Colloquium on higher education of electronic engineering in Serbia

Faculty of Electronic Engineering, May 18, 2004,
organized within the MIEL'04 Conference

Niš, January 23, 2004.

Dear colleague,

Within the Tempus CD_JEP-17028-2002 a project is undertaken for innovation of the curriculum in Electronics at the faculties teaching electronics in Belgrade, Niš, and Novi Sad. The realization of this project coincides with the initiative that started one year ago at the Chair of Electronics at the Faculty of Electronic Engineering in Niš. Now we propose these two initiatives to meet at a "Colloquium on higher education of electronic engineering in Serbia" that would take place on May 18, 2004, at the faculty of Electronic Engineering in Niš, during the MIEL'02 conference. In the next an attempt will be given to explain the possible goals and scope of this meeting. Also the way in which it should be organized will be proposed. A list of possible invited speakers will be given, too.

Electronics, alike any other trade, becomes more and more influential on the human society. The reason for that is mainly due to the fact that the very electronic products are produced in huge quantities so interfering with every one's life. In addition, electronic subsystems become part of almost any industrial product nowadays. This is why the educational institutions on electronics are so widespread and why tremendous interest for studies of electronics is present for a long period of time. To have such influence, however, this trade should cope with several circumstances, two of which will be mentioned here.

Being one of most influential trades, electronics asks for responsibilities in higher education. The way how and what the students are thought in school now, will undoubtedly influence the human society tomorrow. And tomorrow means short and long term. From the other side, thanks to the fast advance of the trade the amount of knowledge whiten it is rising exponentially imposing specific request to the students what, in general, is not encountered within other trades. This, to say in soft terms, generates a slight reluctance or fear of studying electronics.

A specific aspect related to higher education in Europe now is the request for diploma compatibility and student mobility what is inherently expressed in the so called “Bologna Declaration”. From the other side, here in Serbia, the subject of diploma compatibility within the country is formally resolved but student mobility is impossible both because of the way how inscription at the university is done, and because of the existence of fundamental differences among the curricula at different faculties.

Finally, the last innovation of the curriculum in electronics in Serbia was performed eight years ago. Having in mind the historical circumstances one may say that it was a great success. Now, however, one should think about European standards and no excuses for the legging are to be sought.

Having all this in mind, while starting the discussion about teaching electronics, in a personal opinion of the author, one should consider many aspects. In the next an attempt will be given to list possible set of subjects to be discussed and possible set of questions to be answered. Of course, the following set of views is not in any respect considered complete and exclusive.

One should address at the beginning what electronics as subject should encompass. What is an electronic engineer supposed to do while in industry. What amount and quality of knowledge related to separate disciplines should take with him at the end of the studies. According to this one should consider the set of sub specializations that are needed (and possible) for the department of electronics. What systems should be considered as electronic systems and thought within the department of electronics.

Not only electronics is thought for electronic engineers. Different neibouring disciplines are to be touched during education. In that sence a question arise as to how much automation, software, telecommunication, information technology etc. will be necessary for an electronic engineer to become versatile an able to accommodate to the challenges of the industrial life.

Similar questions arise when the neighbouring disciplines are to be considered. Namely, the amount of electronics knowledge needed for telecommunication, automation, energy etc. was always triggering discussions among professionals.

The very process of teaching is also to be considered. Questions such as the amount of laboratory work, exercise, and technology of teaching are of primal importance. Here investments in education i.e. price of the curriculum innovation is to be highlighted. Question is whether one can start any innovation with no budget. In other words, a question arise asto how can modern engineering knowledge be transferred to the students with technology of teaching as old as 2000 years.

Subjects referred to as "fundamental disciplines" such as physics, material science etc. are to be discussed separately. Namely, most of the knowledge given at these disciplines (especially within physics and mathematics) suffers of two deficiencies. First, a grate amount of teaching is repeating the high-school knowledge what spends time on the expense of the engineering education. Secondly, the rest of the knowledge is thought according to traditional curriculum that was civil and mechanical engineering oriented and politically loaded (Newton-mechanics, fluids, geometry, three-dimensional mathematics, abstract algebra, social and political sciences and similar). Having no intention to reduce what is necessary, the question arise as to what is the optimal way of transferring basic knowledge while not overloading the students, and misleading from the main-stream knowledge.

A special consideration should be the dynamics of improvement of curriculum. Namely, one should teach new knowledge permanently, of cause. Question is, however, should that be done by innovation of contents of existing set of fixed subjects or by permanent (or periodical) innovation of the subject list. In the first case we have a situation in which no equal diplomas will be given neither at the given faculty (looking in time) nor at different faculties (looking in space). In the second case a question arise on compatibilities of diploma having in mind that divergence in the subject list may happen very easily.

The foreign participants are expected to contribute to the collective oppinion that we are trying to build here by writing and speaking about their personal views and experiences, and about the state of the art and future trends in their countries. Representation of the existing curricula will be welcommed.

These and many others are the questions we are to address during our meeting. We expect everyone will express his own opinion and will influence the rest of us to improve our views to the subject. The "Proceedings" of the Colloquium is expected to be one of the basic materials allowing the entrance the next phase of improving the curriculum of electronics.

To make this colloquium as successful as possible the following colleagues were invited to prepare their contributions:

Prof. Y. Papananos, University of Athens, Head of the Tempus JEP
Prof. O. N.-T. García, University of Madrid, Participant to the Tempus TJP
Prof. M. Popović, University of Belgrade, Participant to the Tempus TJP
Prof. V. Malbaša, University of Novi Sad, Participant to the Tempus TJP
Dr V. Zerbe, University of Ilmenau
Dr. M. Zwoliński, University of Southampton
Prof. B. Djordjević, University of Niš, Chair of Electronics
Prof. M. Radmanović, University of Niš, Chair of Electronics
Prof. P. Petković, University of Niš, Chair of Electronics
Prof. N. Stojadinović, University of Niš, Chair of Microelectronics
Prof. D. Pantić, University of Niš, Chair of Microelectronics
Prof. B. Milovanović, University of Niš, Chair of Telecommunications
Prof. D. Drača, University of Niš, Chair of Telecommunications
Prof. G. Djordjević, University of Niš, Chair of Automation
Prof. B. Dimitrijević, University of Niš, Chair of Measurements
Prof. R. Stanković, University of Niš, Chair of Informatics and computer techniques.

This list, however, should not be considered neither as final nor as exclusive. We consider this Colloquiu open to any participant willing to give a contrubution to the discussion with completely equal treatment of both the written contribution and the oral discussion. In fact this letter shoud be considered as open invitation. No contribution will be rejected.

The participants are expected to send a writen contribution of approximately four pages to

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no later that March 01, 2004. This will allow as enough time to prepare the proceeding in advance and to organize the complete Colloquim.

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Teaching Electronics in Undergraduate EE Students

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MICROELECTRONIC CIRCUIT DESIGN GROUP

Annotation: The article is the printed version of the original Power Paint presentation

- **Problem:** Enrollment in electronics major drops during the past few years
- **Cause:** New 'computer generation' students are departed from hardware-oriented design activities

- Today's students are familiar with computers and their usage: they are software agile and more or less take software for granted: *Somebody somewhere else designs the hardware*.
- Today's students do not have:
    - Hands-on experience (e.g. radio amateurs)
    - Patience
- They need to re-establish contact with the hidden hardware!

Problem:

- Since students are used to immediate gratification, teaching circuit analysis theory well in advance before presenting practical applications, will make them loose interest and motivation.

Solution:

- Introduce theory and practice in the same course.
- Move this course in earlier semesters.
- Make the course essentially a lab course while maintiningconsistency with basic theoretical concepts.

Yet another problem:

- Today's EE curricula are overcrowded (NTUA for example has more than 60 courses in a 5-year Dipl. Eng. study)
- The introduction of another course, especially in the early semesters, will exaggerate the problem.

Solution:

- Remove a later course from the curriculum. However this must be carefully done in order to ensure a smooth transition.
- Leave all courses coexist at the beginning and follow a gradual transition to new curriculum.

- Such courses have already been successfully introduced in many schools:
  - Columbia University
  - UC Berkeley
  - MIT
  - Univ. of Illinois
- NTUA plans to introduce a series of general lab. courses starting from first semester. Curriculum is under restructuring.

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Hints for the first lab. course:

- Allow students to experiment with real hardware! Do not introduce computer simulation at this stage. _Reality before virtual reality._
- Provide the bare-minimum background theoretical knowledge before executing the experiments but let the experiments motivate further study.
- Provide fool-proof constructed boards to the students to guarantee immediate successful operation of the devices.
- Focus in time-domain measurements and analyses as time-domain analysis is directly associated to the *real world*.
- Avoid *systematic* analysis and concentrate on simple principles like Kirchhoff'slaws.
- Do *not* teach digital before analog! _We live in an analog world._

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Experiments included in the first lab. course as suggested by Prof. Y. Tsividisin his book "A First Lab in Circuits and Electronics"

- Introduction: Good lab. practices and other useful hints (ground connections, dc V and measurements etc.)
- Simple DC circuits
- Introduction to time-varying signals: introduction to oscilloscope operation and use
- Basic characteristics of opamps
- Amplifier design using opamps; the audio amplifier paradigm

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Experiments - cont'd

- RC circuit transients - more on measurement techniques
- Filters and frequency response
- LC circuits & resonance
- Diodes and their applications
- Modulation and radio reception
- MOSFET characteristics and applications
- Principles of amplification
- Bipolar transistors and amplifiers
- Digital logic circuits: gates and latches
- Flip-flops and registers
- Counters

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Lab. equipment

- For the introductory laboratory course, only the simplest type of equipment is needed: The students must not resort to complex instruction manuals in order to be able to operate the equipment!
- Simple boards with basic components and leads attached to them must be prepared in advance by the Department's electronics shop.
- Robust constructions must be provided to sustain abuse of hundreds of students that will be practicing during the semester.

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Feedback

- The introduction of such a course in the previously mentioned universities, gave excellent results already: The students loved the course and the purpose of motivating them was met since the enrolment in electronics major increased during the following years.
- The lab. course should be carefully monitored by the Department and students' feedback should be always considered and carefully taken into account.

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Electronics lab. courses: a step forward

- Having established a good background knowledge and practical lab. experience, computer simulation techniques and procedures can be safely introduced in later courses.
- Extensive use of state-of-the-art EDA tools for microelectronic circuit design can run in parallel with more advanced theoretical electronic design courses.
- Access to EDA tools is now available through Europracticethanks to the on-going TEMPUS Project.
- Theoretical design courses can be combined with more advanced laboratory courses employing the equipment purchased through the TEMPUS Project.

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References

- Most of the presented material was based on the paper: “TeachingCircuits and Electronics to First-Year Students” as presented by Y. Tsividisat the 1998 IEEE ISCAS Conference.
- Other relevant material:
  - R.A. Rohrer, “Taking circuits seriously”, IEEE Circuits and Devices, vol. 6, ces, vol. 6, no. 4, pp. 27-31, July 1990
  - J.A.Orrand B.A. Eisenstein, “Summary of innovations in electrical engineering curricula”, IEEE Trans. Education, vol. 37, pp. 131-135, May 1994
  - S.W.Director, P.K.Khosla, R.A.Rhorerand R. Rutenbar, “Reengineering the curriculum”, Proc. IEEE, vol. 83, pp. 1246-1269, Sept. 1995

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Predlog za osnivanje Odseka za elektroniku

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1. Stručni i naučni profil Odseka za elektroniku

Elektronika je deo elektrotehnike koji se bavi analizom, projektovanjem i realizacijom komponenata, kola i sistema, koji služe za obradu informacija. Elektronika je spoj sistemskog znanja i raspoložive tehnologije. Fizički osnovi elektronike su vezani za kretanje elektrona, koje se prvo izučavalo kod kretanja u vakumu (elektronske cevi), a potom u poluprovodnicima.

Sa napretkom tehnologije, naročito poslednjih trideset godina, oblast elektronike se proširila i danas obuhvata konstrukciju i primenu poluprovodničkih komponenata, projektovanje i primenu integrisanih kola, elektronske sisteme za merenje i upravljanje, elektronske sisteme za konverziju energije, komunikacione sisteme, projektovanje i primen kl računara, digitalnu obradu signala, mikroelektromehaničke sisteme, itd.

Naravno, ni na jednom fakultetu u svetu se ne proučavaju sve oblasti elektronike istim intenzitetom, s obzirom na materijalne i kadrovske mogućnosti, interes privrede i tradiciju. Na Katedri za elektroniku Elektrotehničkog fakulteta u Beogradu, koja je osnivač Odseka za elektroniku, posebna pažnja u stručnom i naučnom radu usmerena je na sledeće oblasti:

1. Analogna elektronika
2. Digitalna elektronika
3. Elektronika VLSI integrisanih kola
4. Računarska elektronika
5. Visokofrekventna elektronika
6. Digitalna obrada signala i slike
7. Energetska elektronika
8. Elektronska instrumentacija i merenja
9. Telekomunikaciona elektronika
10. Industrijska elektronika

2. Organizacija Odseka za elektroniku i planirana usmerenja

Osnovni ciljevi koji treba da budu ostvareni osnivanjem Odseka za elektroniku su sledeći:

- Da studenti dobiju sistemska znanja i upoznaju potrebne tehnike za analizu, projektovanje i realizaciju elektronskih komponenti, kola i sistema.
- Da se studenti upoznaju sa srodnim oblastima, kao što su: telekomunikacije, sistemi upravljanja, računarstvo i elektroenergetika.
- Da studenti dobiju dovoljno znanja za projektovanje složenih sistema koji sadrže mikroprocesore, mikrokontrolere, digitalne procesore signala i programabilna kola.

Da bi se realizovali postavljeni ciljevi, predmeti će biti podeljeni u četiri grupe:

1. Bazni predmeti – Ovi predmeti treba da daju studentima sistemska znanja potrebna u elektrotehničkoj struci. Koncentrisani su u prve dve godine.
2. Bazni predmeti iz elektronike – Ova grupa predmeta pokriva ključne oblasti elektronike. Čini je veći broj obaveznih i izbornih predmeta od druge godine do postdiplomskih studija.
3. Osnovni predmeti iz srodnih oblasti (telekomunikacije, sistemi upravljanja, programiranje, računarska tehnika)
4. Opšte-obrazovni predmeti (strani jezici, sociologija, ekonomija, pisanje tehničkih dokumenata i izrada dokumentacije, standardi, metode projektovanja, itd)
5. Izborni predmeti iz elektronike i srodnih oblasti – Ova grupa predmeta omogućava specijalizaciju u određenim oblastima, prema želji ili potrebama studenata.

U sadašnjoj fazi, na Odseku za elektroniku se ne predviđa formalna podela na smerove, već će se neophodno stručno usmeravanje obaviti putem izbora grupe izbornih predmeta. Svaka grupa izbornih predmeta sadrži predmete iz jedne od oblasti elektronike navedenih u prethodnom odeljku. Prvi predmet u grupi je preduslov za pohađanje nastave ostalih. Student mora odabrati najmanje jednu grupu izbornih predmeta, dok ostale bira slobodno sa široke liste predmeta Odseka za elektroniku i srodnih odseka. Time se daje mogućnost nijansiranja svakog usmerenja prema željama studenata i potrebama privrede.

Početno definisanje grupa izbornih predmeta će se obaviti prilikom usvajanja nastavnog plana, a može se menjati u skladu sa razvojem elektronike, materijalnim i kadrovskim mogućnostima Katedre za elektroniku i Elektrotehničkog fakulteta.

Postdiplomske studije ponudiće mogućnosti za dalju specijalizaciju u određenim oblastima, ali i proširivanje znanja iz srodnih oblasti. Na postdiplomskim studijama će se takođe izvršiti i obrazovanje kadrova za naučno-istraživački rad u institutima i razvojne delatnosti u privredi.

3. Preduzeća i ustanove sa kojima Fakultet može u značajnijoj meri da sarađuje

Poslednjih desetak godina je zbog opšteg pada privrednog razvoja došlo do znatnog smanjenja saradnje Elektrotehničkog fakulteta sa preduzećima i ustanovama u oblasti elektronike. Trenutna struktura domaće privrede se svodi na manja i srednja preduzeća koje rade u oblastima telekomunikacija, računara, informatike, projektovanja VLSI kola, merenja i upravljanja, procesnog upravljanja, zastupanja stranih preduzeća, servisa državne uprave i finansijskih institucija.

U poslednjih godinu dana saradnja se povećava. Naročito je perspektivna saradnja sa malim i srednjim preduzećima koja se bave novijim oblastima elektronike. Među najvažnijim potencijalnim partnerima za saradnju treba pomenuti sledeće firme: Informatika a.d., IRITEL a.d., Pupin Telekom DKTS, HDL design house, ELSYS design Elektroprivreda Srbije, Telekom Srbije, Armija SCG, državna uprava, Institut Mihailo Pupin, Institut Imtel, itd.

5. Procena mogućnosti za zapošljavanje studenata koji završe Odsek za elektroniku

Na tržištu rada trenutno ne postoje nezaposleni inžinjeri koji su završili Smer za elektroniku. Takođe, iz kontakta sa kolegama iz privrede, vidi se da postoji znatna potreba za tim profilom inžinjera elektrotehnike, kao i da se na takvim mestima zapošljavaju inžinjeri koji su završili slična usmerenja koji ne mogu u potpunosti da zadovolje zahteve koji se pred njih postavljaju. Prema tome, očekuje se da će svi kandidati koji se upišu na Odsek za elektroniku, a koji uspešno završe diplomske studije, moći da nadju zaposlenje u struci za koju su se opredelili.

6. Procena interesa kandidata za upis na Odsek za elektroniku

U poslednjih nekoliko godina se na postojeći Smer za elektroniku upisivalo 20-40 studenata. S obzirom da se procenjuje da je interes za oblast elektronike u porastu, da su mogućnosti za zapošljavanje odlične, kao i da će novi nastavni plan omogućiti kvalitetnije obrazovanje inžinjera elektronike, očekuje se da bi se na Odsek za elektroniku upisivalo 50-60 kandidata. Ovaj broj je u skladu sa mogućnostima za zapošljavanje, kadrovskim i prostornim mogućnostima Katedre za elektroniku i Elektrotehnićkog fakulteta.

7. Potrebna sredstava za razvoj i modernizaciju nastave i način njihovog obezbeđenja

Elektronika, kao struka koja je izložena čestim tehnološkim pomenama, zahteva stalnu inovaciju nastave, a posebno računarsko-eksperimentalnog dela. Zbog toga je za praćenje svetskih trendova potrebno ulagati značajna sredstva, koja su u poslednjih desetak godina bila smanjena. Procenjuje se da će u narednih pet godina biti potrebno ulaganje od oko 500.000 € u razvoj i modernizaciju nastave elektronike.

S obzirom da Fakultet, odnosno nadležno Ministarstvo prosvete, ne može da obezbedi ova sredstva, nastavnici i saradnici Katedre za elektroniku su se angažovali ili će se angažovati na pribavljanju sredstava iz donacija i projekata. U toku su sledeće aktivnosti:

- Realizacija TEMPUS projekta za restrukturiranje nastave elektronike u vrednosti od oko 340.000 €, od čega će za opremu biti utrošeno oko 140.000 €.
- Realizacija donacije firme SUN Microsystems, koja obuhvata računarsku opremu u vrednosti od oko 45.000 $.
- Realizacija donacija drugih firmi (Texas Instruments, Altera, Xilinx, Intel, itd).
- Priprema još jednog TEMPUS projekta manjeg obima, koji bi obuhvatio modernizaciju nastave iz oblasti koje nisu bile predviđene prethodnim projektom.
- Angažovanje nastavnika i saradnika na komercijalnim projektima iz kojih će se delom finansirati obnavljanje opreme i nabavka literature.
- Povećanje angažovanja nastavnika i saradnika na projektima koje finansira Ministartstvo za nauku i tehnologiju, iz kojih će se delom finansirati obnavljanje opreme za istraživanja i nabavka potrebne literature.

Nastavni plan Odseka za elektroniku

1. semestar						
	Predmet	**Status**	**Časovi (P+V+L)**			**Krediti**
1.1.1	Matematika 1	O	3	3		7
1.1.2	Osnovi elektrotehnike 1	O	3	3		7
1.1.3	Programiranje 1	O	3	2		5
1.1.4	Fizika 1	O	3	2		5
1.1.5	Laboratorijske vežbe iz Fizike 1	O			2	2
1.1.6-7a	Praktikum iz korišćenja računara	I**	1	1		2
1.1.6-7b	Praktikum iz Programiranja 1	I**			2	2
1.1.6-7c	Društveni predmet 1 (Sociologija)	I**	2			2
1.1.6-7d	Strani jezik 1	I**	2			2
1.1.6-7e	Praktikum iz Osnova elektrotehnike 1	I**	1	1		2
	Ukupno		12-16	10-12	2-4	30
2. semestar						
1.2.1	Matematika 2	O	3	3		7
1.2.2	Osnovi elektrotehnike 2	O	3	3		7
1.2.3	Programiranje 2	O	3	2		5
1.2.4	Laboratorijske vežbe iz Osnova elektrotehnike 2	O			2	2
1.2.5a	Fizika 2	I*	3	2		5
1.2.5b	Osnovi računarske tehnike	I*	3	2		5
1.2.6-7a	Praktikum iz Programiranja 2	I**		2		2
1.2.6-7b	Praktikum iz Matematike 2	I**	1	1		2
1.2.6-7c	Društveni predmet 2 (Uvod u menadžment)	I**	2			2
1.2.6-7d	Strani jezik 2	I**	2			2
1.2.6-7e	Praktikum iz Fizike 2	I**			2	2
1.2.6-7f	Praktikum iz Osnova računarske tehnike	I**	1	1		2
1.2.6-7g	Praktikum iz Osnova elektrotehnike 2	I**	1	1		2
1.2.6-7e	Uvod u elektroniku	I**	1		1	2
	Ukupno		12-16	10-13	2-4	30
3. semestar						
2.1.1	Matematika 3	O	3	3		6
2.1.2	Teorija električnih kola	O	3	2		6
2.1.3	Osnovi elektronike 1	O	3	3	1	7
2.1.4	Električna merenja	O	2		3	4
2.1.5a	Fizička elektronika	I*	3	2		5
2.1.5b	Programiranje 3	I*	3	2		5
2.1.6	Računarska analiza elektronskih kola	P			2	2
	Ukupno		14	10	6	30

4. semestar						
2.2.1	Matematika 4	O	3	2		6
2.2.2	Digitalna elektronika 1	O	3	2	1	6
2.2.3	Analogna elektronika 1	O	3	3	1	6
2.2.4	Signali i sistemi	O	3	1	1	5
2.2.5	Organizacija računara	O	3	2		5
2.2.6.	Matlab praktikum	P			2	2
	Ukupno		15	10	5	30
5. semestar						
3.1.1	Digitalna elektronika 2	O	3	2	1	6
3.1.2	Sistemi automatskog upravljanja	O	3	1	1	6
3.1.3	Osnovi telekomunikacija	O	3	2	1	6
3.1.4-5a	Osnovi projektovanja IK	I**	3		2	5
3.1.4-5b	Električne mašine	I**	3	1	1	5
3.1.4-5c	Digitalna obrada signala	I**	3	1	1	5
3.1.6	Praktikum iz tehničke dokumentacije	P			2	2
	Ukupno		15	5-7	6-7	30
6. semestar						
	Predmet	**Status**	**Časovi (P+V+L)**			**Krediti**
3.2.1	Računarska elektronika	O	3	1	2	6
3.2.2	Elektromagnetika	O	3	2		5
3.2.3	Osnovi projektovanja VLSI sistema	O	2	1	2	5
3.2.4-5a	Analogna elektronika 2	I**	3	2	1	5
3.2.4-5b	Digitalne telekomunikacije	I**	3	1	1	5
3.2.4-5c	Energetska elektronika	I**	3	1	1	5
3.2.6	Praktikum – komponente elektronskih kola	P			2	2
3.2.7	Praktikum iz računarskih mreža	P			2	2
	Ukupno		14	6-7	10	30
7. semestar						
4.1.1	Projektovanje digitalnih sistema	O	3	2		5
4.1.2	Upravljački računarski sistemi	O	3	2		5
4.1.3-5a	Projektovanje VLSI kola 1	I***	3		2	5
4.1.3-5b	Sistemi za digitalnu obradu signala	I***	3	1	1	5
4.1.3-5c	Senzori i pretvarači	I***	3	1	1	5
4.1.3-5d	Sinteza električnih filtara	I***	3	1	1	5
4.1.3-5e	Osnovi projektovanja IK	I***	3		2	5
	Električne mašine		3	1	1	5
	Digitalna obrada signala		3	1	1	5
4.1.6	Praktikum– Projektovanje štampanih veza	P			2	2
4.1.7	Seminarski rad	O				1

4.1.8	Projekt	O				2
	Ukupno		15	5-8	5-7	30
8. semestar						
4.2.1	Projektovanje elektronskih sistema	O	2	1	2	5
4.2.2-4a	Analogno-digitalna elektronika	I***	3	1	1	5
4.2.2-4b	Projektovanje VLSI kola 2	I***	3		2	5
4.2.2-4c	VF elektronika	I***	3	1	1	5
4.2.2-4d	Elektromagnetska kompatibilnost	I***	3	1	1	5
4.2.2-4e	Upravljanje električnim pogonima	I***	3	1	1	5
4.2.2-4f	Optoelektronika	I***	3	1	1	5
4.2.2-4g	Sistemi u realnom vremenu	I***	3	1	1	5
4.2.2-4h	Elektronski merni sistemi	I***	3	1	1	5
4.2.2-4i	Digitalna obrada slike	I***	3	1	1	5
4.2.2-4j	Digitalna obrada govora	I***	3	1	1	5
4.2.2-4k	Audiotehnika	I***	3	1	1	5
4.2.2-4l	TV tehnika	I***	3	1	1	5
4.2.2-4m	Analogna elektronika 2	I***	3	2	1	5
	Digitalne telekomunikacije		3	1	1	5
	Energetska elektronika		3	1	1	5
4.2.5	Diplomski rad	O				10
	Ukupno		11	3-5	5-6	30
9. semestar (magistarske studije)						
5.1.1	Izborni predmet 1	I****	3	1		6
5.1.2	Izborni predmet 2	I****	3	1		6
5.1.3	Izborni predmet 3	I****	3	1		6
5.1.4	Izborni predmet 4	I****	3	1		6
5.1.5	Strani jezik	O	2			2
5.1.6	Seminarski rad 1	O				2
5.1.7	Seminarski rad 2	O				2
	Ukupno		14	4		30
10. semestar (magistarske studije)						
5.2.1	Izborni predmet 4	I**	3	1		6
5.2.2	Izborni predmet 5	I**	3	1		6
5.2.3	Strani jezik	O	2			2
5.2.4	Seminarski rad	O				2
5.2.5	Magistarski rad	O				14
	Ukupno		8	2		30

Primedbe i objašnjenja:

Status predmeta:

- O – obavezni predmet,
- I* - Izborni predmet (bira se jedan od ponuđenih),

- I** - Izborni predmet (biraju se dva od ponuđenih),
- I*** - Izborni predmet (biraju se tri od ponuđenih),
- I**** - Izborni predmet (biraju se četiri od ponuđenih),
- P – praktikum.

Izborni predmeti u 7., 8., 9. i 10. semestru se mogu zameniti i predmetima sa drugih odseka.

Bazni predmeti iz elektronike (Slušaju ih svi studenti Odseka za elektroniku):

- Osnovi elektronike 1
- Analogna elektronika 1
- Digitalna elektronika 1
- Digitalna elektronika 2

Usmerenja (Mora se izabrati prvi predmet i najmanje tri od preostalih):

1. Analogna elektronika (Osnovi projektovanja IK, Analogna elektronika 2, Energetska elektronika, Senzori i pretvarači, Sinteza električnih filtara, Projektovanje VLSI kola 2, Elektromagnetska kompatibilnost, Optoelektronika, Audiotehnika, TV tehnika)
2. Elektronika VLSI integrisanih kola (Osnovi projektovanja IK, Analogna elektronika 2, Projektovanje VLSI kola 1, Projektovanje VLSI kola 2, Elektromagnetska kompatibilnost)
3. Digitalna i računarska elektronika (Osnovi projektovanja IK, Digitalna obrada signala, Digitalne telekomunikacije, Projektovanje VLSI kola 1, Sistemi za digitalnu obradu signala, Elektromagnetska kompatibilnost, Sistemi u realnom vremenu, Elektronski merni sistemi)
4. Digitalna obrada signala i slike (Digitalna obrada signala, Digitalne telekomunikacije, Sistemi za digitalnu obradu signala, Elektronski merni sistemi, Digitalna obrada slike, Digitalna obrada govora,)
5. Elektronska instrumentacija i merenja (Digitalna obrada signala, Analogna elektronika 2, Sistemi za digitalnu obradu signala, Senzori i pretvarači, Sinteza električnih filtara, Elektromagnetska kompatibilnost, Optoelektronika, Sistemi u realnom vremenu, Elektronski merni sistemi)
6. Energetska i industrijska elektronika (Električne mašine, Analogna elektronika 2, Energetska elektronika, Senzori i pretvarači, Sinteza električnih filtara, Elektromagnetska kompatibilnost, Upravljanje električnim pogonima, Sistemi u realnom vremenu, Elektronski merni sistemi)
7. Visokofrekventna elektronika (Osnovi projektovanja IK, Analogna elektronika 2, Digitalne telekomunikacije, Sinteza električnih filtara, VF elektronika, Elektromagnetska kompatibilnost, Optoelektronika, TV tehnika)
8. Telekomunikaciona elektronika (Digitalna obrada signala, Analogna elektronika 2, Digitalne telekomunikacije, Projektovanje VLSI kola 1, Sinteza električnih filtara, VF elektronika, Elektromagnetska kompatibilnost, Optoelektronika, Audiotehnika, TV tehnika

Antares: A Synergy between University Education and Research, Development and Technology Innovation Groups

O. Nieto-Taladriz[*]*, A. Araujo, D. Fraga, J.M. Montero and J.I. Izpura*

Abstract – Although Education and other activities related with Research, Development and technological Innovation (R+D+I) are all integrated by the Universities, their typical organization leads to a low coupling among them. In this way, R+D+I activities are usually carried out by small elitist groups with a high degree of external self-funding. The activities of the above groups are leaded by professors and also are directly related with postgraduate Education (mainly Ph .D. but also Ms. Sc. in a less degree). On the other side, undergraduate education, also carried out by the above professors, generally is poorly connected with their R+D+I activities. Therefore, one of the most difficult tasks in an University Department is to make compatible its educational purpose with its innovation activity performed through the research and the development activities of its research groups.

In this article we report on a successful experience about a close cooperation of the above activities within an University Department which has leaded to the design of the Antares platform suitable for educational purposes on microprocessors as well as for R+D+I activities carried out by one of the research groups of the Department. The synergy due to the above situation opens new opportunities for further cooperation among Education and (R+D+I) activities.

I. Introduction

The *Departamento de Ingeniería Electrónica* of the *Universidad Politécnica de Madrid* is a University Department composed by 28 Professors, 5 Technicians and 3 Administratives. It leads teaching duties in the *Escuela Técnica Superior de Ingenieros de Telecomunicación* and it maintains several R+D+I lines in parallel with its education activity, one of them oriented to embedded systems. The common point of convergence for the educational and the R+D+I activities described here is the study and design of microprocessor-based systems. The educational activities of the above Department in this field and within the 5 year career of the *Ingeniero de Telecomunicación*, comprise the following set of undergraduate subjects: a theoretical one in the 3rd year, (*SEDG: Sistemas Electrónicos Digitales*) together with a practical laboratory also in the 3rd year (*LSED: Laboratorio de Sistemas Electrónicos Digitales*), just following the former. There is also an advanced theoretical subject (*ISEL: Ingeniería de Sistemas Electrónicos)* and a second laboratory (*LSEL: Laboratoio de Sistemas Electrónicos*) both in the 5th year of the career. All the above subjects are related with microprocessor systems and one of our main goals was how to approach with continuity and complementariness the above subjects in order to have coherent stages in the formative process of our *Ingeniero de Telecomunicación*, and how to connect our students with our R+D+I activities on embedded systems. All the above would give them an education in the state of the art, although it would require some modern equipment for the above

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laboratories. If a synergy of the above objectives was obtained, the formation received by our undergraduated students would be a high quality one, taking advantage of the real experience and dedication of the professors, and other experienced people which could also include the R+D+I staff.

In our previous *64M2 educational* plan which has been active until few years ago, the subjects of the 3rd and 5th courses about microprocessors were performed on two different microprocessor systems, offering a vision about the two dominant microprocessor families in those years: Motorola and Intel. However, the diversity of architectures available in the market at this moment does not clearly support this approach. The high capabilities of today's processors (both in processing power and in the integrated peripherals they have), their low price, the wide use of high-level languages for their programming and the free distribution software tools easily available, have changed drastically the panorama. Today it is possible, and sometimes preferable, to use a single platform able to offer different perspectives of systems based on microprocessors and microcontrollers, both at a basic level (without an operating system, working directly on the microprocessor and its peripherals), as well as at a high level (on the basis of an operating system supporting application developments and device drivers).

Recently our Department received some funding to bring up-to-date the equipment of its 3rd year Laboratory about microprocessors, within the framework of the recent *P-94* educational plan. One possibility was to buy some standard microprocessor development boards but we decided to design our own system instead, using the experience on the subject of the LSI group, a R+D+I group within our Department, LSI coming from *Laboratorio de Sistemas Integrados*. The result is the Antares platform, a microprocessor development board based on the powerful MC5272 integrated system, being used by the LSI group for its R+D+I activities. The above platform not only serves perfectly for the 3rd year Laboratory subject, but also it fits very well in the more advanced 5th year Laboratory due to its performances, peripherals and communication capabilities, thus saving equipment costs. Therefore, the theoretical subject in 3rd course has been modified accordingly to give the proper support and the necessary basis for the new platform.

II. Educational Laboratories

The practical education and training on microprocessor based systems is given to our students through the *Laboratorio de Sistemas Electrónicos Dgitales* and the *Laboratorio de Sistemas Electrónicos*.

II.I Laboratorio de Sistemas Electrónicos Digitales

The *Laboratorio de Sistemas Electrónicos Digitales* (LSED) is a crowded laboratory, attending about 400 students per year. The students have to design, build, test and document a complete microprocessor-based system (both HW and SW) organized in groups of two people.

The starting point is a written description of the system to be implemented, with an extension of about 30 pages. It includes the functional specifications and requirements of the system (scope, general description and the scenarios of usability), part of the system analysis (system block description and a detailed description of the main subsystems) and both system and block implementation guidelines (modularity and a proposed SW base architecture that includes task distribution techniques among the main process and sub-processes, making special emphasis on the use of interruptions).

Starting from the proposed specification, the student must perform the complete analysis of the system (the initial specification is always incomplete and partially inconsistent) and to make its design, implementation, test and documentation. The target system changes every year and the student must develop a completely functional prototype with its associated documentation, passing an individualized oral examination.

The evaluation of each student is performed in two steps: the first one is a continuous evaluation through the presentation of intermediate deliverables (helping Professors to verify the evolution and originality of the work), and the second one is the final examination using the complete documentation of the system and an oral examination (the Professors verify that the prototype fits the initial specifications and formulate individualized questions to determine the capacity of each student to explain the obtained results, degree of participation, etc.).

The approach we follow for this laboratory is to show the students not only the microprocessor capabilities and implementation technologies (the main objective) but the systemic point of view were systems are a multidisciplinary works (microprocessors and programming are the tools to build systems including communications, signal processing, mathematical operations, controlling, telemetry, user interfaces, etc.).

An important point covered by this laboratory is the management of real time components. The proposed approach to learn about these components is the use of routines that attend periodic interruptions, although it complicates both system debugging and the development of the prototype. To help students, some recommendations are provided in the initial description about how to face the problem of the real time, mainly the concurrence and the resource sharing [3].

Taking into account these general guidelines, this is a laboratory oriented to design a complete system (open to the students creativity and encouraging them to reach their own solutions), with a systemic character and close related to the design of simplified (as far as possible, both economically as time demanding) consumer systems, partially guided (orienting to teach the students how to organize the different laboratory sessions to reach the objectives in a professional-like environment) and with a high emphasis on the creativity and the professionalism of each group of students (to reach the maximum mark, the students must implement optional improvements on the basic proposed system, supposing more than a 15% of the total, or afford the design of an special practice). Other factors like the technical writing quality, the skills for oral communication, group working capabilities, etc. are also individually valued.

This laboratory is closely connected with its corresponding theoretical subject (*Sistemas Electrónicos Digitales SEDG*), previously studied, and centered in the same microprocessor and peripherals. Both subjects try to balance a high formative content both in the basic knowledge and the system design with an accessible workload.

II.II Laboratorio de Sistemas Electrónicos

The *Laboratorio de Sistemas Electrónicos* takes place on the second semester of the 5th year and has a non mandatory character within the specialty of *Electronics*. The first consequences of these facts are the small number of students, about 20, allowing us to afford a personalized training and evaluation of each student.

The main objective of this laboratory is to design from scratch a complete electronic system applying the same methodology as used in industrial environments and covering the different tasks from the marketing or sales engineering to the industrialization, passing from the research and development engineering. It includes the following aspects:

- Design methodology.
- System specification from vendor to the engineering department.
- Design and validation strategies for complex systems.

- System characterization and test.
- Documentation, including user manuals, and technology transfer.

Secondary goals are to stimulate the student’s creativity and initiative, introduce them to the methodologies used on professional engineering teams, and act as a bridge between the previously studied subjects within an academic approach and their professional career as productive engineers.

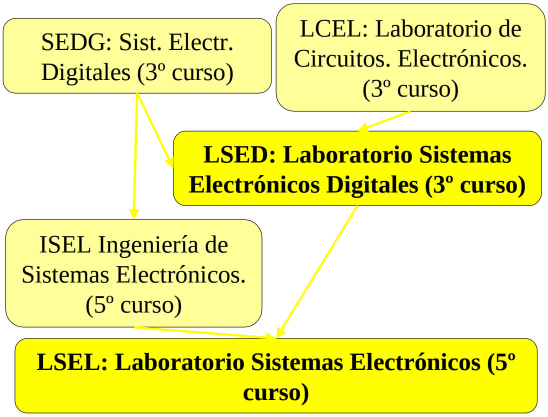
As time and effort to be applied by the students to this laboratory is limited, we have moved from the programming in assembler used in the *Laboratorio de Sistemas Electrónicos Dgitales* to high level programming, module reusability, the use of a *Linux* operating system and the extensive use of *Internet* for the acquisition of building blocks.

The natural evolution of the students that follow this laboratory is to use the performed work as a base for their *Proyecto Fin de Carrera*. With this scope on mind, the creativity, novelty and functionality of the platform are an essential requirement.

To cover the described scenarios, we have specified some generic base platforms the students use to develop the system. These basic general purpose basic platforms are tuned to communication applications and include a wide variety of communication interfaces of and the possibility of adapting them to new technologies.

Before the development of the *Antares* platform and its educational version (*DAntares*), the platforms have been used on this laboratory, based on microprocessors Motorola 68000, 68HC11 and 68331 did not support the development of ambitious practices [2] because of the low performances on processing capabilities, memory and peripherals.

As an example, a system including speech synthesis or recognition, with these platforms (with included a low capacity in non-volatile memory to store the voice patterns and samples) only allowed audio processing with a bandwidth of 2 KHz, very far from reality.



III. *Antares*: The need for a common basic plattform

The LSI know how in the design of embedded systems, its disposition for the cooperation in the graduate education and the effort of a group of Professors of the *Departamento de Ingeniería Electrónica* led to the creation of a working group to design of a new platform, *Antares*.

The design of the new platform has been focused to fulfill a set of specifications, some essential and other advisable to maximize its use both for education and research and development activities. One of the basic requirements for the platform was to use a state-of-the-art technology in order to support professional and advanced developments. With this approach it is possible to get a better student motivation, it guarantees its application in research, development and technology transfer projects and prepares the students to face real professional systems of immediate implantation on the market.

Other important restriction was the necessity of taking the complete control on the platform design to be able to use it in industrial research and development projects and to include improvements and modifications when needed, some of them results of the students work.

Along the last years it has been a meteoric advance in telecommunication technologies, with a proliferation of new communication networks, both for short distance (Bluetooth, WLAN, ICM, PLC, etc.), and for long distance (GSM/GPRS, UMTS, ADSL, satellite, etc.), which is specially suited for the development and use of embedded systems. To address the development of student practices on telecontrol and telemetry over the new communication networks, the platform must be able to support these new technologies and include the possibility of Internet access by supporting a wide variety of physical networks and being able to accede and provide services over the TCP/IP protocols.

Once settled the objective of designing an embedded system development platform we can list the main characteristics that differentiate them from the general purpose computers:

- **Price:** One of the most important constraints in the design of embedded systems is the final price per unit. These equipments are usually fabricated in large quantities (tens of thousands units) and thus, this factor becomes a fundamental parameter to be considered in the design. To achieve this objective, application tuned platforms using slow clock microprocessors and minimizing the built-in memory are mandatory. In general, these systems do not include an operating system, although we can also find enlightened ones if flexibility is needed, due to the hardware limitations. In our platform we have opted to include an operating system to gain in flexibility and reduction on the students design effort.
- **Power consumption:** This is another important factor to consider at the design time because most equipments are battery powered.
- **Size:** As in the case of power consumption, most embedded equipments are portable or have an important restriction in size.

The base platform has been used in Laboratorio de Sistemas Electrónicos for the last year is based on PC-104 equipment with Linux operating system, and including libraries and tools for rapid prototyping. Nevertheless, these platforms are very expensive and prone to crash on non trained hands, as the student ones, which makes the yearly supporting cost rather expensive.

According to hardware, the educational platform must be generic enough to allow the development of a wide range of applications without adding external hardware, and provide powerful connections to add specific hardware as needed.

To provide flexibility it has to include an operating system allowing the applications to access the different hardware resources, as memory or communication ports, provide a file handling system and to support multitasking. The desired characteristics of an operating system for an embedded system are:

- **Reliability**: Main consideration is its robustness and dependability; it has not to fail under any circumstances.
- **Multitasking:** It is common to find in the embedded systems several synchronized tasks running at the same time, whose implementation is much simpler if the operating system supports multitasking. These kinds of operating systems automatically manage the hardware resources allowing all the tasks to use the same resource without interferences among them.
- **Oriented to communications:** As previously settled, the main area of applications is the development of embedded equipments over the new communication networks, thus it is necessary that the operating system supports the widest number of facilities on this field (TCP/IP, PPP, Bluetooth, etc.).
- **Easy hardware control:** It must provide support for the complete and hierarchical control of the platform hardware.

Considering that the first students contact with this platform in within the third year, with a low level of experience on circuitry, it is mandatory to provide it with a set of protections to allow the daily work without damaging the base hardware and an easy maintenance of the equipment. Finally, it is advisable to provide the student with well known interfaces that allows an easy integration of additional hardware elements, as serial and parallel ports or analog inputs and outputs.

The main conclusion when analyzing the platform design requirements is the necessity of developing two printed circuit boards, a first one with the complete system functionality and another one with the protections.

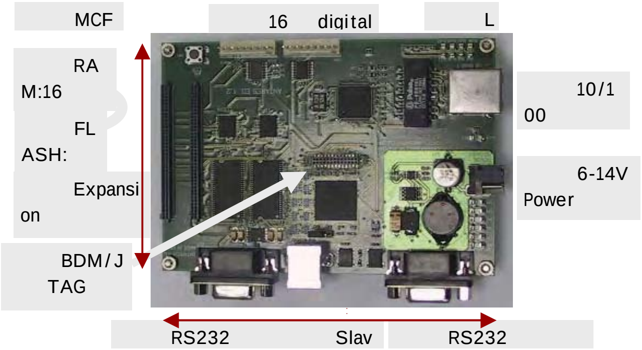
IV. *Antares*: Description of the generic plattform

This point describes the base board hardware and briefly summarizes the selected solutions when more than one design alternatives exist. The name we have chosen for the base platform is *Antares*t.

Antares is build around the Motorola *Coldfire* family of microcontrollers, and uses the M5272C3 because its suitability for communications. The general features of *Antares* are the following ones:

- Motorola 32 bit microprocessor MCF5272
- SDRAM memory: 16 MBytes
- Flash memory: 4 MBytes
- Ethernet interface
- Two RS-232 serial ports
- USB slave interface
- BDM/JTAG interface for debugging and direct Flash memory program
- Eight digital LCMOS outputs
- Eight digital LCMOS input/outputs
- Four general purpose signaling LED
- Complete Motorola expansion bus access
- Switching power supply accepting DC input voltages from 8-14 Volts.

The picture shows the *Antares* platform with its size and the different modules location. The board has a high integration density, on a 10 layer PCB, which allows a high degree of compactness, 12cm × 9cm.



Next points describe in detail the different modules.

IV.I Microprocessor

For *Antares* it has been selected the Motorola *Coldfire* MCF5272 microcontroller attending three main reasons, its performances for the development of communication oriented embedded systems, the Linux support and the compatibility with the old 68000 microprocessors wich allows a non dramatic transition in the educational subjects.

The *Coldfire* is a 32 bit microcontroller, evolution of the 68000 family, oriented to the embedded systems market, and is the Motorola strategy to address these applications for the next years. It is a 32 bit RISC microprocessor with variable instruction length. With instructions of 16, 32, or 48 bits, the generated code is more compact than the obtained in the classic 32 or 64 bits RISC architectures. This feature allows a more efficient memory usage and a bandwidth reduction in the instruction reading cycle, what increases the global performances of the system and reduces the amount of needed memory.

Another *Coldfire* advantage is its compatibility with the 68000 family, allowing an easy program migration between them, which is very convenient to migrate from the old 68000 based platforms applications to *Antares*, and specially the different in house developed tools for helping the Professors.

Motorola uses for the *Coldfire* family a different strategy to the general purpose microprocessors customers, as Intel or AMD, where the main effort to get better performances is to increase the clock frequency. The *Coldfire* approach is to develop a set of different chips around the microprocessor core that are tuned to fit families of applications by the inclusion of different peripherals.

Among all the models, available at the board development time, in the *Coldfire* family, we selected the MCF5272 because it integrates on a single chip all the communication peripherals that we wanted for our platform, including interfaces as Ethernet or SPI. This communications capability makes this microcontroller the most indicated for applications oriented to Internet, telephony on networks, LAN, WLAN, etc.

IV.II MEMORY

The memories selection, type and organization, for the platform are as important as the microprocessor and have a high impact on the system performance.

The platform integrates SDRAM memory and uses the internal controller included in the MCF5272. It incorporates two MT48LC4M1A2 SDRAM memory modules parallel connected to create a 32 bits bus, and allowing a total of 16 MBytes of RAM memory.

The platform also includes Flash memory for non nonvolatile storage and support two configurations with one or two memory banks of 2 MBytes, which ends with a total of 2 or 4 MBytes on board.

IV.I Interfaces

In an embedded systems development platform with the requirements we have previously stated, the communication capability and the interaction with external devices play a fundamental role, and imposes the integration of multiple communication interfaces.

In addition to the general communication interfaces as Ethernet, RS232 and USB, suited for connecting external standard devices and Motorola specific interfaces and bus to connect external chips, we have also included digital and analog input/outputs to allow the platform to interface external heterogeneous devices. The Motorola expansion bus available in a connector is very important because it allows the expansion of the platform by connecting external boards.

The Ethernet interface is built in two parts, the controller, integrated on the MCF5272, in charge of accessing the shared medium (MAC), and external hardware that performs the physical level functions, the voltage level conversion transformer and the twisted pair RJ-45 connector.

Antares also includes a BDM/JTAG interface to speed up the application debugging on the platform and minimizing the necessity of simulators, usually very expensive. The selection of the interface to use (BDM or JTAG) is done through a jumper.

The *Antares* expansion bus interface consists on two parallel connectors with the entire externally available MCF5272 chip signals to allow a full flexibility in board expansion with new hardware.

IV.III Power supply

Antares uses, when fed from mains, any external power supply from 220/125V AC to 8-14V DC and an output current higher than 200mA. This output is transformed to the internal board voltages 5V and 3.3V by a switching regulator for maximum efficiency.

V. *Dantares*: *Antares* oriented to a basic education

For a development platform, to successfully face a massive laboratory with students that are have not a high degree of practical skills in electronic systems, the inclusion of strong and reliable protections and robust mechanics is of vital importance. If properly designed and maintainability has been considered, also helps to lower the annual maintenance cost and to maximize the availability of the equipments throughout the students working time.

To cover this objective, and based on the previous experience of the Professors team in building “student proof” protections, like the 68000, 68HC11 and 68331 systems [2], we decided protect the externally available analog and digital inputs and outputs against overvoltages and shortcircuits, the most frequent actions in an educational laboratory.

Although a redesign of the *Antares* PCB was considered, we decided to build a separate protection board on which Antares is piggy backed via the expansion bus. This approach allows covering the complete spectrum from the student’s microprocessor initiation (fully protected) to the advanced embedded system design. The protection board also includes a 220V AC power supply, a mechanical box and receives the name of *DAntares*.

Opposite to the *Antares* requisites of minimum power consumption and size, to face the design of the protection board we only considered the robustness and maintainability of the equipment. It contains a linear 220V AC to DC power supply instead of a switching one for robustness, the protection circuitry has been design with no power consumption restrictions to increase the protected input/outputs bandwidth, a large set of LED has been included as informative visual interface for application debugging, etc.

Starting from the *Antares* platform, the protection board provides to the outside world, and as additional functionality for education purposes, two analog inputs and one analog output connected through the Motorola synchronous peripheral interface SPI, extends up to 32 the number of input/output pins, three interruption inputs, one timing input, three PWM inputs and one timed output. All these signals are optocoupled and buffered, allowing a bandwidth of 100 Ksamples/sec.

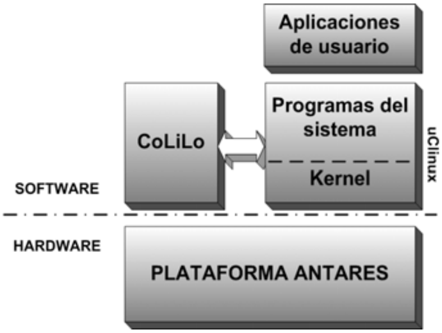
Analog input and outputs use 12 bit converters with track-and-hold controlled via the Motorola serial synchronous bus QSPI, the chips are the MAX1246 for the inputs and the MAX5352 for the outputs. The protection is provided by the HCPL7840 isolation amplifier with more than 50 KHz of bandwidth. Digital inputs/outputs are protected by HCPL2631 isolation high speed optocouplers.

The mechanical aspects are of special relevance in a board for massive inexpert usage. The box is metallic with a polycarbonate upper part for visibility; the connectors are female DB-25 and DB-9 for the digital signals and BNC for the analog ones. All connectors have been selected for their high robustness and standardization.

VI. Application development software for *Antares*

This part of the paper briefly describes the software used in *DAntares*, both external and in house developed. Software architecture is shown in the following figure.

On top of hardware is placed *CoLiLo*, the operating system charger, whose function is to initialize the hardware and to install the operating system. Next step is covered by the selected operating system, *µCLinux*, divided in kernel and system programs. The highest level is covered by the user applications. In parallel we can find the tools used for the development software. The following points briefly describe the different parts.



VI.I CoLiLo

The functions of this software are to configure the platform hardware and to recover a *µCLinux* distribution image which is stores on the Flash memory. We have started from the *CoLiLo* source code, initially developed by Rob Scott under GNU license, performing the necessary modifications to adapt it to the *Antares* hardware. New functionalities to test the hardware modules correct operation of and the possibility of charging different *µCLinux* images have also been added.

VI.II µCLinux

*µCLinu*x is an adaptation of the *Linux* operating system to work on microprocessors without memory management unit (MMU), as in the MCF5272 case. This operating system is smaller than standard *Linux* distribution, what makes it very suitable for embedded systems.

Kernel size, including the most common options, is below 500 KBytes and the complete distribution (Kernel plus applications) is below 900 KBytes. As with *Linux* distributions, the code is open, allowing a complete access to the operating system source code. This is one of its best advantages for education, and not only for education, because it is possible to take full control over the entire design.

Another strong point for the use of *µCLinu*x is that it is based on a *Linux* kernel, sharing all its advantages as: multitasking operating system, modular architecture, multiple network protocols support (TCP/IP, PPP, SLIP, etc., support for multiple file systems as NFS, Ext2, FAT32, FAT16, etc.), robustness and reliability, availability of the source code, as distributed under GNU license it is free, the software control of the hardware is very easy, etc.

It is possible to find *µCLinu*x distributions for a large number of microprocessors, including the Motorola *Coldfire* family. The *µCLinux* distribution is composed by three well differentiated software blocks: the kernel, based on the version 2.4.x. we have modified to adapt the standard distribution to the *Antares* platform; the standard C library (*libc*) and its implementation for microcontrollers and finally the applications. The *µCLinux* distribution integrates different applications both for the system (i.e.: the command interpreter) and for the user applications (i.e.: a Web server).

These three blocks compose the system base software. The most relevant modifications have been performed on the standard *µCLinux* distribution to adapt it to the *Antares* hardware are the following ones: Flash memory controllers, SDRAM memory controllers, the development of specific controllers for several hardware interfaces and the file system support.

VI.III Development tools

The software development station is composed by a PC with a *Linux* distribution installed. This standard platform with free software allows the students to work at home and not necessarily in the laboratory, increasing its usage ratio. To help the programmer we have created a developer toolkit that includes a cross compiler, a cross debugger and a lot of useful tools which allows the user to also develop applications in a platform different from the *Antares* one.

The second tool for development is the BDI2000, a device that allows software debugging using the GNU debugger via the *Antares* BDM interface. This tool allows the user, among other possibilities, to write directly on the Flash memory, trace the content of the microprocessor registers, execute programs step by step, etc.

VII. A free application development toolkit for *DAntares*

Although it is possible to find in the market high quality development environments for the *ColdFire* (i.e. Metroworks), the license prices and special cables for program loading and debugging through the BDM interface are unaffordable for a massive usage in the laboratories. On the other hand, the actual free tools based on GNU-*Linux* are not intuitive enough to be used by students with little experience in system programming.

As results of teaching several years around Motorola microprocessors, we have developed for them two graphic frameworks running on Windows, both including an editor, an assembler and a debugger, and a complete set of manuals and practices for teaching students.

We have selected one of them, whose name is *DBUG*, because it only needs a serial port to connect the development station to *Antares* (the other one, *TUTOR* uses a BDM interface) and an in house developed monitor program, resident in the system non-volatile memory.

The modifications to the original monitor have imposed important changes in the application (because of the different commands and messages that the PC and *DAntares* exchange). Fortunately, there have been nonstructural ones because the operation philosophy is the same in both cases: during program execution and debugging a thread is in charge to monitor and to control the board.

In parallel to the modifications in the development toolkit, it has been necessary to also adapt the *DBUG* monitor modifying the memory map, initialization of the new devices, handling the flash memory, etc. The use of a Motorola evaluation board, used as reference, allowed us to parallelize the development of both HW and SW with remarkable success and reduction in development time.

The availability of the complete set of GNU tools for the C language allowed us to integrate them as scripts in the system to provide a high flexibility in programming and debugging. Although during the debug process, the assembler code is always visible (the student has to be conscious that the program is being executed on a physical machine and use the hardware resources and special features by the inclusion of code in assembler), is possible to debug directly in C, track variables by the name (not only by address), etc.

VIII. Working experience with *DAntares*

The practical experience obtained up to now with the *Antares* and *DAntares* platforms both in education and in engineering are extremely good. A testing pack has been developed to monitor the system integrity both for validation and in house board maintenance, providing real merit figures. Testing software has two levels, at *CoLiLo* level it verifies the RAM memory, general purpose LED, RS232 interface, expansion bus, input/outputs (with an additional board), interruption and PWM lines, counters and system reset; and at *μCLinux* kernel level the USB, QSPI and Ethernet interfaces are tested.

The first pilot was carried out by a reduced workgroup in the *Laboratorio de Sistemas Electrónicos* to test the system in a real and controlled environment, previously to its implantation on the massive laboratory. The practice was an *mp3* player connected to an IP external server, using the *Antares* Web interface. The selected mp3 file had to be reproduced in *Antares* using the D/A converters. The experience was very positive both for the students and the Professors, validating the platform robustness and educational validity.

Actually new projects to develop hardware and software for the platform, including residential bridges and ICM networking for domotic applications are ongoing.

Other projects in the research, development and technology transfer activities are also being carrying ourt around this platform, as energy save system for buildings, greenhouses and extensive crops fertirrigation systems, systems to improve the Alzheimer illness quality of life, etc.

IX. Conclusions

The fruitful experience commented on this paper shows that cooperation between the R+D+I groups and the graduate education can be extremely productive in both senses. Graduate education improves with the state of the art technologies derived from the R+D+I groups and these ones can get better motivated and formed students for the future incorporation to the groups.

DAntares platform has been a complete success not only because it is a fully controlled and a state of the art microprocessor development system with in house maintenance capabilities, but also because the final price per equipment is less than buying commercial systems.

As conclusion of this fruitfully synergy, a new cooperation has started to afford the development of a new board that integrate *Antares* and an FPGA to cover the education on microprocessors, digital electronics and digital architectures.

Acknowledgement

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Primena preporuka Bolonjske deklaracije na Elektrotehničkom odseku Fakulteta tehničkih nauka u Novom Sadu

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REZIME

Odlukom nastavno-naučnog veća Fakultet tehničkih nauka Univerziteta u Novom Sadu počeo je sa pripremama za izradu novih nastavnih planova i programa i nove organizacije studija. Novi nastavni planovi i programi i sistem studiranja treba da uvaže preporuke Bolonjske deklaracije i ispune uslove za akreditaciju i sa druge strane da doprinesu poboljšanju efikasnosti studiranja i kvalitetu nastave. U ovom radu ukratko su izloženi ciljevi, principi i praktičan pristup u pravljenju novih nastavnih planova i programa na Elektrotehničkom odseku Fakulteta tehničkih nauka.

CILJEVI

Osnovni ciljevi koji treba da se postignu novim nastavnim planovima i programima i organizacijom studija na Fakultetu tehničkih nauka (FTN) u Novom Sadu obuhvataju:

- Uvažavanje preporuka Bolonjske deklaracije i prednacrta novog Zakona o visokom školstvu (onog dela Zakona koji se odnosi na strukutru i organizaciju studija, koji nije sporan i verovatno će biti deo budućeg Zakona). Osnovna intencija Bolonjske deklaracije jeste jačanje istraživačkog potencijala kroz kvalitetne i visoko kompetentne poslediplomske (magistarske i doktorske) studije.
- Priprema za deo akreditacije koji se odnosi na nastavne planove i programe.
- Uvođenje mehanizama za neprekidno praćenje i unapređenje kvaliteta nastave. Prilagođavanje evropskim standardima kontrole kvaliteta.
- Povećanje efikasnosti studiranja.
- Povećanje fleksibilnosti studija sa više izlaznih profila u skladu sa potrebama tržišta.
- Usklađivanje nastavnih planova i programa sa razvojem novih tehnologija.
- Uvažavanje potreba regionalnog razvoja.

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PRINCIPI

U pravljenju novih nastavnih planova i programa FTN će se rukovoditi sledećim principima:

- Poći od postojećeg stanja, na osnovu rezultata analize identifikovati one aspekte postojeće organizacije studija koje možemo sačuvati i one delove koje moramo promeniti.
- Organizuju se dve vrste studija: strukovne i akademske.
- Strukovne studije su kraće (180 kredita), imaju manje teorijskih sadržaja i direktno su orijentisane ka primeni. Najveći deo nastave organizovan je oko laboratorijskih vežbi pri čemu su teorijski sadržaji usmereni na uspešno praćenje praktične nastave. Posle završenih strukovnih studija organizuju se specijalističke studije u trajanju do jedne godine (60 kredita).
- Akademske studije su naslednik postojećih studija. Osnovna razlika u odnosu na postojeće studije je što se deo naprednog gradiva iz dodiplomskih studija prebacuje u magistarske studije čime se ukupna dužina dodiplomske nastave skraćuje sa 9 na 8 semestara (240 kredita).
- Magistarske studije u trajanju od dva semestra (60 kredita) treba da budu aktuelne, visoko kompetentne i da omoguće direktan pristup najnovijim znanjima i tehnologijama. Sadržaj magistarskih studija može da se menja iz godine u godinu. Za razliku od dosadašnjeg stanja, magistarske studije postaju deo redovnih studija i finansiraju se iz budžeta.
- Uvode se doktorske studije u trajanju od tri godine (180 kredita) koje finansira Ministarstvo za nauku, tehnologije i razvoj.
- Na svim vrstama studija gradivo treba da bude struktuirano u male celine, koje studenti mogu da lako savladaju. Svi predmeti treba da budu jednosemestralni, treba jasno profilisati module i uvesti veliki broj izbornih predmeta.
- U cilju preciznog određivanja opterećenja studenata i obima gradiva uvodi se kreditni sistem ekvivalentan ECTS-u. Kreditni sistem treba da suštinski podrži merenje opterećenja i obima gradiva vezanog za izborne predmete.

PRAKTIČNA REALIZACIJA PRINCIPA NA ELEKTROTEHNIČKOM ODSEKU

Osnova za transformaciju akademskih studija treba da budu postojeći nastavni planovi programi. Predlog je da se transformacija uradi u dve etape koje su uslovljene načinom finansiranja.

U prvoj etapi se postojeći nastavni planovi menjaju na sledeći način:

- Prepoznaju se kursevi sa naprednim, poslediplomskim karakterom i oni se isključuju is dodiplomskih studija. Na ovaj način treba isključiti najmanje onoliko takvih predmeta koliko može da popuni jedan i po semestar nastave. Ovaj korak je neophodan da bi se studiranje skratilo sa 9 na 8 semestara.

- Prepoznaju se predmeti koji čine osnovnu okosnicu odseka (smera) i oni se proglašavaju obavezni. Preporučuje se da predmeti prve i druge godine budu obavezni sa izuztkom predmeta iz oblasti humanistickih i društvenih nauka.
- Svi ostali predmeti su izborni. Po pravilu izborni predmeti na jednom smeru biraju se među obaveznim predmetima nekog drugog smera, čime se obezbeđuje kontinuirano finansiranje izbornih predmeta. Među izborne predmete mogu biti uvrštene čitave grupe predmeta sa drugih smerova.
- Postojeći dvosemestralni predmeti čiji sadržaj želimo da zadržimo na akademskim dodiplomskim studijama, transformišu se u dva jednosemestralna predmeta sa eventualno novim nazivima.
- Neki predmeti, pored dužine trajanja, mogu da suštinski menjaju sadržaj i naslov.
- Uvode se i neki potpuno novi predmeti.

U drugom koraku uvode se izborni predmeti koji nisu obavezni ni na jednom smeru. Ovi predmeti uvode konkurenciju i proširuju mogućnosti izbora u okviru osnovne struke. U okviru plana treba da bude prostor za strani svetski jezik, humanističke predmete i predmete vezane za etiku struke.

U okviru izbornih predmeta treba da bude prostor za:

- Opšte obrazovne predmete ili predmete sa drugih fakulteta/departmana na Univerzitetu.
- Predmete koji se odnose na inženjersku struku u širem smislu (sa bilo kog odseka FTN-a)
- Predmete koji se odnose na matični odsek (sa bilo kog njegovog smera).
- Predmete sa smera.

OSTALE PREPORUKE

Elektrotehnički odsek treba da jasno i precizno definiše svoju misiju, viziju i obrazovni cilj.

Vežbe treba da budu u najvećoj meri laboratorijske. Auditorne vežbe se redukuju na neohodni minimum što zavisi od predmeta i raspoložive opreme.

Ocenjivanje studenata treba da bude kontinuirano, tako što se ocenjuju sve aktivnosti studenata i one ulaze u završnu ocenu. Na predmetima na kojima postoji, završni ispit organizuje se jedan put, na kraju semestra. Studenti koji ne savladaju gradivo sa prolaznim uspehom, moraju da ponove ponovo slušaju predmet.

Na svakom smeru odrediti jednog ili više nastavnika (mentora ili savetnika) koji pomažu studentima u izboru predmeta. Svaki student mora da ima potpis mentora kojim se overava lista izbornih predmeta. Uloga mentora je da vodi računa o izlaznom profilu diplomiranih studenata, redosledu slušanja predmeta, određivanju broja studenata na izbornim predmetima i drugo.

Nastava na pojedinim predmetima može da se izvodi svakog semestra, svakog drugog semestra ili ređe, u zavisnosti od broja studenata.

ZAKLJUČAK: KRATKOROČNI ZADACI

S obzirom na nerazjašnjen način finansiranja, predlaže se realizacija sledećih zadataka do početka nove školske godine.

- Uvođenje kreditnog sistema kompatibilnog sa ECTS.
- Priprema informacionih paketa za sve nastavne planove i programe po jedinstvenoj metodologiji.
- Priprema i uvođenje dodatka diplomi.
- Prevođenje svih predmeta u ekvivalentne jednosemestralne predmeta
- Definisanje obaveznih i izbornih predmeta i njihov redosled. Izborni predmeti treba da bude oni predmeti koji su obavezni na nekom drugom odseku ili smeru. Predmeti mogu da budu povezani u module (celine) koje obezbeđuju znanja i veštine iz određene oblasti.
- Obezbeđenje bar 50% valorizacije rada studenata u toku semestra. Uvođenje polaganja jednog završnog ispita na kraju semestra sa mogućnošću da se završni ispit ponovi samo jedan put.

Digital Design: Computer Science or Electrical Engineering?

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Abstract

The use of hardware description languages has moved digital systems design closer to computer science. Software engineering techniques are needed to manage complex designs. Deep sub-micron effects have made digital design more asynchronous and more analogue. Therefore there is a tension between high-level abstraction and low-level detail. In this paper, it is argued that we should increasingly teach digital design as if it were a form of software engineering and that the low-level effects must be estimated in the design tools. This is a challenge to universities, both in their teaching and in their research.

1 Introduction

In the past two decades, the world has “gone digital”. CDs have replaced vinyl records; digital photography has replaced film and television, radio and telephones have all become digital devices. Increasingly, therefore, *electronic* engineering has meant *digital systems* engineering. With the advance of digital technology has come a massive increase in complexity. Design tools have struggled to keep pace with this new complexity. Similarly, engineering education has found it difficult to stay in touch.

Along with complexity another phenomenon has appeared. As the feature size of integrated circuits shrinks, gates and flip-flops behave less like synchronous digital devices and more like analogue components. It is now more correct to think of integrated circuits as transmission lines connected by switches and not as gates connected by equipotential wires.

Thus, we have two conflicting pulls: on the one hand in order to control the complexity we need to describe digital hardware using software engineering techniques; while on the other we need to be familiar with electrical engineering principles in order to understand and control the sub-micron effects.

In this paper, we will review the digital design curriculum as it has been taught. We will then examine what we can learn from computer science in order to teach the management of complexity. We will argue that to manage the non-synchronous, analogue features of deep sub-micron design we need a new generation of design tools and a new curriculum for a new generation of electronics engineers.

2 Digital System Design 1980-2000

In most electronic engineering degree programmes digital design forms one of the main themes alongside analogue circuit design, programming and physical electronics. Here, we distinguish electronic engineering from electrical power engineering, in which there is an emphasis on machines and high voltages. In some institutions there was a move towards electronics in the decades before 1980. In others, such as the University of Southampton, electronic engineering has always been a distinct discipline.

Through the 1980s, the digital design theme would have included topics such as: Boolean algebra; Boolean minimisation using Karnaugh maps; optimisation of logic in terms of TTL packages; state machines; state minimisation; and mapping to JK flip-flops. Depending on the institution these subjects would have been more or less theoretical, with perhaps an element of design and build in the laboratory. Related topics would have included computer architecture, including bus architectures and assembly language programming and integrated circuit design.

By the mid-1990s, VHDL and Verilog were starting to appear, together with programmable logic. Thus topics such as TTL package minimisation and optimisation in terms of JK flip-flops became obsolete. By removing these topics, there was room in the curriculum to introduce RTL design, including synthesis and simulation. FPGAs made it possible for students to design much more complex systems. It was also realised that design for test is an important aspect of digital design and topics such as the single stuck fault model, scan path design and BIST could be included.

The power of the design tools has revealed a difficulties however. At first glance (and to weaker students) a specification in VHDL is not that different to a C program. The design process has similarities to programming a PIC or other embedded processor: the "program" is compiled and downloaded onto an integrated circuit on a development board. Moreover, the complexity of both FPGAs and embedded processors means that it is impossible to debug either hardware or software designs *in situ*. Finally, we cannot simply give an FPGA or a processor with 100s of pins and operating at 2.2V or less to students and expect them to build circuits in the laboratory.

Thus in practice digital systems design has become a branch of software engineering.

3 Computer Science Lessons

We can regret this transformation of the digital design process or we can welcome the change and seek to exploit it. So, what can we learn from computer science?

The most significant change in computer science teaching in the last 20 years has been the evolution in computing languages. In 1980, computer science students would have been taught FORTRAN IV and possibly Lisp. Today students learn Java and C++. It is said that "real programmers can write FORTRAN in any language"! This is true, but good programmers can use the expressive power available in C++ to write shorter programs that achieve the same task. The key here is abstraction and management of complexity. It is relatively easy to map a FORTRAN program into assembler; it is almost impossible to do the same with a C++ program.

It is not just the mainstream programming languages that have changed. Software management tools have made it easier for teams to develop programs – even simple tools such as makefiles allow programming tasks to be shared. Version control systems (RCS, CVS) allow changes to be tracked. C++ has vast libraries of functions that can easily be used to build sophisticated applications. Scripting languages (e.g. Perl) allow systems to be built from small components.

Perhaps the most significant advance has been in the development of formal methods such as model checking. It is practically impossible to test for every combination of data; formal methods can be used to validate a specification against a final implementation.

By analogy, digital hardware design, in the form of RTL synthesis, is still in the FORTRAN era. Software engineers no longer care exactly which machine instructions are executed, but digital hardware designers are obsessed with knowing exactly what flip-flops are created. IP reuse is talked about but seldom done. Ironically, many engineers are forced to learn Perl in order to make the EDA tools work. And formal methods are not mentioned in polite company!

This situation cannot continue. There is a "design gap". A consumer integrated circuit might remain in production for a few weeks, but might have taken several hundred man years to design.

The current response of integrated circuit manufacturers is to export design to low wage economies, such as India and China. Thus the cost is kept low by reducing the cost per engineer. An alternative model is to increase the productivity of each engineer. The lessons of computer science suggest a way to achieve that objective.

4 Electrical Engineering Tamed

The argument for abstraction might be countered by observing that as devices get smaller the engineering problems get more difficult. As educators we can promote the use of software engineering tools. As researchers, however, we have new opportunities in trying to reconcile electrical engineering with computer science.

At this point an example might be useful. A common problem in RTL design is that of timing closure. A designer wants to achieve a certain speed with minimal hardware costs. Speed versus area is the classic trade-off. In order to minimise area, resources are shared. In order to share resources, multiplexers must be included. Therefore, when synthesised the design does not meet the speed requirements. Hence, the shared resources are no longer shared, but this makes the design larger and the delays greater, due to longer wiring. Thus the speed gets worse, not better and thus timing closure is never achieved.

The problem arises because the synthesis tool estimates performance only in terms of logic delays, not wiring delays. The solution, as implemented in so-called physical synthesis tools, is to estimate the wiring delay and to include this as a cost in the optimisation function. It is important to appreciate that, at this level, the wiring cost is estimated – it would be prohibitive to perform a full layout at each optimisation iteration.

In a computer science view of synthesis, the physical effects are ignored. In an electrical engineering view, these effects dominate the design process, impeding abstraction. We need to tame the electrical engineering problem by producing relatively simple high-level models of the low-level effects. In the timing closure problem, this is done by generating a floorplan of the design and estimating typical and worst-case delays. We do not attempt to calculate exact delays. In fact this estimation has a second benefit: the floorplan is based on high-level information about the design, which is lost during synthesis. The floorplan can be passed onto low-level layout tools, allowing them to produce a better solution more efficiently.

To date, relatively little work has been done in high-level estimation. In commercial tools, physical synthesis has been applied at RTL, but there has been research into using similar techniques at a behavioural level. Similarly, the cost of a design in terms of overall area, power and testability can be estimated at an early stage. Problems such as crosstalk and asynchronous communication could be designed out of a system at an early stage. We should, perhaps, think of this as architectural exploration rather than behavioural synthesis. Models and tools for performing these estimates and, importantly, for arbitrating between conflicting objectives are needed and could provide a fertile area for university research. Such tools would therefore allow us to control complexity.

5 A Curriculum for Digital Systems Design

It is not really possible to design a curriculum for digital systems design in isolation. In practice an electronic engineering degree should also include: Mathematics; Circuit Theory; Analogue Design; Computer Architecture; Programming; Solid-state Physics; Electro-magnetism; Communications; Signal Processing; and so on. Different countries have degrees of different lengths. Different institutions have different specialisations and structure their programmes in different ways. We can outline key topics that should be included in a digital systems design theme.

In the first year, it is clearly necessary to introduce the basics: Boolean algebra; Karnaugh maps; gates; flip-flops; state machines and programmable logic. Laboratory exercises will include the use of simple programmable devices and hence require the use of languages such as Abel. There is a clear need for students to understand, from a practical point of view, the need for decoupling capacitors and the effects of sending pulses along transmission lines.

In the second year, hardware description languages (VHDL, Verilog or SystemC) can be introduced. Coupled with this is the need to introduce students to simulation and RTL synthesis tools. Even though an FPGA can be easily reprogrammed, it should still be right first time, because it is almost impossible to access internal states for debugging. The principle of dividing a design into controller and datapath can be taught with all these subjects being assimilated through design exercises. Finally the idea of design for test should be introduced, together with the principles of test pattern generation.

In the third and subsequent years, the level of abstraction can be moved upwards. At this point software tools (e.g. CVS) need to be introduced. Verification principles, particularly formal methods, and tools need to be explained. With the increasing complexity of systems on chip, the idea of a single, global clock is no longer tenable and design for asynchronous communications needs to be introduced. As we now no longer distinguish so rigidly between hardware and software, we can introduce the idea of hardware/software co-design.

As high-level synthesis tools become more readily available, they need to be introduced into the curriculum. At first these will be university tools, suitable only for advanced courses. It is inevitable, however, that such tools will become industry standards and their use must be promoted in the teaching of digital design.

6 Conclusions

With increasing use of hardware description languages, digital design is starting to resemble software engineering. At present, tools and techniques do not fully support modelling and estimation of low-level electrical effects. As a result of industrial pressure and university research tools will emerge. It is only through the adoption of software engineering methods that the complexity of future generations of digital devices can be managed.

Is digital design computer science or electrical engineering? Undoubtedly, the answer is that from the designers’ point of view, digital design will increasingly resemble computer science. We will still need, however, tool builders who understand electrical engineering and there will be occasions when the assumptions implicit in those tools break down. We still need therefore generations of fully rounded electronics engineers.

A Course of Studies - Computer Science Engineering

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Abstract

Presented is a course of studies - Computer Science Engineering. The main study emphasis are: intelligent systems, integrated hardware and software systems, multimedia information and communication systems, telecommunication and measurement technology and systems engineering. The average period of study is 10 semesters, of it 4 semesters stage I study and 6 semesters stage II study, including study/project work and master thesis (Diploma), a 6 weeks practical course up to the 4th semester and a 20 weeks specialized practical course (internship). The student will finish with a Diplom-Engineer (Master) in the field of computer science engineering. For further informations please visit website http://www.tu-ilmenau.de.

1 Goal and contents of the Study

The classical studies of Electrical Engineering and Computer Science do not any longer meet the requirements of the in creasing demands for future developments. The common education for Energy Engineers, Engineers of Microelectronics and Engineers of Information Technology discloses **defincien**cies in skills and abilities of Computer Science whereas in the field of computer scientific education essential aspects of Electrical Engineering / Electronics and of system understanding are missing. In future we will have to deal with growing complex systems that include an increasing part of information processing components for information processing and exchange. The design of these systems requires the development and management of modells of information systems and information processes with algorithmic development and optimizing methods.

The study of Computer Science Engineering is an engineering college course with orientation in Systems Engineering. It regards instruments and methods of Information Science and of Electronic Engineering. Being rewarded the degree of Diplom Engineer for Computer Science graduates not only obtain the knowledge of mathematical-physical basics but they also possess the essential basic knowledge of information-oriented branches of Electrical Engineering. Simultaneously they acquire knowledge of application oriented fields of Computer Science and Systems Engineering (Cybernetics). This combination and the methods, proceedings and instalments of Computer Science and Systems Engineering enable graduates to develop complex technical systems with a high degree in information processing. For that purpose they master the fields of system design and abstraction from realization technology.

During the study students develop skills in

- individual and responsible work with scientific methods
- systematic analysis and development of complex systems
- system-technical understanding and design of software and hardware technical contexts
- • understanding and influencing technological changes in research and applications as well as their environmental effects

- specialized teamwork, technical and social competence
- • independent learning and research.

The education has a strongly practice-oriented character. Suitable results open up a various field of professions to the graduates in all technical innovative branches of the industry. In that context the representative spectrum of special branches of studies is of main importance.

2 Structure of the Study

The regular duration of the study, including the practical engineering training and the elaboration of the Diplom thesis, is ten semesters with approximately the same regard in Electrical Engineering and Computer Science.

The study is divided into the Stage I studies (basic study) consisting of four semesters and the Stage II studies (main study) consisting of six semesters. The Stage I studies end with the Diplom pre-exam, whereas the Stage II studies including the practical engineering training, the study/project work and the Diplom thesis is completed with the Diplom exam.

The educational program covers eight semesters. It includes compulsory couses, optional compulsory courses and a wide spectrum of complementary subjects. The Stage I studies of the course of Computer Engineering consist of 90 credit hours within four semesters, e.g. an average of 23 credit hours per week to get the pre-Diplom within the regular duration of study.

Compulsory subjects during the Stage I studies are:

- Mathematics: 23 credit hours (Linear Algebra, Analysis, Numerical Mathematics, Theory of Probabilities)
- Physics: 12 credit hours
- Computer Science: 22 credit hours (Technical Computer Science, Theoretical Computer Science, Neural Compu tation, Artificial Intelligence, Software Technology, Op erating Systems, Computer Networks and Telecommuni cations, Databases)
- Electrical Engineering: 33 credit hours (Basics of Electrical Engineering, Electromagnetic Eields, Elec tronic Semiconductors and Circuits, Electronic Measur ing Technology, Telecommunications Technology, Sig nals and Systems 1, Automation and Systems Engineer ing)

In the following table is **illustrated** stage I studies.

semester				
1	Mathematics	Physics	Computer Science	Electrical Engineering
2				
3				
4				
exam	pre-Diplom			

The total of credit hours during the Stage II studies amount to 90 credit hours. These split up into

- 6 credit hours of the main subjects of Computer Science and Electrical Engineering
- 15 credit hours each of the optional compulsory educational complex of Computer Science and Electrical Engineering
- 4 credit hours of compulsory laboratory practical studies
- 40 credit hours of optional compulsory courses of the main fields of the study
- another 4 credit hours of main seminars and
- 6 credit hours of non-technical optional compulsory courses which should be reserved for courses of Business Economy and Jurisprudence

In the following table is illustrated stage II studies.

semest.				
5	main subject	optional compulsory cources of Computer Science	optional compulsory courses of Electrical Engineering	laboratory practical studies
6				
7	internship			
8	optional compulsory courses of the branch of study and the non-technical field (6 credit hours)			main seminars and project work
9				
10	Diplom thesis			
exam	Diplom			

3 Areas of Specialisation

Students need to absolve 40 credit hours of optional compulsory courses within their branch of study, and they need to enroll in eight to ten of these credits for the exams. For that purpose students are given the possibility to individually structure their study in favour of their interests and to set own priorities. At the moment students can choose from the following branches:

3.1 Applied Computer Science in Technology and Environment

The study mediates knowledge about the applications of the basics of Computer Science and Electrical Science in specific problems. Since more than 80 per cent of the expenditure of development in all applications of Computer Science very often belong to software design, one complex of subjects is dedicated to applications oriented software design. From a wide field of technical applications the main emphasis lies on gathering and preparing graphic information within the fields of Robotics and Process

Computer Science. In the field of nontechnical applications the stress is put on the complex of Environmental Computer Science.

3.2 Integrated Hard- and Software Systems

The spectrum of courses shall enable students to predominantly develop information processing products. Their goal is the mixed realization of hard- and software components which strongly influence each other and special tasks. The complexes of system specification, system design, system validation and mixed implementation (generation of software and hardware) will be discussed within different aspects.

3.3 Medical Computer Science

Medical Computer Science in connection with Biomedi-cal Technology, Medical Biometry and Epidemiology gains an increasing importance for medical research and practice. Through methodic approaches and application solutions with the use of methods and tools of Computer Science it reveals the whole field of medicine from doctors practices to hospitals or highly specialized research. Its specification results from the close interdisciplinary connection with the medical field of application.

3.4 Multimedia Information and Communication Systems

High-performance networks, also called Information Highways, distinguish themselves by high transfer and exchange capacities and low error rates. On the basis of modern digital networks new generations of applications are established that offer natural ways of communication and information. Thus arise higher requirements for software and transmission systems; i.e. the transfer of X-rays claims a high data rate in medical image processing, whereas audiovisual communication claims low delay times. Modern communication and information society asks for new service forms which make useful information available in less time.

3.5 Systems Engineering

Control Technology with an understanding of automated systems form the foundation for this branch of study. On **this** basis particularly the cybernetic (entire) aspect of the development of methods, strategies and decision software for complex processes plays a significant role. That not only involves technical but also environmental and ecologic processes.

Integrated modell development, simulation and process optimization as well as knowledge processing and utilization are of special importance. Systems Engineering aims at providing complex systems with "intelligence" to enable them to register changes within environment and the own system, and to react "intelligent" according to system specific valuation characteristics. Such systems arc automatic machines, environment systems or man-machine-systems for example. Charakleris-tics are: adaptation and learning abilities, robustness and fault-tolerance, co-operation, self-optimization and autonomy.

3.6 Telecommunication and Measuring Technology

This branch of study offers the possiblity to gain knowledge and skills in fields that were traditionally connected with Electrical Engineering but that at present change **through** the combination of hard- and software. The future need of communication goes far beyond the predictable extent in the fields of human and computer communication including multimedia. Examples are: automatic measuring and appropriate signals processing from the local range up to interconnected global satellite supported remote sensing systems. Computer Science for that purpose plays an important role not only for the conception and design of such systems in the stage of calculation and simulation but also for the realization of technical appliances and operation. The material-technical realization requires knowledge of fields, waves and electronic circuits as well as mathematic founded knowledge of signal and code structures.

4 Internships

Until the Diplom pre-exam students need to prove a six weeks basic internship. It can be absolved prior to the study or partly prior to the study. Fields for the basic internship are fundamental mechanic, thermal and electrical processing techniques. A vocational training in a respective branch of skilled crafts or technology may be accepted as a basic internship as well.

Furthermore after the successful completion of the Diplom pre-exam students have to absolve a special internship of 20 weeks duration continuously, and preferably with the same company. The internship shall involve scientific engineering tasks and it shall give an insight to professional business. It serves the preparation for the future profession, and it should be absolved prior to start of the special branch of study.

5 Diplom Exam and Completion of the Study

The Diplom exam consists of the Diplom thesis, two exams in the main fields Computer Science and Electrical Engineering, two exams each in the optional comulsory courses of Computer Science and Electrical Engineering and three exams in the special branch of study. The non-technical optional compulsory subject finishes with an exam as well. After the successful completion of the Diplom exam students are awarded the degree "Diplom Engineer".

6 Possible Fields of Profession

In the same way as the possible fields of activities the chances on the job market for graduates of the study of "Computer Engineering" are various and ever-changing through the constant adaptation to present stages of development. Therefore graduates face a constantly increasing field of possible professions, such as:

- industrial control techniques,
- Computer Integrated Manufacturing (CIM),
- aviation and astronautics,
- mobile robotics,
- medicine technology,
- navigation technology,
- communication technology,
- measuring technology,
- embedded computer applications,
- home electronics,
- complex systems in technology and environment,
- media computer science,
- research and teaching.

7 Conclusion

In the course of the globalization the Bachelor-Master system has itself to the world-wide de facto standard developed. In the sense of a future-oriented development all technical disciplines must be integrated into the Bologna-Process. The development of internationally understandable attractive study offers is possible and the positioning in the world-wide eduction market too. Career ways become more flexibly, further training and lifelong learning for each individual more understandable. For the employer graduates with internationally well-known conclusions offer new possibilities of the personnel development.

A Review on Education of Electronic Engineers Emphasized to Teaching of Measurement Skills

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Abstract: A brief review on the electronic engineer education and some idea how to exceed noticed defect in this education process is presented in this issue. According to the content of articles from foreign magazines and from internet addressing to this subject, one can be seen that education reform in general is very actually theme all over the world. Pressure to change the present education system arises from the fact that there is a disharmony of low efficiency study in versus a sudden and rapid growth of new technologies, especially information technology. Relevant questions are what skills and experiences might an employer in industry look for in a future electronic engineer and what electronic engineers should to learn in metrology.

I. GENERAL OBSERVATIONS

When my esteemed colleague prof. Vančo Litovski invited me to prepare my contribution for this colloquium I did not have any inkling of what problem I accepted. Even though I was given the intention of what should have written, the theme is still too more complex. Namely, there are so many entangled factors that impact the faculty education system. As we get down to essential reform education of electronic engineers, those factors can not be neglected. Changing only the curriculum and syllabus of courses is not sufficient, but the radical reform of the position of all education associates and other sociable factors in relation to realisation of the curriculum and its syllabus is certainly needed.

For that reason, it is necessary to get the answers to certain as it seems simple questions that can not be obtained only from direct associates in education (academic staff and audience), as follows:

- Who needs electronic engineers - is it nation's need, assumed unknown user, or both?
- What profile and which level skill graduate engineers would be educated in, that is, what working market is expecting from each future graduate electronic engineer - is it industry, service sector or something alike?
- What annual number of electronic engineers is needed for some estimated time in the future and who will pay for their education?
- Who and how might educate electronic engineers?

The above questions may seem simple, but if there is no answer then every education reform will be based on the assumptions that will not be of any concern, as it has been proved in practice, and any reform efforts concerning education process will be in vain.

Thus, in our country, within branches of electrical and electronic engineering in the long run there must be a defined development strategy of the industrial and service sectors as well as economic including long term real needs for this kind of workforce. Of course, besides other participants, all universities should be helped in defining this strategy and each of them entails its own set of tasks and responsibilities. Also, without new improved experiments it would be preferable to use experience and the achievement of developed countries, especially the one in transition that might be gradual implemented suitable our needs.

Thanks to the Internet and other magazines that I get as the IEEE member, I have noticed that a number of papers in magazines and on conferences in the world deal with reform, that is, with a new project on engineering education, especially for test and measurement (T&M) designers for the new millennium[1].

At the end of the last century and beginning the new millennium, from the point of the global world view a number of proposals and projects on engineering education have been initiated, as it is estimated that the present state of education system can not satisfy the requirements of modern industry as well as economics. It was especially impacted by sudden and rapid development of the information technology in almost all human activities, particularly in the field of communication and global international goods and service trade. Also, the development of the information technology is affected by the rapid progress in microelectronic and at present even in nanoelectronic technology that results in the achievement of computer science and engineering.

Some estimates are shown that for any important electronic product development, the software effort is usually significant, even about 40% or more of the total engineering effort. On the hardware side, the amount of digital circuitry especially has increased, displacing analogue circuitry with the mixed-signal mode integrated circuits, as the cost per digital gate has plummeted. From there, employers and economists of industrial companies have many problems to achieve strategic advantages through development design of their products that must meet standards to modern industry from viewpoint of quality, reliability, effective price and smaller size.

On the other hand, in spite of that large engineering progress, an economical estimate has shown that the global world's economy over the recent past have had serious problem to accomplish the growth of productivity despite to much investments for information technology both in production of goods and service sector.

Nobel Prize-winning economist Robert Solow has pointed that "we see computers everywhere except in the productivity statistics". That productivity measures do not seem to show any impact from new computer and information technologies have been labelled the "productivity paradox." Productivity growth has slowed every decade since the 1960s while investments in information technology have grown dramatically. Some take this as proof that information technology doesn't affect productivity[1].

In that conditions, education system particularly in engineering disciplines may not be insensitive both to that no expected occurrences in economy and in respect to educator's responsibility, so that there is a real pressure in the world to undertake thorough analyses and to carry out a necessary reform of education process, disregarding an extremely dynamic progress of that branch.

What scope of changes have been undertaken in the our education system only through the last 50 years one can see from one of the facts that in the 50's of the last century in Serbia was only one general education profile of electrical and electronic engineering labelled as graduate engineer of electrical engineering. Later, this profile is branched to two profiles: graduate engineer of electrical engineering with the majors of energetic and telecommunications.

Since the foundation of the Electronic Major at the Technical Faculty in Niš (1960), later separated into the Faculty of Electronic Engineering (1969), out of the general profile of the graduate engineer now we have six new profiles: automatics, electronics, industrial energetic,

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[1] http://www.neweconomyindex.org/productivity.html

computer engineering with informatics and telecommunications. Today, almost all faculties of electrical engineering educate graduate engineers for five to six different majors, and among them electronic major. Through study, these profiles are based on the fundamental theory on mathematics, electrical engineering (electromagnetic and circuits theory), physics, electronics and some measurement. From the second year of study, every particular education majors have own professional coerces followed by the final examination.

II. ON PRESENT EDUCATION SYSTEM

A critical point in this approach to engineering education is depth of analysis for each section in basic subjects. There are always the simplified examples for explaining certain rules or methods using only letter symbols, such as avoiding numerical calculus or giving explanations that are too general or too indefinite. Those methods give students only qualitative results, but not quantitative as measure of value that results so the audience have not skilled sense of quantity value. Defect of knowledge caused in that way is inversely proportional to the audience experience. While this kind of education might be acceptable for an experienced audience, as at postgraduate study, at undergraduate it is absolutely unacceptable [2].

The qualification of our graduate engineers according to the current curriculum and syllabus at the existed study is on the scholar level of theoretical knowledge as much as it is needed to only pass examination. To pass examination, more students are accommodated with demands of their teaching staff by using usually the questions and tasks for preparing their exams from previous very frequent examination periods. Learning (no study) is mainly by means of taking notes on lecture, from teacher’s textbooks and exercises and from other similar attainable publications. Relationship and coordination between particular syllabuses are very poor and gradual and sequence of taking exams is not respected. In very often cases, students at final years of study got through their back warded exams from the first or second year of study. From there it is evident of what importance the exams that represent the base for studying the following subjects are.

Taking into consideration (none) supplying of laboratories and their treatment at faculty, practical education of students at laboratory exercises is not at all satisfied as real needs of moderate techniques and economics are concerned. Non adequate concern for practical education is resulted mainly out of the subjective reasons. There are teaching courses within the engineering profile which curriculum anticipates practice exercises, but they are not performed or are performed on very poor level by the obsolete teaching means and according to the usual custom.

Knowledge of this kind without practice exercise may have been sufficient at one time when graduate engineers after having got a serious job at first position they had a possibility to gain paying time for their additional creativity skill through advanced training at their position or at other well-developed companies. This kind of education in contemporary market competition is not so economical, but graduate engineers are expected to be immediately engaged on a profitable jobs where the index of success of their applying skill in practice is estimated by quality, price, period of goods and services disposal and finally by gain of profit.

III. WHAT PROFILES OF ELECTRONIC ENGINEER

This topic can be formulated in detail by a question as follows. What and how should the graduate electronic engineer learn to satisfy the needs of his profession scope from an idea to finally realisation of the subject work (product) on his job in industry, service sector or sector of special purpose?

From the viewpoint of technological development in the long run, the work subject in electronics include production of goods and services of vital importance for our daily way of life and work and are based on electronic technology and engineering, from sophisticated equipment used in a modern hospital to state-of-the-art fibre optic communications. In the working world the dominant place in the range of this profile nowadays take computer engineering, telecommunications and consumer electronics.

In our case, what is expected of the electronic engineer now and in the near future probably is as follow:

- innovation work on existing non-competitive (obsolete) products to new products that may satisfy the present needs, first of all on the contemporary domestic market,
- application of the new techniques and electronic technologies in public service sector,
- transfer of technologies for production of goods and services according to standards in relative stable markets,
- cooperative works in industry and in public service sector that meet standards of the wider region,
- another less range works for special purposes.

Therefore, to define profile of electronic engineer directed to one subject work type is not so simple. Graduate engineer may find himself at all phases of electronic production in the row of tasks like design, development, setup of production process and providing assign quality level to both production process and final product. To meet all these working conditions, graduate engineer must be skilled in knowledge in reference to function, characteristics and possibility of moderate typical microelectronic components used in all kinds of electrical signal processing (analogue, digital and mixed-signal) over all frequency range.

The application range of microelectronic component and circuitry on products, resulting in interdisciplinary expert team, is wide. Basic tools that skilled engineer must be able to use are typical software tools and electrical and electronic measurement and test equipments. For that reason, the adequate balance is needed between necessary knowledge in the electronic components, circuits and systems, on one hand, and on the other hand the knowledge in using the proper tools, that may be achieved only through practical education.

Practical experiences of an engineer have a particular importance, because at solving some occurrences in production design, the general and long-term exhausted analyses of known problems are of any benefit. For solving the problems of the impact of the mutual interconnection, shielding, grounding, noise reduction, crosstalk and other like, practical experience and skill is preferable than theoretical knowledge. Engineers for those jobs have to be educated in laboratory by the real practice solutions rather than they have been satisfied only with obtained results by means of software simulation tools. Nowadays, from the viewpoint of profit and market competition, long term engineering education over the training period in industry is not economically acceptable. Preparing, introduction, maintenance and control of both production process and final product require from graduate engineer to know all jobs shared for skilled worker, craftsman of service, technician, associate degree, bachelor degree, and he must be able to use engineering documentation and literature from the field of his profile.

Therefore, a necessary graduate electronic engineer may be obtained by means of effective study that means possible shorter time of study and a narrow scope profile according to the needs of contemporary market. Engineering education requires a balance the need for skill that can be applied immediately versus a strong foundation in applied mathematics and science. Engineering educators are obliged to maintain this balance. Employers have the same dilemma – the need for new hires that can jump right in versus engineers prepared for the long haul[3].

The various engineering professions are easiest to define if we follow the process by which a new product is developed, manufactured and practically used. The positions of electronic engineers according to the traditional roles are: *test engineer, design engineer*, *product engineer, systems engineer* and *service engineer*. Although these engineering professions are involved in the development, production and service of electronic products, each profession entails its own set of tasks and responsibilities. Putting to work the graduate engineer as service engineer is not economically acquitted because this job can be successfully done by the skilled technicians or person with associate degree level. But, under our circumstances most of the graduate engineers now get a job in service sector or they are unemployed because the industry has been in economical crisis for a long time.

IV. INSTEAD OF CONCLUSION:

Whether measurement in electronics or electronic in measurement

In spite of the fact that measurement is unavoidable activity at almost any technological process in both industrial and public sector, it is not a sufficient reason for introducing a separated profile in our engineering education system based on the measurement science - metrology. In the scholarly circles and wide expert public there is no dispute with certain significance of metrology as one of a primary measure of technological level of every country, but some visible interest in studying measurement as separate discipline is not noticeable. In addition, the lack of familiarity with term "metrology" confused by term "meteorology" restricts interest for the subject education.

Some of the possible reasons are spreading of metrology in all branches of science and technique and the large volume of competencies for expert metrologists. Besides, many experts in their fields usually consider measurement simply to be something one must do in the engineering. Because they have a conceited but naive reason: “If you understand the scientific principles of a technology, you should surely be able to measure the parameters in that technology, and measurement uncertainty is much ado about nothing” [4].

Metrology education at the Faculty of Electronic Engineering in Niš is only a small part of the general theoretical and practical measurement aimed to the basic principal of electrical and electronic measurement. Although over the last two decades, continued innovation in information technology has completely changed the field of electronic instrumentation and measurement, the curriculum of graduate electronic engineer has provided less than 3 percent of total classes during all of study. Can there be enough time for student education on basic, legal and applied (industry) metrology?!

Therefore, only this fact is sufficient to conclude how metrology education is important for acquiring skill of the graduate electronic engineer which should tomorrow do as test *engineer*, *design engineer*, *product engineer*, *systems engineer* or *service engineer*. The various jobs functions of an electronic engineer in metrology are easiest to define by examine the process of development, production and quality control of product.

In the world, it is noticed now a tendency to profile forming of engineers as a generalist (able to adapt to new technologies), a specialist (in command of the current technologies), and a practitioner (competent to perform both generalist and specialist work in a modern industrial context). Each of these categories should be supported in engineering education through relevant course content available in lecture, laboratory, and project formats [5].

Every electronics course should contain elements of measurement and uncertainty analysis, and uncertainty analysis should also be taught as a course. This approach will bridge the gap between courses taken at other schools without adequate attention to uncertainty, and a strong metrology curriculum which emphasizes uncertainty analysis in every measurement. Graduates might have broad degrees in mechanical, industrial, or electronic engineering technology, with a metrology specialization. These degrees will have the versatility to stand alone in any job market, including metrology, and the student will be able to “hit the ground running” in any metrology or test laboratory environment.

Certainly metrology laboratory technicians, engineers, managers, and ISO assessors from government, military, and private organizations are prime customers in the workforce; but so are teachers and students in the secondary school systems.

Why should students know the systems approach to electrical/electronic measurement? The answer to this question has been done by authors of cited paper [6]. They said: "we should start by considering the skills required of an engineer in general, progressing to those of an engineer using and/or designing measurement system. A closer look at the design process will help us to orient the answer and to see how the system approach to electrical measurement may constitute an appropriate background for development of the skills required of a measuring system specialist".

In measuring whether in order to troubleshoot an existing circuit, to characterize and define a new circuit, or to find the value of some other physical variable, many of applied science and engineering in general, and of electronics in particular, have been involved.

In general, a common task is to find appropriate solution how to use some electronic means to make a measurement. Questions like what, how, by means of what and why measure are fundamental in measurement and answers to them might be given only in theory of measurement. It is the naive sense that is possible to measure something and to use the information gained for some particular purpose, without knowing much about measurement theory. But, there comes a case when it is necessary to understand a little more about it in order to gain the maximum utility from the performed practical measurements.

Modern instrumentation embedded by digital signal computer can provide high performance of automatic calibration, measurement data processing and communication. This complex equipment may be used without detailed knowledge how it works and what it measures. Once the measurement data from object of measurement has been transferred to digital form, its accuracy and number of significant digits no longer important. Measurement data is obtained too easy using the computer, but many digits of data row convey a false sense of accuracy and information. The real danger for students is that it is too easy to play using software simulation that acts more like a toy than a serious tool. What this means is that students are enjoying an easy-going life in the dimensionless, virtual word of a computer simulation, but are not learning enough about the real, dimensioned world where they must practice engineering. Valuable measuring data can be obtained only by carefully examine of measurement condition, accuracy, uncertainty and resolution. The only cure for that is a systematic approach to I&M education that includes improving basic understanding of the natural sciences [7, 8].

It is vital to recognize the importance of measurement as a complete process, including the concept of uncertainty analysis. From the metrological view point the study of metrology is the study of measurement uncertainty giving answers how to avoid it, how to minimize it, and how to quantify it.

Finally, whether measurement in electronics or electronic in measurement is left open question for educators. In order to point out in what way engineering teaching should be improved I proposed to my colleagues to read the paper: "Implementing the Seven Principles: Technology as Lever’’ by Arthur W. Chickering and Stephen C. Ehrmann, on website: http://www.aahe.org/technology/ehrmann.htm#Top

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Towards New Electronics Curriculum In Serbia

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I. INTRODUCTION

The quantity of global knowledge in the world grows very fast. One may consider it is proportional to the volume of a sphere which radius rises linearly with time. Our profession considerably contributes to this trend. We may claim that there is no other vocation with similar impact on human society.

However, unlikely to the positive influence on the surrounding world, electronics engineers (EE) are not recognized and respected as they should be. This started from the very beginning of electronics. W. Brattain, J. Bardeen and W. Shockley have waited eight years to be awarded for inventing transistor by the Physics Nobel Prize in 1956. Moreover, Jack S. Kilby waited almost 50 years to receive in 2000 the Nobel Prize for his part in the invention of the integrated circuit.

Despite to the status, this field of science is spreading much faster then the education system is able to follow. This is particular problem for poor countries and countries in transition. Good EE education requires money for sophisticated equipment and experienced trainers.

The goal of this paper is to initiate discussion on subject how and what to teach today in order not to jeopardize the future. Unlikely to classic scientific papers, my intention is not to give final solution for the topic. I doubt that anyone is able to do this in the moment. Instead, I'll try to give small contribution by considering three topics. Firstly the next two sections will discuss current position of EE, particularly in Serbia. Secondly, we will try to find out how to improve EE status. The one of solutions requires innovation of electronics curriculum. therefore, the paper will conclude with general observation of future EE education.

II. POSITION OF EE IN THE WORLD

It seams that the current position of EE in USA can be used as a benchmark for the rest of the world. However, one glance on the third column of Table 1 indicates that Physicians & surgeons starts with almost twice higher earnings then electronics/computer engineers. Comparing with lawyers the rate is 1:1,5.

According to [Gib02] in USA during 2002 Electrical and Computer engineers dominated over other engineering disciplines as Fig. 1 shows.

A good news is that median incomes for EE rise faster then the inflation rate [Bel97]. Unfortunately the engineering unemployment rose in 2002 from 4.1% to 4.8% despite the overall unemployment felled [Lyn02]. Moreover, the unemployment in computer science rose from 4,8% to 5,3%.

Table 1

Occupation	**2002-2012 employment growth [%]**	**Median annual earnings [$]**
Physicians & surgeons	19.5	>138,400
Lawyers	17.0	90,290
Computer soft. eng., systems software	45.5	74,040
Computer hardware eng.	6.1	72,150
Computer soft eng., applications	45.5	70,900
Electronics engineers, except computer	9.4	69,930
Economists	13.4	68,550
Electrical engineers	2.5	68,180
Computer programmers	14.6	60,290

(data derived from U.S. Department of Labor Bureau of Labor Statistics, www.bls.gov)

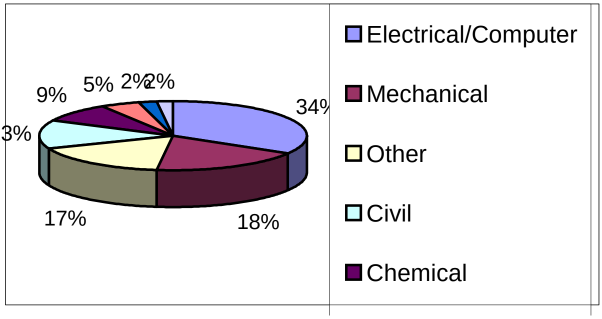


Fig. 1 Engineering disciplines in USA in 2002

The situation is not better in Taiwan where “a new EE, just out of university with no experience, can expect to make from $900 to $1,200 per month" [Car99].

EEs are in similar position in Germany [Mat02].

As result, the interest for studding electronics and computer engineering in Germany decreased from 21000 to 11000 between 1980 and 1990. After stagnation it is rising again from 1997.

III. CURRENT POSITION OF EE IN SERBIA

The gloom image of EE in the world becomes almost black when we focus on Serbia. Actually, break-down of overall industry in Serbia during the eighties was accomplished by the sanctions at the beginning of the last decade. It was the time when I asked the authorities at the faculty to buy 5 transistors BC108 for laboratory exercises but they were able to buy just 2! Thinking about new instruments was equal to science-fiction. Firstly, there was no money; then there was no instrument produced in the country and, at least, there was no legal possibility to import an instrument from abroad. The same situation was with components. Of course, we have smart people in our country with very good smuggling skills. They help us to survive, but we paid and still are paying the price.

Although the all industry was stopped, we still had very good exporting product – engineers. Basically electronics engineers. Many of my colleges and I used to say, with proud, that our "products" are best-sellers on the world market.

Now I often ask myself if it was really our success or our defeat?

In comparison with all other productive occupations the position of EE was good for the people who wanted to start new life far away from the disturbed Balkan region. The immigration policy in many countries from Canada to New Zeeland encouraged a lot of young people (under 40 years old) to settle in alternative homeland. They had opportunity to work in the field of electronics, to attend many advanced courses, to cope with real problems related to manufacture and they growth up in very good engineers. Most of those people are ready to help colleges in Serbia. Fortunately, some of them have good positions now. We, as their professors, are proud to say they were our students.

However, it is very depressing to see another army of young EEs that were not able to find job on the native soil and had not enough courage or reasons to left parents. A lot of them started jobs that have no connection with Schrödinger's equation. They began carriers as cigarette, money or, at the best, computer dealers. Unfortunately, their agony is not finished yet. I feel very sad every time seeing my colleague that works as a salesman assistant in a supermarket. Moreover, I feel some kind of shame when I see any of my ex-student working something else trying to earn for living. Then we should all ask ourselves whose wrong investments were they?

Fortunately, despite to all obstacles, there are EEs who started their own job here in Serbia in Nish. (In fact, the number of self-employment engineers is modest even in developed countries with long free-market tradition: in USA it is between 3-4,7%). It is real pleasure looking how their companies grow up. That put us in position to be satisfied with the fruits of our work. Maybe they are cleaver or luck enough to succeed independently of education, but they are giving us hope that electronics engineering has future in this region. For them, and all other future students we should ask ourselves "What to do in order to improve status of EE in Serbia?"

IV. HOW TO IMPROVE STATUS OF EE IN SERBIA?

There are three subjects that are responsible and therefore in charge to find the solution:

- state
- industry
- universities

The **state** affects our lives through several appearances: as municipal, regional, republic and federal government. They have the key role in defining strategies. The federal and republic governments have to define national strategy and to mach it with strategies of neighboring countries and EU. Good examples for the impact of state on position of EE comes from Alaska [Kei02] and New Hampshire [Eco01] where average wages are much higher then in the rest of US and predicted growth of employment in 1998-2008 is greater then 30%.

The idea of founding innovation centers in Serbia seams to be very promising. We may expect that innovation center Nish helps in reestablishing our town as industrial center of the south-east Serbia. This way of thinking (and doing) is suitable illustration how republic and municipal governments can influence on engineering profession.

The state(s) in all forms have to prepare framework that will regenerate industry. In better production oriented environment there will be more jobs for engineers.

Industry has changed its profile during the transition. Instead of strong “Elektronska industrija” with more than 30000 employees, now we have small and medium enterprises. Big factories are patient to accept engineers with wide theoretical background and rich enough to invest in additional education. They easily can to employ teams of engineers that are able to solve complex problems. The spectrum of their products is as broad as the knowledge they want from their engineers.

Oppositely, owners of small factories want to employ specialists capable to solve problems in the narrow area of their production interest. When vendor decide to change sort of product he changes the expert.

Universities are directly responsible for quality and quantity of knowledge offered to their students. Figure 2 shows difference between this two values.

The quantity of knowledge of an EE determines his price on the labor market. Simultaneously, the worth of a school is measured in number of valuable engineers it produced.

In order to create high rated engineers, universities in Serbia have to adjust their curricula. The guidelines for an innovated curriculum lies in structure of knowledge an engineer needs to stay competitive on the labor market.

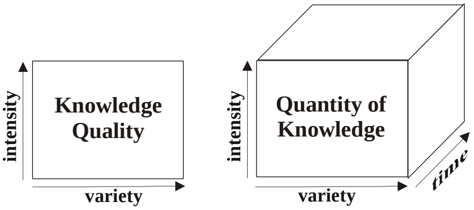


Fig. 2. Quality and quantity of knowledge

The improvement of the EE status lies in clearly differed professionals from dilettantes . Like MVP in basketball, the most valuable engineer (MVE) should be paid more than others. That will arise competition for knowledge and real values in our society.

V. THE POWER OF KNOWLEDGE

Electronics engineering requires managing with very wide knowledge. Figure 3 shows set of disciplines engaged in electronics. Its trapezoidal shape tends to illustrate how small contribution in materials stirs up development of new devices, circuits and systems. The area of each trapezoid corresponds to the number of engineers involved in the field.

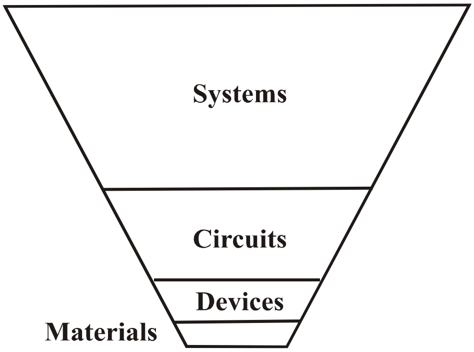


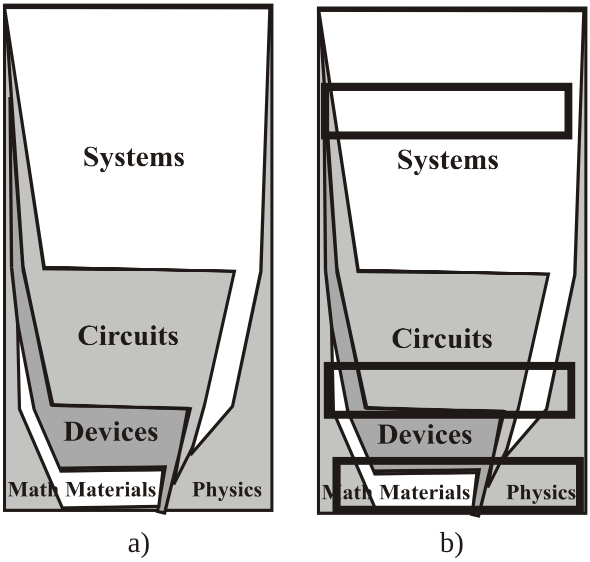
Fig. 3. Disciplines engaged in electronics engineering

This figure shows increased need for system engineers. Today their number exceeds all other engineers and their voice is louder. All of them claim that present electronics can sustain entirely on systems and consequently, there is no need to study circuits or devices. Unfortunately, they forgot that new systems relay on new circuits, devices and materials. When we exhaust possibilities of current FPGAs who is going to design the next one? Who will be able to understand how it works and why it does not work in certain circumstances?

Definitely, an ideal engineer should know all disciplines, but is it possible? When we talk about 'all' disciplines we think about variety of the knowledge, as Fig. 2 shows. Simultaneously, we have to consider intensity, or magnitude of knowledge. This opens the question of optimal intensity/variety ratio that an engineer needs to achieve desired quality of knowledge. What is better (or less worse): to know everything about nothing or to know nothing about everything?

For the future labor market in Serbia we can count on small enterprises. As we have pointed out previously, they will prefer engineers specialized in particular fields. However, every EE should ask himself is it worth to tie his destiny to current trends in electronics. It may be very dangerous because trends are changing quickly in this discipline. The treat of loosing job increase with the narrowness of the field. This is one of reasons why the tenth trend for the future in [Sch99] is "retreat from subspecialization".

The area of needed knowledge (quality) is presented in Fig. 4 a). Obviously, it is hard to



a) b)

Fig. 4. a) The area of needed knowledge for EE
b) Example of three possible curricula for EEs with the equal qualifications in different fields.

image an electronics curriculum capable to encompass the overall area.

Understanding basic principle of materials and devices requires more fundamental knowledge of physics and mathematics. Climbing up toward systems, one needs less subjects related to elemental scientific branches.

Instead a rigid school organization, the credit system proposed by Bologna Declaration (signed by Serbian authorities) offers flexibility in choosing area of prospective knowledge. Therefore three different students may choose three different area with the same knowledge quality, as Figure 4 b) shows.

Another issue is time of studding. It puts into scope quantity of knowledge. What is the proper measure for average students?

From the state's point of view the study should last as short as possible – it is cheaper. Students have the same attitude. Their interest is to start work and to get back money they spent during study. Therefore they prefer to find job and postpone investments into the own future by additional learning. This trend was noted in US in 2001 [Gib02].

In contrary, the appropriate knowledge quantum needed for MVE requires longer studies.

The student's ability to percept some dose of knowledge is subjective. Therefore it is good to personalized it. Future students must have chance to choose not only the quality but the quantity of knowledge, as well. This will make differences between engineers.

Another aspect of good curriculum is the amount of practical skills it may develop. The main weakness in our current EE education is the lack of hands-on training. When/if the innovation centers open, they will be good teaching polygon for students.

Although the field of electronics is very wide and getting bigger every day, modern EE have to posses skills from some other professions. Along with the impact our gorgeous profession have on all others, EE needs knowledge related on different fields from biology, and medicine to mechanics and aerospace. Besides, the future engineer needs non-technical skills, as well [McG99]:

- The ability to lead, influence, and persuade.
- The ability to deal effectively with ambiguity and take risks.
- Decision making and sound judgment.

All this implies that EE needs lifetime education.

VI. CONCLUSION

Given survey of skills and knowledge an EE needs, did not cope with particular branches within electronics engineering like control systems, robotics, telecommunications, power electronics... Besides it was no place in the paper to distinct electronics in different frequency domains or different technologies. Even without them the presented field of required knowledge is wide enough. Therefore it is difficult to imagine one school that will be able to offer to future students an unique curriculum that will result in universal electronics engineer.

At least it is impossible until one finds some alternative way for knowledge transfer. Till then, we need a flexible school where every individual student can find himself. As Editor-in-Chief of Today's Engineer pointed in [Gay01] "There is no such person as the average engineer. ... Some are more creative and innovative than others. Some are more systems-oriented. Some are more entrepreneurial. ... The engineering profession needs all of us ... the tomorrow-thinkers as well as those who focus on getting today's work done.”

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Remarks on the Organization of Teaching Electronics in Serbia

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Abstract

This paper presents some consideration about the level and organization of teaching in electronics in Serbia, with a particular emphasis on teaching this subject at Departments of Computing[1].

Introduction and General Comments

The considerations in this paper are motivated by the fundamental questions about the necessity of reformation of the education system in Serbia. Thus, it is the best to first express our attitude towards this subject.

Political and economical changes in a society, usually strongly related, necessarily highly influence the education and scientific work. Unification of Europe caused such changes in the education systems in EU countries resulting in introduction of internationally agreed standards, emphasising strong cooperation, unification of criteria in teaching and evaluation of the work of students and teachers, mobility of both students and faculties, equalization of the level of knowledge provided, the way of teaching, supporting equipment and related facilities, etc.

Dramatic changes in Serbia in over than a decade have influenced the education system in our country strongly, sometimes even beyond description by imposing inadequate laws and rules, besides economical difficulties, and in other ways. These numerous internal and certain external influences, as for example, restricted communications, and others, culminating in a few months break in teaching and direct destruction of educational facilities in 1999, have imposed strong challenges to the education in our country. Another aspect is that we have to adapt our system to the changes in the education in the EU and other international standards.

There are at least three possible answers to this fundamental question about scheduling of the work towards the reformation and the way to implement it:

1. The reformation now, extensive and fast,
2. Now, but slowly, and restricted,
3. Minor adaptation as an answer to the changed circumstances in the international environment.

There are many pro and contra reasons for each of these answers. Main concerns regarding the first two answers are, that negative consequences of the reformation and all possible mistakes

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[1] The name « Department of Computing » is used in this document as the closest to the Serbian name and to express the equal importance of software, hardware and applications.

will be visible only after several years, when first generations of students complete their education under the new system. Thus, fast but not properly founded changes can be dangerous. In spite of that, we want to explicitly state that we are personally strongly inclined to the first answer. The main reason that determines this attitude is not related to the level and contents of knowledge provided to the students, which have been already discussed quite much, but are rather economical and related to the psychological and other requirements, or more precisely, the overload for the students, which all together make the educational system inefficient and inadequate. The organization of teaching and regime of study combined with the rigid methods of evaluation of students, lack of efficient control of the work of teachers, and other reasons, make the average time of completing the study in the area of electrical engineering in Serbia much longer than estimated in officially accepted university programs. The results are very expensive studies when we take into account that students have to be supported by parents or in general, by the society, for a couple of years longer instead of starting to work and, in this way, returning back to the society. In this remark, we stress on inadequate facilities offered to students at the universities, which do not concern just the lack of modern equipment and elementary comfort in lecture rooms, but also a frigid ex cathedra teaching without much interaction with students and their involvement into the various aspects of the real university work. We hope that other aspects that reflect this problem, as for example, desire to keep the status of a student as long as possible for unemployment problems in the country or obligatory military service for male students, would be solved by the government and other relevant state and political institutions.

Inadequately estimated requirements often imposed to the students, lack of coordination in the time schedule of the requirements and task assigned to a student, a rigid purely administrative system of control of the work of students, in practice mainly reduced to the requests to pass a sufficient number of exams to be assigned to the next year, that proved quite inefficient in the past, lack of control of results of exams after the exam period as a measure of the quality of work of the teaching staff, and other reasons, result into difficult studies with rude psychological pressure to students. We can easily observe that after completing the study many students are feeling tired and exhausted, and without much willingness to continue professional learning at the working place.

We believe that a similar situation is present at other related faculties and universities in Serbia. These are the reasons sufficient to argue for an immediate start of the reformation however paying a strong attention to avoid as much as possible the eventual mistakes.

Some other reasons from the point of view of the concrete interest of Faculty of Electronics in Niš are discussed in [1].

Level of Teaching in Electronics

It is often heard and commonly accepted that electronics are everywhere around much present in everyday life, that necessarily has to be taught in each modern education system. This completely resolves the basic question, do we need electronics as a part in our education system in the country? However, another important question raises for small countries as Serbia, from the present situation at the electronics production and market World map and distribution of centres of power in this area. This is the question - teaching up to which level of expertise should be provided by our education system in the country. This is a legitimate question taking into account the small probability to take a considerable role in the production and marketing of electronics, and on the other side, the cost of a proper organization of teaching of electronics. The definitive answer should be absolutely the highest level, since restricting to the consumer of electronics level means exposing to uncritical buying of licences, impossibility for their adaptation to local circumstances and possibly improvement. In general, dependency on foreign consultants and experts.

However, taking into account expenses of organization of such studies and requests in ensuring the level of quality, we would suggest the reorganization of the present system. In that respect, we vote for a system of accreditation and licensing of institutions and individuals that may be allowed to organize postgraduate and doctoral studies as well as post-doctoral research. Further, we want to suggest to join and share resources between the universities and other relevant institutions in the country. We propose the organization of a National school for doctoral studies and postdoctoral research, whose main task will be organization of courses that will be offered for doctoral studies and related research activities. Although intended to prevent localization in a negative sense, this proposal does not implies centralization of study in Serbia neither a monopoly in organization of this highest level of study. The School will not assign students, neither recognize ranks nor issue diplomas. That will be done by the Faculties as it is now, and the Faculties will be allowed to organize and offer the courses to students at postgraduate studies. However, the School will be in charge to organize courses, besides those organized at the Faculties, by engaging the best experts in the area, including experts from abroad. The courses will be realized at different Faculties, or some other places, and will be attended by postgraduate students from all the Faculties. These courses will be recognized and accepted by the Faculties as a part of fulfilments of requirements for a Ph.D. diploma at every particular Faculty. In this way, the School will support the organization of high level courses at Faculties and does not represent a competing institution in organization of doctoral studies and post-doctoral research. These courses can be also offered to engineers in industry as a part of continuous learning. Activity of the School can be extended to the organization of various seminars, colloquia, summer schools for advanced students, etc.

The School should work under auspices of the Ministry of Education or Ministry of Science. It will consists of few employees, that will organize courses, engage highly recognized lecturers, and undertake the administrative work in communication with Faculties and registering attendees. Fig. 1 explains the role of the National School in doctoral studies and postdoctoral research. It shows that the role of he National School is to help Faculties to organize high level courses at doctoral studies and postdoctoral research, moreover courses organized by whatever the School or particular Faculties could be shared. The School should be also in charge for courses for continuous learning for engineers in industry to avoid possible problems that may appear if this job is left to the level of particular Faculties and companies without a supervision that is always recommendable. The same model should be extended to other areas in education system in Serbia.

Teaching of Electronics at Undergraduate Studies

At undergraduate studies, teaching of electronics should be organized in a way to meet two goals

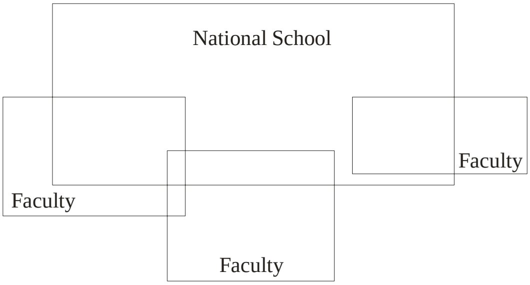

Fig. 1 National School and postgraduate studies.

1. Ensure a basis for development of electronics as a separate scientific discipline and offer courses with the required content to students in this subject that would specialize further in different branches of electronics.

2. Provide fundamentals of electronics required for a general knowledge of an electrical or computer engineer and notions necessary for understanding and study at other education profiles in these.

These goals can be achieved through organization of different programs whose contents and the way of realization (number of lectures, exercises, lab exercises) would be determined by the specific requirements of the education profiles to which particular programs are intended.

The programs should be defined in cooperation with experts in teaching in education profiles to which they are intended. Some concepts and required knowledge may be left to be introduced at the places where they will be used within lecturing in these different areas. This would make easier the courses in electronics themselves.

The programs in electronics should be realized through a series of specialized and properly sized courses, rather than an extensive general course. Efforts should be made to provide written materials for each course, prepared by following the recommendations in Fig. 2, and besides lecture notes, some appropriate carefully selected chapters from nationally or internationally recognized textbooks should be recommended. Whenever possible, teachers and tutors should be encouraged to use modern technical teaching facilities.

Faculty and Departments

Teaching is an educational process, and should be supported by the corresponding organization of the Faculty. The main background idea is that teaching should be considerably based on the laboratory work and this would not be finished after just completing a required set of lab exercises. Instead, labs should be open for students at any available time. In that respect, whenever possible, research and teaching labs should not be completely separated, which will permit to gradually involve advanced students into research work at the Faculty.

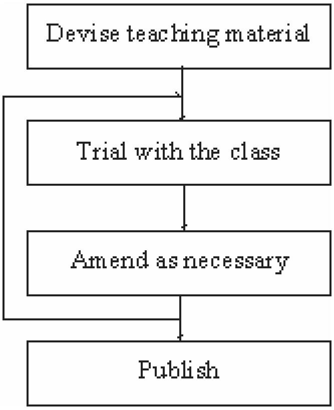

Fig. 2 Recommendations for preparing lecture notes.

It follows that teaching and research Labs should be the basic organizational units of the Faculty, with Labs working in the same area united into Departments. The Departments in the related areas can be united into higher organization units called, for example, Divisions. Fig. 3 shows this possible organization the Faculty. A reasonable union of departments could be between Departments of Computing and Telecommunications, or Electronics and Automation Control and Robotics, or Computing and Electronics, Computing and Mathematics, etc., which will depend on the concrete programmes of study offered by the departments and their research areas. Efforts should be made on the national level to provide a synchronization of the teaching programs at the doctoral studies and research areas to avoid unnecessary overlapping of programs at different Faculties and provide a complete coverage of the scientific areas at the national level in the country. That should ensure a complete and well established education system in Serbia.

With respect to teaching, Labs should be in charge for organization and offering courses in the area of their expertise. The Departments should determine education profiles by combining courses offered by the Labs into reasonable and complete Programs. To accomplish that, Departments may require Labs to provide some particular courses if there are available knowledge and human resources. If not, then required courses may be provided through the cooperation with other Faculties in the country or abroad. The Divisions can create new education profiles offered by the Faculty by combining courses offered by the constituting Departments and other Departments at the Faculty.

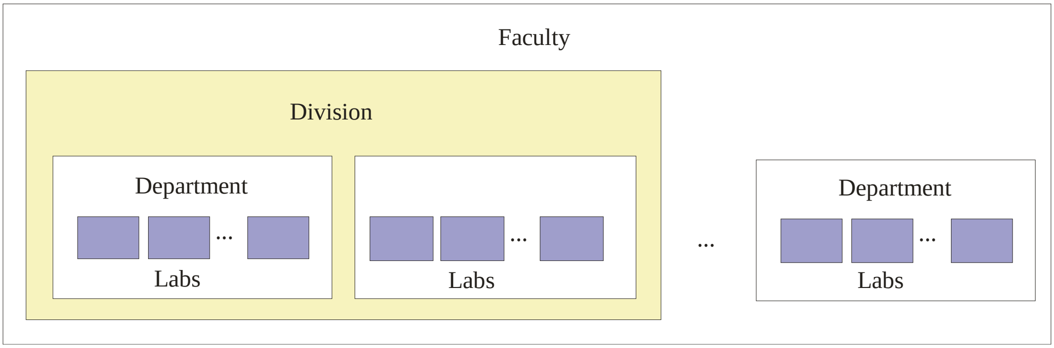

Fig. 3 Structure of the Faculty.

Programs in Mathematics, Electronics, and Computing

The interaction and links between these three areas will be briefly discussed based on the example of the problems of automation of the design of complex systems.

In practice, we are requested to design increasingly complex systems within shorter time spans. To achieve the necessary increase in productivity, the level of abstraction at which design entries are made must be raised. In this respect, we need strong links between mathematics, computer sciences and electronics. Mathematics should provide models that will permit to describe systems at varying levels of abstraction. Computer science provides for algorithms of synthesis at logical level, while electronic should provide methods for final physical realization.

The first embedded computer applications were simple enough so that their design principles were well understood. Recently, the increased integration level of VLSI circuits has brought very large and complex embedded systems into existence which is why the traditional ad hoc design methods fail more often than before. An increasing number of people in the embedded systems design community are looking for answers in formal methods, which are mathematically justified, rigorous approaches to specification and design. At this level, formal methods involve software-assisted proofs to allow mechanized reasoning about the behaviour of a system.

In that respect the programs in mathematics at the Department of Computing should be upgraded with some lectures on particular subjects, as for example, in mathematical logic, temporal logic, temporal logic of actions, Petri nets, etc.

At the Departments of Computing, a basic course in electronics should be provided as a course obligatory for all the students. Then, few different courses should be offered to students in software, hardware and information technologies including signal processing and similar areas. The contents and number of these curses should be adapted to serve the best study in the major topics for students in these particular subareas of computer engineering and computer science. The contents for each particular course should be determined by following the guidelines of IEEE/ACM [2] however by taking into account particular local circumstances and needs. In particular, coordination of the contents of courses in electronics is, with other courses at the Department of Computing, of a considerable importance. These courses in electronics should be offered as electives, however, as prerequisites for the corresponding and related courses at the Department of Computing for which this appropriately selected knowledge in electronics is required. Together with the obligatory basic course in electronics, these electives should provide a well organized sufficient knowledge in that subject for every student at Departments of Computing in their specialization in different subareas.

We give the following example to explain better what we expect as a possible contents of these electives in electronics.

Various methods of signal compression are a standard part of courses at Departments of Computing. Courses discussing concrete realizations of these methods in hardware from the point o view of electronics would provide a complementary knowledge in these topics.

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ELECTRONICS AND TELECOMMUNICATIONS IN NEW CURRICULA

INTRODUCTION

Bearing in mind that our country singed Bologna Declaration last year and accepted all the rules of the declaration and dynamics of making curricula at the Faculty of Electronic Engineering in Nis since its foundation (1968, 1980, 1990, 1998), it seems that “Colloquium on higher education of electronic engineering in Serbia” takes its place at the right time.

Taking into consideration the current situation in the field of higher education in Serbia, it is necessary to take over urgent activities on the reform with the aim to reach unique European principles concerning higher education, established upon Bologna standard (unique European Credit Transfer system, mobile students and teachers at European universities, integrated five-year studies of engineering).

Infrastructure and standard of higher education at our faculties significantly lag behind developed countries (computer education, communications, laboratories, experimental work, etc.). It is necessary to provide appropriate financial means for realization of education upon Bologna model in order to harmonize all activities during the studies (lectures, practical classes, homework, projects, seminar papers, colloquium preparation and examination taking) with prospective European countries. The main aim is the quality, rationality and efficiency of studies.

PRACTICAL ENGINEERING EDUCATION

Improvement and development of technology and computer science brought up the education level growth of engineers. A well-educated engineer represents one of the most important resources today. It is evident that higher education is only a first segment of the process without which a good engineer would not exist. Through his work, an engineer develops that process.

After graduation from faculty, the young electronic engineer entering industry begins a second phase of engineering education: professional training for engineering practice. Since the universities' primary orientation is research, it is with great difficulty that new engineers discover and acquire the practical expertise which will allow them to become full-fledged professionals in industry.

That the engineering faculties are composed mostly of researchers with little representation by professional practitioners is a serious shortcoming. Therefore, the main idea is that the curriculum should be broadened and depended and that there should be an orientation toward professional engineering practice as well as research.

Design-oriented courses, although very difficult, are valuable preparation for work in industry. In such a course, a team of students is given rough requirements for an engineering task, and must write specifications, design, build, and deliver a prototype device to do the job.

As for our faculty, influence of domestic industry and economy (especially Electronic Industry Nis) on education of electrical engineers was of a great importance. It used to lead to important changes in making curricula or it used to cause the opening of some brand new departments. Unfortunately, the situation today is not like that.

ELECTRONICS AND TELECOMMUNICATIONS

As it is known electronics has developed very fast during the past ten years. However, some of the disciplines of engineering have developed even faster, for example telecommunications.

What amount of electronics knowledge is needed for telecommunications and vice versa will be considered in the following set of views.

Modern data communications are based on generation, transmission and processing of signals, which often may be very complex. Achieving these functions requires different electronic components. Their miniaturization is becoming more important every day.

Students in the telecommunication program learn the principles and details of data transmission methods and systems. They work with both digital and analog technologies. Of course, conversion of analog signals to digital domain and vice versa presents a significant aspect in system consideration. The conversion may be relatively simple (in the case of binary signaling), or significantly complex (for example QAM signals or coded modulation). Very often, the errors appearing during the analog-to-digital signal conversion process determine the overall system performance.

During the transmission, a signal may incur different destructive effects, such as distortion, noise accumulation, channel interference and crosstalk, etc. The signal usually passes through different electronic components during the processing, adding to the signal a certain amount of distortion and noise, thus contributing to the overall performance degradation in a communication system. Students are required to understand different types of noises and interferences that might be generated within the electronic components qualitatively and quantitatively, in order to be able to evaluate the performance of a communication system. Moreover, the students should be aware of the techniques that may be undertaken to compensate or minimize such negative effects of electronic signal processing, without significantly affecting its function.

Communication systems are being used in many different application domains, offering an increasing number of sophisticated services to end users. These services are based on the ability of the systems to both transfer multiple types of information at very high speeds and process complex information efficiently. User requirements for electronic products that provide new services with lower cost and higher quality are the driving force for high technology researchers and practitioners.

Modern communication devices can be embedded in a single chip, usually referred to as system-on-chip (SoC). Communication SoCs are designed with several different types of intellectual property cores, including processing elements (embedded processors, digital signal processors, microcontrollers), storage elements (memories of various types and sizes), high-speed, multi-gigahertz interfaces for both wired and wireless applications, and analog and mixed-signal intellectual property cores (phase locked loops, mixers, etc.). The number of components in an SoC is growing rapidly, and the communication infrastructure on a single SoC is major concern. In fact, on-chip interconnect will increasingly be implemented as a network on a chip, complete with network interfaces, routers, and packet or circuit switching. Although the distances over which communication takes place differ by many orders of magnitude, the fields of on-chip networking and computer networking are clearly related.

The commercial wireless industry is begin driven a need for inexpensive radio frequency integrated circuits with low-cost packaging and manufacturing processes.

Therefore, students should be able to understand improvements in microelectronics, and bear in mind the possibilities of implementing required functions in VLSI circuits. Furthermore, the specific procedures for testing and verification of SoC should be known to students pursuing a communication career.

Although the number of Internet hosts has multiplied by a factor of 1000 over the last decade, the rate of installing commercial trunk transmission systems has been some 20 times lower. A vast increase in the transmission capacity is therefore needed to bridge the gap. Much effort is being devoted to achieve trunk transmission systems beyond 1Tb/s by combining time-division multiplexing (TDM) with wavelength-division multiplexing (WDM).

High-speed TDM systems have several merits. Many functions, including multiplexing, demultiplexing, retiming, reshaping, and regeneration, can be integrated in a simple and compact manner using high-speed integrated circuits.

One of the major issues in implementing an ultra-high-speed TDM system is the development of ultra-high-speed electronic integrated circuits. Very mature Si technologies are now being utilized for commercial 10 Gb/s (STM-64) systems. Recently, next-generation 40 Gb/s-class integrated circuits use high electron mobility transistors (HEMTs) and heterojunction transistors (HBTs) based on III-V compound semiconductors like GaAs and InP, and even Si bipolar transistors and SiGe HBTs. Ultra-high-speed integrated circuits are one of the keys to achieving large-capacity optical communication systems.

WDM system introduce several new optical component technologies into field use. The key enabler was erbium-doped fiber amplifier (EDFA), built using many types of optical components. It made possible the amplification of optical signals without conversion back to the electrical level, thus removing the attenuation limitation for the distance span of optical transmission.

Moving from pure WDM transmission to the other WDM network functionalities, optical switching has a key role. Micro-electromechanical systems (MEMS) have emerged as a leading technology for realizing transparent optical switching subsystems. Optical switching technologies are very crucial to future mobile broadband all-optical IP networks.

Accordingly, the new curriculum should encompass all mentioned above components.

CONCLUSION

Should the curriculum in Electronics be improved hastily or should it be done step by step?

On one hand, would engineers who had already attended classes in Electronics before the reform be in the same position as those after the reform? Is it fair to students to make such radical changes of curriculum?

On the other hand, can a step by step reform disable students to learn about the latest trends in science?

A good balance between these questions is needed. One is for sure: the reform of the program should start as soon as possible in order to make it easier for students. The reform must not be something which should be applied and then forgotten. It should be a responsible and continuative process.

A place of Control Engineering in Modern Education in Electronics Engineering

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Introduction

A reform in education of Electronics Engineering at universities from transition countries imposes several important issues upon which agreement must be achieved. First, it must become compatible with modern european standards. A formal mean is to start applying ECTS and to define ‘diploma supplements’. Second, having in mind actual industrial potentials and needs, we must define specializations in electronics engineers curricula. Third, we must preserve certain level of diversity in our education to enable education of specialities needed in a transition period of our industry. Finally, it must be a process supported from both, inside and outside. From inside, university employees need to recognize their need for the reform and, accordingly, to start changing topics, means and approach to education of modern engineers. From outside, this process must be recognized as an imperative towards modern industrial country, thus supported by national foundations in education and research.

Here we contribute working hypotheses and a tentative list of subjects from control engineering field suitable in electronics engineering education.

Working hypotheses

A list of general hypotheses is given below:

H.1. We need a new concept with emphasis to interdisciplinarity. We can not reorganize only actual subjects to start the reform.

H.2. Bachellor of science (BSc) in EE are needed for technology transfer. Masters of Science (MSc) in EE is needed for both, technology transfer and development of new technologies. MSc studies are in some cases predoctoral studies.

H.3. Teaching in BSc should be a combination of all compatible disciplines. Teaching in MSc may be an interdisciplinary combination of electronics and other disciplines.

H.4. System 3+2 years (BSc+MSc) is probably better than 4+1 year.

H.5. All subjects should be selectable and one-semester. Subjects need to be interconnected in many ways: many of them should be prerequisite for subjects in the last years.

H.6. Not more than ten specialities should be defined as an outcome.

Control Engineering in Electronics Engineering Education

Control Engineering is the scientific and technology discpline that greatly benefits from the developments in electronics engineering. On the other side, a complex scientific and technology projects with control issues as primary goals, necessarily demand comprehensive teams of many engineering specialities, especially basics of electronics engineering. As a member of such a team, an electronics engineer needs to have understanding in many relating fields, including control engineering.

A tentative list of selectable subjects in electronics engineering education shold be devided in three major areas:

- classical control engineering,
- industrial automation, and
- modern control applications.

The following list of subjects is a proposal for further discussion among teachers, professionals, and students. The list is divided into three major areas of control engineering and applications; not according to undergraduate/graduate criteria. Subjects are selectable.

The Classical Control Engineering shold cover the following subjects:

Signals and systems

Basic signals and types of systems, linear time-invariant (LTI) systems. Fourier analysis, frequency response, and Laplace transforms for LTI systems. Fourier analysis for discrete-time signals and systems, filtering, modulation, sampling and interpolation, z-transforms, sampling/aliasing. Natural frequencies, pole-zero diagrams. Transform techniques for circuits analysis in continuous-time and in discrete-time systems.

Classical control theory

Mathematical modeling of linear systems for time and frequency domain analysis. Transfer function and state variable representations for analyzing stability, controllability, and observability; and closed-loop control design techniques by Bode, Nyquist, and root-locus methods. Controllability and observability. Pole placement. Observer design. Lyapunov stability analysis.

Digital control systems

Sampled-data systems, sampled spectra and aliasing. Z-transform. Stability analysis and criteria. Frequency domain analysis and design. Transient and steady-state response. State-space techniques. Controllability and observability. Pole placement. Observer design. Lyapunov stability analysis. Programmable logic controllers. Digital filters.

Nonlinear control systems

Nonlinear differential equations, second order nonlinear systems. Equilibrium and phase portrait, limit cycle, harmonic analysis and describing function. Lyapunov stability theory. Absolute stability. Popov and circle criterion. Input-output stability, small gain theorem, averaging methods, and feedback linearization.

Modeling and simulation in control systems

Introduction to the mathematical modeling of dynamical systems and their methods of solution. Advanced techniques and concepts for analytical modeling and study of various electrical, electronic, and electromechanical systems based upon physical laws. Emphasis on the formulation of problems via differential equations. Fuzzy and Neuro modeling. Digital computer simulation.

List of subjects in Industrial Automation that belong to control engineering topics:

Process control theory and practice

Basics on industrial controls and automation. Industrial information theory and practice. Sensors and actuators in industry application. Process systems. Process control theory. Large scale systems. Understanding of wiring diagram creation, hardware selection and programmable logic controller design and operation.

Applied control systems and Instrumentation

Analog signal transducers, conditioning and processing; motors and other actuation devices; AD and DA converters; data acquisition systems; microcomputer interfaces to commonly used sensors and actuators. Design principles for electronic instruments, real time process control and instrumentation. Computer controlled instrumentation to collect data for modeling of physical systems using statistical analysis.

Industrial machine control

Application of the principles of electromechanical energy conversion to the analysis of various devices, which configure power and control systems. Basic power electronic components are introduced and applied to circuits used in power generation and in control of energy conversion devices.

Industrial robotics

Basic robot components from encoders to microprocessors. Kinematic and dynamic analysis of manipulators. Jacobians. Open-and closed-loop control strategies, task planning, contact and noncontact sensors, robotic image understanding, and robotic programming languages. Robot control theory and practice.

List of subjects in Modern Control Applications, that requires input from control engineering, covers mostly intelligent machines like robots, home appliances, and various gadgets.

Advanced Control Systems

Introduction to feedback control theory. Classical control system design. LQ, LQG, H2 control system design. Multivariable control system design. Uncertainty models and robustness. H_∞-optimization and μ-synthesis. Matrices and norms.

Man-Machine interaction

Basic principles of information and energy transfer between man and machine. Identification and modeling of human performance. Mechanical and congnitive user modeling. Prototyping and designing of user interfaces. Learning systems. Guidelines for building applications for: PDA, cellphones, industrial devices, computers, smart home appliances. Guidelines for applications in different environments: stand alone, client/server, web.

Intelligent systems and machines

Definition of intelligent machines and systems. Definition of mechanical intelligence. Intelligence in assessment. Differences between natural and artificial solutions. Motion and manipulation as basis of intelligence development. Natural ways of movements and interaction. Mechanism design by functional imitation of natural solutions. Biomimetics. Functional robustness of mechanical design for control problem simplification. Intelligent actuation as functional copy of natural ways of movements. Actuators with integrated sensors and controllers at primitive control level. Methods and techniques of interaction modeling. Design of controllers with integrated models. Examples of intelligent machines..

Intelligent control

Theory, design and application of feedback control systems containing elements of artificial intelligence (AI). Feedback control theory: deterministic, stochastic, optimal, adaptive. Limits of conventional control. Neoromorphic control systems: connectionist approach to Al, closed-loop control architectures containing neural nets. Learning control strategies. Knowledge-based control systems: symbol-processing approach to AI, representing and manipulating knowledge bases, rule-based expert systems, closed-loop architectures. Fuzzy and hybrid systems. Implementation and applications. Bayesian probability theory as tool to handle uncertainties.

Introduction to robotics

Characteristics of modern industrial manufacturing. Coordination of movements in machines. Mechanical joints. Robot as an universal machine. Basic subsystems of robot. Modern solutions in mechanical design of robots. Actuators and systems for force and torque transmission. Sensors in robotics. Structure of control subsystem. Hierarchical approach in control. Motion planning in workspace. Robot programming. Examples of robot applications in manufacturing. Robots in production and machine loading. Robotized assembly. Autonomous guided vehicles.

Service robotics

Environment entropy as motive for robot application. Robots in non industrial halls, offices, hospitals, houses, and outdoors. Specifics of robot construction of interaction with unstructured environment. Autonomous drive and control. Vision, sound, distance and touch sensors. Flexibility and robustness of control system. Underwater, land and air robots. Ordnance robots. Automation of work and living space. Robots in medicine. Robots as universal asistants in surgeries and robots in diagnostics.

Systems Engineering Design

Introduction to the macro-techniques of engineering design including performance, reliability, management control, redundancy, man-machine systems and testing techniques. Design, construction, test and evaluation of the approved projects.

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.

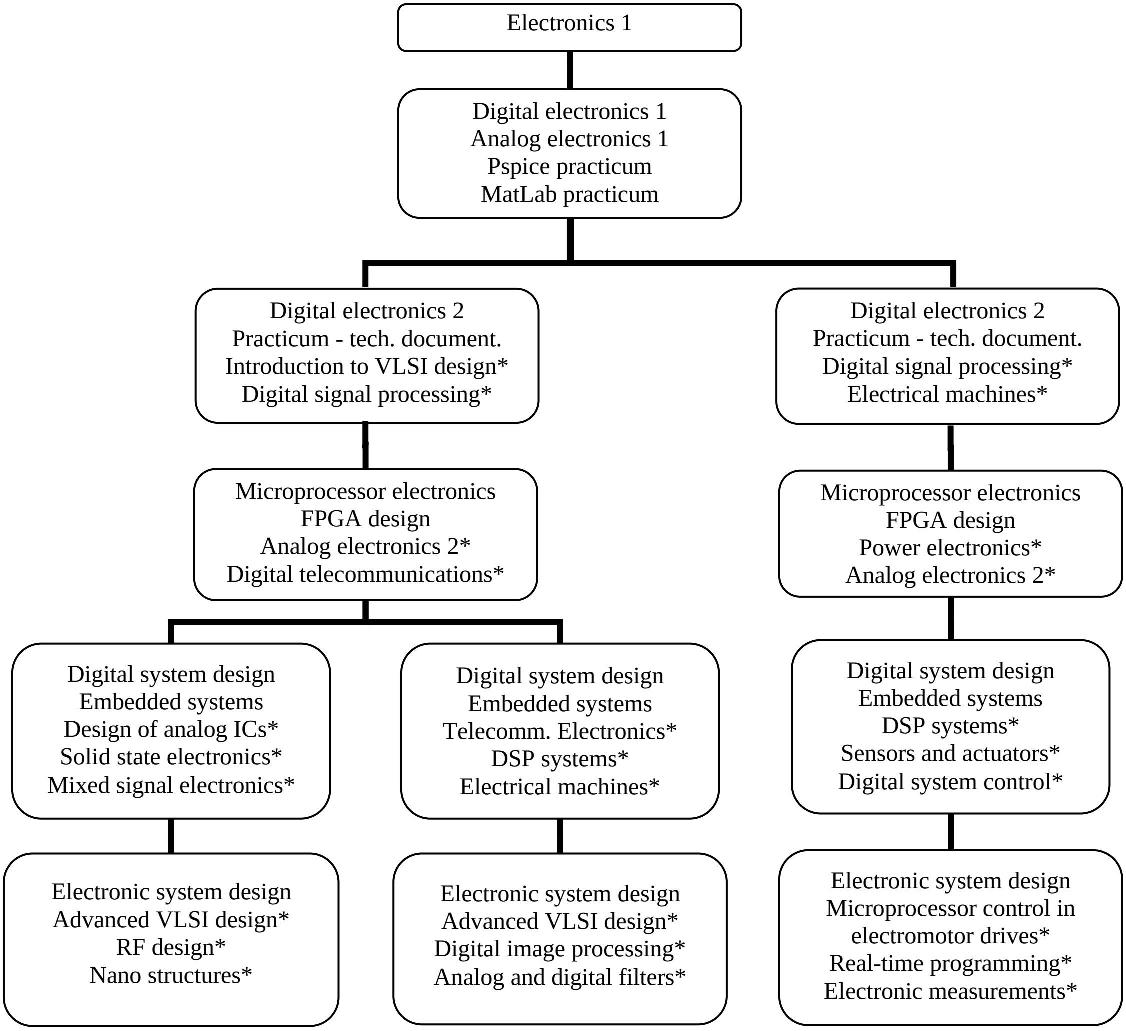

Figure 1. *A sketch of the proposed curricula. The asterisk stands by the elective courses.*

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.

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

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[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

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