Some ideas on reforming electronic engineering studies at the University of Belgrade

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Abstract – Problems and possible solutions in restructuring the entire curriculum in electronic engineering at the University of Belgrade are presented. First results in the reform are also presented.

Introduction

The work described here is a part of our effort to restructure the entire electrical engineering curriculum so that it allows the integration of our faculty into the European family of higher education (Bologna declaration). We aim to develop undergraduate and graduate programs for electronic engineers by adapting the content, structure and methodologies, which will give students the possibility of getting the diploma in less time, while gaining more practical knowledge.

There are many nicely planned and carried out curricula on universities with large resources, mostly in USA, EU, Australia and Canada. Just by searching relevant jurnals in education, one could find very interesting ideas on how to reengineer the electrical engineering curriculum to keep pace with technology. For example, practicaly the whole issue of IEEE Transactions on Education was recently dedicated to visions on ECE education in the future [1]. One could ask why not reproduce them at universities in Serbia, specifically at the University of Belgrade. We think that it is not possible, since our university, like the majority of world's universities, has to deal with the problems of lack of resources, both for computer and lab equipment which is inadequate in quantity and quality, and for financing the work of their staff. That means that some new ideas have to be introduced. On the other hand, we do try to modify to our cirumstances some of the many succesful ideas implemented at other universities, for example [2].

We will first state the most important problems in higher education in Serbia, with some outlines of possible solutions. A description of our proposed curricula follows, with a short description of our pilot course.

Problems and Some Solutions

There is a myriad of problems facing the faculties and faculty staff at the universities in Serbia, most of them shared by the majority of world universities. These problems restrict the ways in which courses can be taught. Here are some of them:

1. The lack of equipment (lab equipment, computers and software), and the lack of space. With the continuous lack of money facing most faculties, this problem is getting worse instead of better in both hardware and software. The hardware problem intensifies as the existing equipment gets outdated or broken without any means of replacement. The software problem is also getting worse, since unlicenced software use, so common until recently, is no longer possible, and many universities are left practically without any software.

The laboratory equipment problem is the worst. For example, our department's only student lab has 13 oscilloscopes, all of them over 15 years old. This lab services more than 1500 students, and hence it has to be open from 8 AM to 22 PM, six days a week. Even with this intense schedule, the number of lab sessions per student had to be reduced from the planned number (which was originally already low), in order to accommodate all the students.

Maybe this group of problems is the hardest to solve. At this point, we found only some partial solutions. For example, all student simulations and designs are restricted to PCs (solving both the space and part of the computer equipment problem by enabling students to work at home). The software problem we try to solve by extensively searching for free software packages or those that can be inexpensively obtained for university purposes. For the lab equipment problem we could not find a general solution, but we partially solved our problems by applying and obtaining funds from the European Commition [3].

2. Overload of professors, and even more, teaching assistants. This overload is due to a large number of teaching hours per week per teacher and to a very high student/teacher ratio. Additionally, the teaching staff is very poorly paid, so that most have to take additional jobs and so have even less time to develop new teaching materials. For example, the Head of our Department, in addition to his organizational duties, teaches 8-10 classes per week. The student/teacher ratio for first electronics courses is over 70 (one professor and two teaching assistants for a group of 250 students).

Until a better and more general solution is found, we try to implement the courses in such a way that the load presented to the teaching assistants and teachers is minimized, while improving the quality of classes. One example is described in Section III.

3. Students are not required to attend lectures, can take exams at almost any time, even years after they enrolled in the course, and have the right to pass to the next level (year of study) without finishing all of the obligations of the previous level. In practice this means that most students enrolled in advanced analog electronics, for example, have not yet passed the introductory electronic course exam.

This is a very problem to solve, since the professors do not have any influence on changing any rules of study (it's all written in the currently binding "Law on University" [4]). It's even impossible to introduce the notion of "requirements" for the courses. (Some of the stated problems may have solutions in the new law on higher education, but it is questionable when will it be passed by the government.) We, unfortunately, do not have any solutions to this problem except indirectly, by improving the way of preparing students for the exams, and thus raising the pass/fail ratio.

4. The students are concentrated only on passing exams (getting their diploma), and not on how much they learn in the process. Using other's work is very common. The problem is worst when projects are in question. Since it is frequently impractical to prepare and grade different projects for every student, we plan to, at least, have new projects for each course in each semester. Since restrictive policies are to be avoided, positive motivation should be employed in order to make the whole class do the projects at the same time.
5. The procedure of changing anything in the curriculum or way of study is complicated. On one side, all structural and legal changes depend on the Government, and thus the professors do not have direct means of influencing them. In this category is the duration of studies, student/teacher ratio, number of exam periods, etc. On the other side, the majority of professors at Serbian universities are older, not very keen on changing anything, wanting to keep all the courses as they are used in teaching them. Thus, it is extremely difficult to eliminate/drastically change any existing course from the curriculum, leading to a narrow field in which any changes have to take place.

There are many other difficulties stemming from one or a combination of several of above stated problems. Maybe the most noticeable is the resulting duration of studies.

At this point, the official duration of undergraduate studies is 5 years: 9 semesters, with approximately 380 lecture-hours per semester, plus one semester for the bachelor Thesis. This is longer than at universities in many other countries, putting our faculty at a disadvantage. The problem is even greater when real duration of studies is considered: more than eight years to get the Bachelor diploma. (The comparative statistics are even worse when looking at time needed to obtain the MS degree.) All this resulted in, among other things, a decrease of interest of high-school students in studying at our institution. For example, in the eighties there were over 1500 applicants for 320-entering student class, and most of them were the top students from the whole country; last year we had 900 applicants for the entering class of 450, among them only around 150 exceptional high-school students (when taking into account their high-school GPA and their success at the entrance examination). Thus we enter a circulus vitiosus, steadily increasing the average duration of studies.

Department of Electronics

Our department has nine professors, eight teaching assistants, and four additional staff. It is responsible for all general electronics courses at the faculty level, as well as the specialized courses within the electronic major (last two years of study). The areas covered by our department are: analog and digital electronics, signal processing, VLSI design, computer engineering, power and industrial electronics, instrumentation and measurements, and telecommunication electronics.

At the moment, around 40 students of each class are majoring in electronics. We expect that this number will rise in the following years[1]. The prospects of finding jobs in the industry for electronic majors are looking good (no unemployed electronic graduates).

In order to give better education to our future students, our department started planning a profound reform of curricula a year ago. This coincided with the trend at the University level to adjust our university level education to the European standards. Although there is still no legal regulative in place, we assume that finally our higher educational system will be based on the Bologna Declaration. The curricula will be composed of one-semester European Credit Transfer System (ECTS) compatible courses, with two semesters per year, and 30 credits per semester [5]. The bachelor diploma will be obtained after four years of study, and the masters after one additional year.

New teaching methodologies will be introduced, with strong emphasis on practical training of the students, and mandatory student projects in all of the advanced courses. The modular structure will be introduced and the new curricula will enable student mobility (EU and regional) with full recognition of previous work. The information and communication technology will be widely used to enable students to have access to all information about their courses, grades, lab sessions, etc.

Our basic goals are:

1. Students should get, as early as possible in the course of study, the fundamental understanding of electronics and become proficient in analysis, design and realization of electronic components, circuits and systems.
2. The students should become acquainted with other fields of electrical engineering, such as telecommunication, control systems, computing and power engineering.
3. Students should acquire enough knowledge to be able to design complex systems including microprocessors, microcontrollers, DSPs and FPGAs.
4. Students should have the flexibility to chose the course of their studies, especially within their major.

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[1] One of the indication of this rise is the number of students enrolled in the new elective course “Introduction to Electronics” in the first year of studies: over ninety.

In order to be able to achieve our goals, we decided to start with electronic major in the second year of study. This means that each department would have one or two basic courses with a very large number of students from other departments, and many more advanced courses just for students of their department.

Proposed curriculum

There will be 4+1 groups of courses in our proposed curriculum:

First group: Basic courses. These courses should give students the fundamental knowledge needed in engineering. Most of these courses are planned for the first two years of studies and are common to all majors.

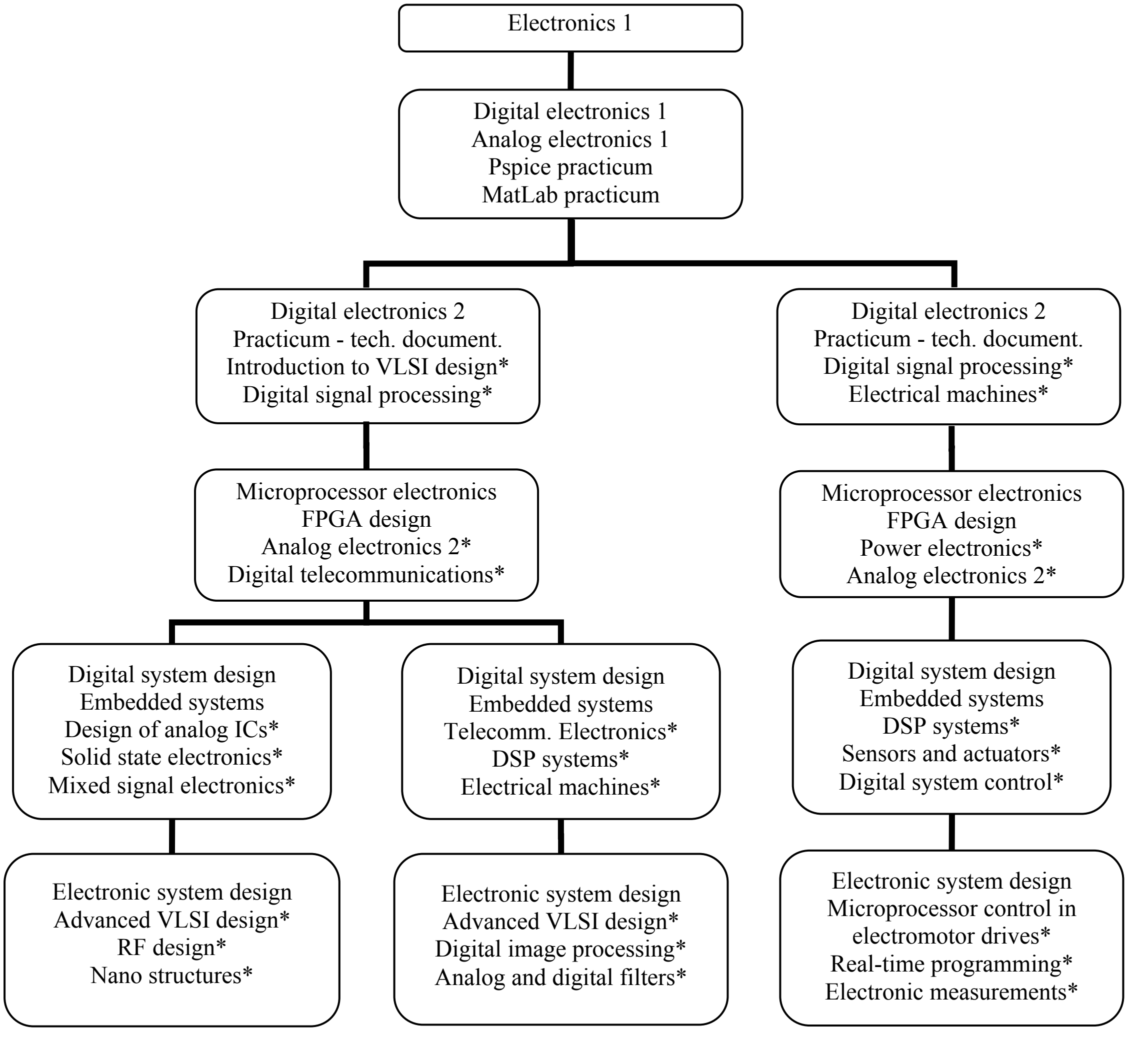

Figure 1. *A sketch of the proposed curricula. The asterisk stands by the elective courses.*

Second group: Basic electronic courses. These courses cover the basic areas of electronics. There are four obligatory courses in this group for the electronic majors[2]. The first course in analog electronics (devices and simple circuits) is in the third semester, and the first digital electronic course in the fourth. This enables planning advanced courses in third and fourth year. In this group there will be another two courses, one digital and one analog, for the students of other majors.

Third group: Basic courses from the other electrical engineering disciplines. One or two basic courses are planned in the following areas: telecommunications, control systems, software, and power engineering.

Fourth group: Advanced electronic courses. These courses will enable a narrower specialization in one of the before mentioned areas of electronics and will all be elective. They will be divided into groups, each group leading to a different specialization (sub-major). At least one sub-major will be required, with two being the norm. The same courses will be offered in the graduate studies, allowing the master students either to get a wider knowledge, or to go deeper into the subject chosen in their undergraduate studies.

Fifth group: Other courses. This group consists of courses in languages, technical writing, management, etc.

The proposed curricula outline is shown in Figure 1.

For example, one electronic sub-major mentioned in the Fourth group above, will be IC design. There will be at least five courses offered by our Department in this group (Introduction to VLSI design, Design of analog ICs, FPGA design, Advanced VLSI design, and RF design), with no limit to the number of courses that can be added. In this group there will also be a list of relevant courses from the other departments (for example, Solid state electronics, Nano structures, etc). In order to get IC design sub-major, student will be required to take the first course and chose another three from the list.

Every level on Figure 1 represents one semester, starting from the third semester (Electronics 1). In the fifth semester students chooses two of the offered electives, on the basis of which they get their sub-majors in the last two semesters. Only electronic courses pertaining to sub-majors of IC design and power electronics are shown on the chart. Also shown are two of many possible combinations of courses for the sub-major IC design (with required course "Introduction to VLSI design"). The left branch shows a path a student interested only in IC design would follow. The right shows what path would follow a student with interest in both IC design and signal processing .

Another aspect of our proposed curriculum is shown in Figure 1: the courses are not “anchored” in pertaining semester as is the practice in practically all Serbian faculties. Instead, all elective courses offered in the fifth and sixth semesters are open as well for students in the seventh and eighth semesters (for example "Electrical machines", see Figure 1). Thus, if a student wants a very wide knowledge, he can get it by choosing a greater number of basic courses (albeit on the expense of some of the advanced courses).

In order to help students with the practical aspect, several “small” courses (called here practices) are introduced. These are mostly computer skill courses, and serve as support courses for one or more core courses.

Most courses will have either a project or intensive lab exercises. Laboratories will be modernized in order to provide students with the knowledge they would easily apply in their everyday professional practice. This part of education will be extensively addressed in new

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[2] This does not include the “Introduction to Electronics”, offered as elective in the first year, and having the purpose to enable the students to make an educated choice of their major.

curricula, since the lab work is the worst part in the present curricula. We plan to introduce new equipment, and to create new laboratory exercises, as well as introduce term projects in all advanced courses. A pilot course for this idea is described bellow.

An Example: One Course Implementation

As a pilot-test of how our ideas of course organization would be implemented, we restructured the course titled Introduction to VLSI design in the 2002/3 school year.

We decided to enable students to go through the whole IC design cycle in this course, from architecture level to the mask level, with the exception of silicon compiling and testing fabricated ICs. (This enables students to do complex design projects independently in the Advanced VLSI course.)

First, why the exclusions? Although the students could learn a lot by compiling their projects and comparing the results with their full-custom implementations, we decided to skip this step because we could not find any silicon compiling software that was at the same time good enough and free. Additionally, it is planned that the students will do more VHDL programming in the course based on FPGAs, and there they will go all way through the synthesis and testing.

The testing was omitted since fabricating ICs is above the means of our university, as well as obtaining the equipment necessary for testing. Additionally, there is no time to fit the design, fabrication and testing into one semester course.

Another question to be argued is why include mask level design in an introductory course. Many professors claim that mask level design is only for those few students interested in microelectronics, and that most VLSI courses, especially introductory ones, should be based solely on high-level design. Contrary to that opinion, it is our belief that it is difficult today, and will be practically impossible in the future to design systems without understanding the transistor and interconnect level. The digital design is becoming progressively more difficult, and digital engineers are less well equipped to face the problems encountered in high speed design than they were 30 years ago, since most of them have very little knowledge of analog electronics and magnetics, resulting in failing of many high-speed design projects [6]. By including mask level design and SPICE simulation of obtained cells, as well as IRSIM simulation of the whole project, the students are given the opportunity at least to see the difference between the intended and real circuit operation.

Organization of the course

The students work in groups of two, thus making the project progress faster, and also getting them used to team work. Team work is almost nonexistent in education systems such as ours, and we think it is very important.

The work on the project starts with the stage of literature search, mostly through the web[3]. The choice of architecture and VHDL design and simulation follows. The students are given most of the code, to enable them to simulate a relatively complex system, not just the small part they designed[4].

The low-level design of a part of the system is then done in Magic, simulations of designed cells in Spice, and simulations of the whole design in IRSIM. All mentoned software and where to find it is described in [7].

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[3] A byproduct of this step is that we introduce the student to IEEE publications.

[4] Obviously, in order for this to work for some projects, the literature search described previously is guided so that they come up with the architecture we have already chosen in advance.

In order to ensure that students not only learn how to design, but also learn how to present their work, each group has to write a formal report/documentation on their project, as well as prepare and give a short presentation of their project. A lot of emphasis is placed on this part of the project, since the authors feel that our engineering students are not prepared at all for this part of their future engineering jobs.

The projects for the next year are prepared by the best students of each class (guided by the teacher). In that way we solved the problem of excessive teachers' time needed for preparation of big student projects. Several students can be found in each class who are enthusiastic enough to do more work than required for passing the course, at the same time obviously learning much more, not only in the course subject, but also in organizing, preparing teaching materials, and teaching itself. Since these students are usually the top students of their class, many of them will end up in academia, and this is a good way to begin preparing them for that carrier (a useful byproduct of the proposed idea).

In order for our idea to work, we had to solve an additional locally specific problem: how to force the students to do their projects on time, i.e. during the semester when the lectures are held (otherwise, there would be no way of helping them through the project, and the whole idea would fall on the fact that one or two groups would do the project as intended, and the rest will just use their results). We succeeded in doing it by having the first exam after the semester much easier than the exams during the rest of the year, and having a fixed deadline for the submission of project reports at the beginning of the next semester[5].

Conclusion

The proposed changes of the VLSI design course were warmly welcomed by the students, as they realized that it gives them a better quality of education, with much greater practical experience through project work. Especially satisfied were the students who continued with the advanced VLSI course, since they are now able to do very complicated projects in that course. Our efforts were also recognized by the European Commition, which approved our TEMPUS project proposal [3] based on the idea presented in this paper, and which will enable a much wider implementation of our curriculum change ideas.

The success of this pilot-course gives us hope that our whole idea would also be successful. We hope that it will give students a better quality of education, with much greater practical experience through numerous project works, and, even more importantly, will enable students to finish undergraduate studies within a reasonable period of time, thus helping the economy of the region on one hand by lowering the price of educating an engineer, and, on the other hand, giving the society better educated engineers at a younger age.

References

[1] *IEEE Transactions on Education*, Volume 46, No. 4, pp 405-485

[2] W. Director et al.: "Reengineering the Curriculum: Design and Analysis of a New Undergraduate Electrical and Computer Engineering Degree at Carnegie Mellon University", *Proceedings of the IEEE*, Vol. 83, No. 9, pp 1246-1268

[3] *Tempus CARDS Joint European Project* JEP 17028, http://www.tempusscg.net/year2002.htm

[4] *Službeni glasnik Republike Srbije*, Volume 54, No. 20, Beograd, 28. May 1998.

[5] http://europa.eu.int/comm/education/programmes/socrates/ects_en.html

[5] The students that do not hand in their reports by that deadline, loose the right to hand it in at all, and have to wait for the next round of projects.

[6] H. Johnson, “Why Johnny Can’t Design a High-Speed Digital System”, *DesignCon*, Santa Clara, CA, 2003
[7] A. Pavasović, J. Popović, "Small Budget, Project Based, VLSI Design Teaching Method", in *Proc. MIEL* 2004.