were required to design a system consisting of programmable MicroBlaze RISC processor [12] connected with basic peripheral controllers (DIP switch, LED and UART). All components of the system were already present as IP cores available as a part of Xilinx EDK Design Suite. After the initial system was implemented and tested, the students had to replace the existing UART core with their own, designed in the previous exercise.

The third exercise introduced multiprocessor system concept to students. They were given the task to design their own matrix multiplier IP core which would serve as a coprocessor to MicroBlaze. While in the second exercise a simple AXI4-Lite [13] bus interface was appropriate enough to connect all the components in the system, the third exercise required the use of more advanced AXI4 bus interfaces. This provided the students with the opportunity to learn more about the AXI4 bus architecture, one of the most prominent bus architecture standards today.

In the last exercise the emphasis was put on design of software for embedded systems, with operating system kernel at the core. Students were given precise instruction on how to configure the hardware platform (consisting of MicroBlaze processor and basic peripherals) so it would be possible to add a minimal operating system kernel on top of it. The target kernel was *xilkernel [14][15]*, specially designed for MicroBlaze processor family.

It must be noted here that a small group of students enrolled in a Digital System Design course did not perform the fourth exercise, but were given a small project as a part of that course. This project also involved designing a SoC with MicroBlaze controller and a set of peripherals, also targeting E2LP Base Board platform.

B. Working Environment

All four exercises targeted E2LP Base Board platform. The components used were the following:

- Spartan 6 FPGA module – for implementing the system designed in VHDL;
- DIP switch, LED and RS-232 interfaces through which the system implemented on FPGA communicated with outer world.

As for the development environment, Xilinx tools ISE and EDK were used. ISE tool was intended for designing a single component (UART controller, matrix multiplier) and EDK for system integration and designing application software. These particular tools were chosen because they are widely used in both education and industry, which implies the students would gain valuable practical knowledge they can put to use in their future careers.

IV. Results and Feedback

Upon completion of each exercise, the students were graded and given a short questionnaire about their satisfaction with the exercises. In this chapter both the results the students have achieved and the feedback they

Table 1 Lab Scores

	Lab 1	**Lab 2**	**Lab 3**	**Lab 4***
Total completion	25/25	7/25	7/25	10/15
Minor errors	0	3/25	10/25	5/15
Mostly solved (>60%)	0	15/25	8/25	0
Unsolved or major errors	0	0	0	0

*other 10 students did DSD project

gave through the questionnaires are presented and discussed.

A. Lab Results

The results students achieved in each exercise are given in Table 1. Task completion was expressed using four levels: total completion, minor errors (the system behaved as expected most of the time but some glitches or crashes were possible), mostly solved (some of the required functionalities were missing) and unsolved or with major errors. For each laboratory task the number of students achieving each level of task completion is stated: for example the entry “7/25” under “Total completion” in “Lab3” means that 7 out of 25 students were able to fully complete the exercise.

The statistics show that the second laboratory task was the most difficult for majority of students. This is not surprising since this is the first exercise concerned with SoC design, the subject most students were not very familiar with up to that point. The third lab has also proved to be quite challenging, but the number of students who managed to solve the task entirely or with minor errors has significantly improved.

The significant improvement visible in fourth exercise is not so much the result of a major leap in students’ knowledge level, but more the result of shift of focus from hardware to software design, the topic most students are more familiar with.

B. Student feedback

After each exercise, students were given a short questionnaire about their experience and satisfaction with the laboratory exercise. The questions were the following:

1. On a scale from 1 (lowest) to 10 (highest) how would you grade clarity of theoretical background - documentation, theoretical explanations?
2. On a scale from 1 (lowest) to 10 (highest) how would you grade clarity of technical instructions, exercises and problems?
3. On a scale from 1 (lowest) to 10 (highest) how would you grade total time and efforts required?
4. On a scale from 1 (lowest) to 10 (highest) how would you grade ease of use of the environment - Xilinx software and BIN download software?
5. On a scale from 1 (lowest) to 10 (highest) how would you grade ease of use of the E2LP platform?
6. On a scale from 1 (lowest) to 10 (highest) how would you grade feeling of immersion - being part of the environment, control over the system?
7. On a scale from 1 (lowest) to 10 (highest) how would you grade to what extent do you think you learned something valuable?
8. On a scale from 1 (lowest) to 10 (highest) how would you grade the overall satisfaction with this laboratory exercise?

The results of all four questionnaires are graphically represented using a chart in Figure 1. From the chart it

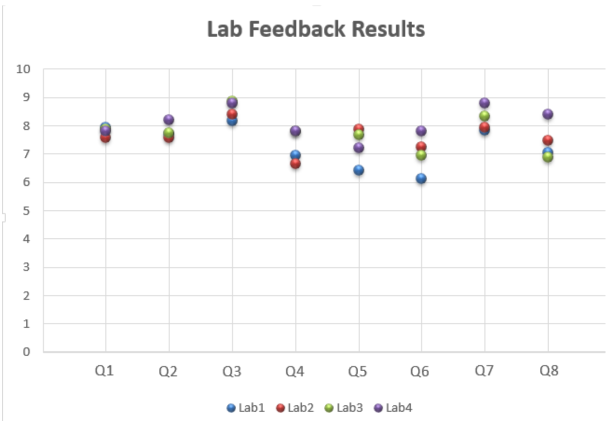

Figure 1 Lab Feedback results

can be seen that the overall impression about the exercises was very good (7 - 9 on the scale from 1 to 10) but the effort invested in solving them was also rather high (8 – 9 on the scale from 1 to 10).

The first two questions were about the satisfaction with the exercise material. The satisfaction was very good (average sore ~ 8) and there is no significant difference between the four exercises. As for the effort invested in solving the exercises, the third and fourth exercise proved to be the hardest (average score ~ 8.5). This is not surprising since the matter covered by these exercises was the most complex. Despite the issues with download software and platform drivers, the overall impression with the working environment was rather good (~ 7), but it can be noticed that the fourth exercise, when the JTAG platform cable was used instead of E2LP download software, was rated the best. Finally, very high scores (~8.5) were obtained for the question about learning something valuable, with visible increase in score as the exercises progressed. This is expected since every exercise was an upgrade from the previous one. As mentioned earlier, the overall impression with the exercises was very good (~8), with the fourth exercise leaving the best impression.

The students had also the opportunity to give written comments for each question. The comments can divided into three categories: positive aspects of the exercise (what students appreciated), negative aspects (critics) and recommendations for future development.

The most common positive comments in the questionnaires were:

- Satisfaction for being able to put theoretical knowledge to practice;
- Learning new skills in embedded system development which can be useful in the future (CV, employment);
- Good support from teaching staff.

The most common negative comments were:

- Platform malfunction (faulty drivers and download application software) happens several times during one exercise which causes frustration and delay.

- Exercises being too difficult/not enough time;
- Lack of prerequisite knowledge;
- Trouble dealing with extensive documentation (other than basic platform manuals);
- Xilinx environment being non-intuitive.

Finally, suggestions for future improvements can be summarized to:

- Fix driver and download application issues;
- Make platform software portable to Linux;
- Learn more about debugging using test benches and simulation.

The feedback results show that the introduction of the E2LP platform was accepted as a welcome change from the regular curriculum even if it required investing more effort in solving the exercises. The students were eager to learn something new and they saw working with this platform as an opportunity to gain valuable new skills in embedded software design, which might help them in their future studies and career development. They were aware that this platform is still in the very early stage of development and production, and thus showed a lot of understanding for the hardware and software issues encountered while working with the platform.

V. Conclusion

The results of pilot introduction of E2LP platform to course Laboratory of Computer Engineering 2 show that the students were able to cope with the given platform and a bit more advanced tasks than usual. The students were aware that they were learning something new and gaining valuable practical skills. They especially appreciated the feeling that they were doing something very close to the “real life” problems and thus willing to invest more effort.

The adoption of this new platform required additional effort from both students and teachers. While students were required to learn many embedded systems design concepts they haven’t encountered in their previous study, or have learned in theory but never put to practice, the teachers had to design new exercises to reconcile the students background knowledge, study programme and platform capabilities.

During the use of platform throughout the semester some issue regarding the platform itself, drivers and application software were observed, but both teachers and students understood it as “infant illnesses” related to early production stage of the platform. In the end, the pilot introduction of E2LP platform to this course can be regarded as successful from both subjective impression given by students during the course and the overall results in the form of students achievement and feedback. It must also be noted that the students have been very cooperative in giving their feedback as long as they felt it was going to make a difference.

To make this platform even better several improvements can be suggested. First of all, enabling remote access to this platform and all of its functionalities would eliminate the need for students to come to the laboratory to do their exercises and thus save a lot of time and effort. Second, additional interfaces for connecting common types of simple peripherals (sensors, step-engines etc.) along with power supply ports of different voltages would be much appreciated. A possible suggestion for peripheral interface expansion would be to provide a proto-board which could use the existing mezzanine interface to connect to the main board. Finally, a public website with all the available materials related to this platform and some sort of means to report bugs or just ask for assistance would significantly improve the platform experience.

References

[1] Faculty of Electrical Engineering and Computing, “ECTS Information Package for Academic Year 2013/2014 – Course Catalogue, Graduate Study”, http://www.fer.unizg.hr/_download/repository/2013_FER-EN-ECTS_Information_Package-Course_Catalogue-Graduate %5B4%5D.pdf, 2014.

[2] G. MacBride, L. Hayward, G. Hayward, E. Spencer, E. Ekevall, J. Magill, A. C. : “Engineering the Future: Embedding Engineering Permanently Across the School-University Interface”, IEEE Trans. Educ., vol. 53, no. 1, pp. 120-127, 2010.

[3] H. Mahmoodi, A. Goel, C. Chen, H. Jiang, W. Pong, H. Shanasser, A. Montoya, J. Du Franco, C. Rodriguez, J. Carrillo, A. Enriquez, “Hands-on teaching of embedded systems design using FPGA-Based tPad development kit”, Proceedings of the “2d Interdisciplinary Engineering Design Education Conference – IEDEC 2012”, Santa Clara, California (USA), March 19, 2012, pp.1-6, ISBN: 978-1-4673-0840-3

[4] V. Subbian, V., C. Purdy. “Redesigning an Advanced Embedded Systems Course: A Step towards Interdisciplinary Engineering Education.” *IEEE Integrated STEM Education Conference*, Princeton, NJ, March 9, 2013.

[5] Zilic, Z.; Karajica, B. "Training for inter-disciplinary multi-sensor system design at all levels", Interdisciplinary Engineering Design Education Conference (IEDEC), 2012 2nd, On page(s): 7 - 9

[6] E2LP Consortium, “E2LP Base Board – Getting Started Manual,” http://www.fer.unizg.hr/predmet/lri2, 2014.

[7] E2LP Consortium,” E2LP Base Board – Technical Reference Manual”, http://www.fer.unizg.hr/predmet/lri2, 2014.

[8] Xilinx, “ISE Design Su*ite”*, http://www.xilinx.com/products/design-tools/ise-design-suite/index.htm, 2014.

[9] Xilinx, “ISE In-Depth Tutorial”*,http://www.xilinx.com/support/documentation/sw_manuals/xilinx12_4/ise_tutorial_ug695.pdf*, 2014.

[10] Xilinx, “EDK Concepts, Tools and Techniques”, http://www.xilinx.com/support/documentation/sw_manuals/xilinx14_1/edk_ctt.pdf, 2014.

[11] Xilinx, “Platform Studio and the Embedded Development Kit (EDK)”, http://www.xilinx.com/tools/platform.htm, 2014.

[12] Xilinx, “MicroBlaze Soft Processor Core”, http://www.xilinx.com/tools/microblaze.htm, 2014.

[13] Xilinx, “AXI Interconnect”, http://www.xilinx.com/products/intellectual-property/axi_interconnect.htm , 2014.

[14] Xilinx, “OS and Libraries Document Collection”, http://www.xilinx.com/support/documentation/sw_manuals/xilinx14_5/oslib_rm.pdf, 2014.

[15] Xilinx, “Using EDK to Run Xilkernel on a MicroBlaze Processor”, http://www.xilinx.com/support/documentation/sw_manuals/xilinx13_4/ug758.pdf, 2014.