Integrating Microelectronics Into A Distance Learning Course

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***Synopsis*— The implementation of a M.Sc.-course in electrical engineering at the Hochschule Darmstadt [2] is outlined. The curriculum and in particular the microelectronics content is discussed. The mixture between hands-on skills and distance learning is not straightforward and has to be balanced for an optimum outcome for the students. Microelectronics is seen as a basic technology which broad applicability and hence is embedded in a more general curriculum, which cover non technical subjects as verbal communication in a professional environment and economics as well as technical subjects from automation and software engineering.**

Keywords- Distance learning, microelectronics and automation education, teaching strategies, course set up

I. General Description of the M.Sc.-Course

Postgraduate education and life long learning is of central focus in the Bologna process and in the rapidly changing world of the electrical and the electronic industry. Therefore ongoing education parallel to the professional career has to be provided by the universities and this not only in business administration but in technical subjects as well. This was the motivation for our institution to develop a distance learning course in Electrical Engineering leading to a Master of Science (M.Sc.) degree. The course duration is 6 semesters part time which is equivalent to a four semester full time program equivalent to 120 credit points in the ECTS system. The development started in 2004. The course setting including curriculum, examination and teaching procedures passed the senate of the University in 2006, was accredited by the accreditation board of the agency ZeVA in 2007 and the first students entered in spring 2007.

Postgraduate further education in German universities has to be financed entirely from tuition fees. Therefore it was a prerequisite for a successful program that a substantial number of potential students can be addressed. Though microelectronics is of central importance in many fields of the industry, a program resting solely on this field would not sustain a self financed degree program. Since the number of engineers working directly in microelectronics manufacturing sites is limited, it was important to offer an interesting curriculum for a broad range of engineers in the field of electrical engineering.

To do so we developed a curriculum consisting of a blend of non-technical subjects (economics, soft-skills), general engineering subjects (simulation, signal conversion, control theory, embedded systems, and software development) and advanced technical subjects. In depth studies are offered in two potential fields of specialization: microelectronics und automation. An extension to electric energy as third field is in preparation. Students select one of these subjects as the central topic of their studies.

The first students started their studies three years ago and more than 50% of them chose microelectronics as their specialization. At the moment 81 students are enrolled. The annual fees are 4400€.

II. Cooparation and Costs

Since up-to-date laboratory equipment is very expensive and top-notch electronic teaching expertise is rare we started this course in cooperation with the University of Applied Science in Aschaffenburg [3]. Here colleagues focus on Chip-Testing and Electromagnetic Compatibility and as a newly founded institution Aschaffenburg offers first class technical equipment. Roughly 20% of the teaching load was taken over by professors of this institution. The cooperation also facilitates access to a broader range of alumni.

As there was no particular know how in administration of distance learning courses available at our institution we linked our new post graduate course with the framework of the ZFH in Koblenz, Germany. The ZFH (*Zentralstelle für Fernstudien an Fachhochschulen*, Centre for Distance Teaching and Learning at Universities of Applied Science) is a scientific institution funded by the states of Hesse, Rhineland Palatina and Saar. There are some 20 distance learning courses available in the ZFH-framework, mostly in social sciences and economics, both on the graduate and on the postgraduate level. The M.Sc. in Electrical Engineering is the first technical course. The ZFH supplies valuable organizational support. All students apply for the course at the ZFH. This institution checks the qualification and submits the data to the Student Service Centre of the Hochschule Darmstadt. Student fees are also collected by the ZFH and assistance is given for marketing, press/media-relations and advertisement.

Since each postgraduate further education course has to be financed without university money, the ZFH provided an initial loan (400,000€), which covered the start-up cost for the course. The main cost factors are the wages for a scientific assistant and a secretary. The development of the course material was costly as well (150,000€). This loan will be fully paid back

The development of the course was sponsored by the Hessian Minister of Science and Arts and by the Zentralstelle für Fernstudien an Fachhochschulen (ZFH) [1] a scientific institution of the states of Hesse, Rhineland Palatina, and Saarland.

during 2010 at the end of the year the course will generate a small profit, which will be used for extensions, improvement, and adaptations of the program.

III. COURSE STRUCTURE AND CONTENT

The course is organized in modules, which in general have a workload of 10 ECTS credit points (CPs). The curriculum is organized in 4 sections (the total number of CPs is noted in brackets)

- A1, A2, A3: General technical and non technical skills (30)
- B: Specialization (30)
    - BA1, BA2: Automation
    - BM1, BM2: Microelectronics
    - B3: Optional subjects
- C: System development and Team-Project (30)
- D: Master Thesis (9 month: 30 CPs)

The curriculum is organized in parallel to the semesters of the university. Students may start in winter or in summer. In general 2 modules are covered by the students in each semester. The thesis project is scheduled for duration of 9 months.

In general we provide 4 sets of printed lecture notes in form of booklets per module. Each booklet (see Fig.1) has approximately 100 pages and it is associated with a workload of 2.5 CPs. Each lecture note is backed up by online material distributed with the e-learning software platform Moodle.

For every module we offer four mandatory classes (4x10 hours) at the university on weekends (Friday and Saturday). During these contact hours we have additional lectures, solve theoretical problems and work with the students extensively in the laboratories. The students take two modules per semester which corresponds to 4 contact weekends per semester. Exams have to be cleared in 180-minutes assessments for each module. Exams are written at the university at the end of the semester break giving the opportunity of an extensive preparation phase. Figure 2 shows a typical semester time table. The course material is sent out in three batches so that it is available four weeks ahead of the corresponding contact weekend.

Figure 1. Sample study booklets

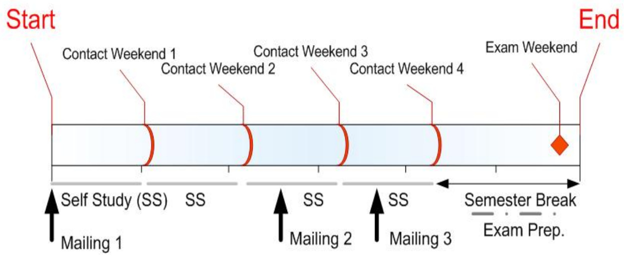

Figure 2. Semester timetable: 4 contact weekends and 3 mailings of course material. The semester break is reserved for repetition and exam preparation. Just before the start of the next semesters we have the examanition weekend with 2 module exams (duration: 180 minutes each)

In summary the theoretical electrical engineering content is 60 ECTS-points. 20 ECTS-points are obtained from non-technical subjects, and 10 credits are obtained from a successful completion of a team project in section C.

The following list shows the topics of the different modules (for details see [4]):

A1 Communication
- Verbal communication I
- Verbal communication II
- Presentation and moderation
- Leading by communication

A2 System-Design and Objects
- Hardware Description using VHDL and VHDL-AMS

Object-oriented Programming
- Part I (JAVA)
- Part II (JAVA)
- Part III (UML)

A3 Signals, Systems, Simulation
- Signal conversion (ADC, DAC, Sigma-Delta-Modulation)
- Signal processing: analog-, discrete time- und digital signal processing
- System theory: mathematical methods, test functions, stability and transfer functions
- Simulation: continuous simulation in time and amplitude, time and value discrete simulation, statistical simulation using Monte Carlo techniques

BA1 Control Theory
- Control systems I
- Control systems II
- Identification of dynamical systems
- Adaptive and learning control systems

BA2 Automation
- Automation-systems
- Sensors and actuators
- Bus systems and process automation
- Visualization of industrial processes

BM1 Design methodology
- CMOS Analogue Circuits: OpAmp-Design
- Digital Systems: Error correction, arithmetic

structures, filters

- Testing and Verification: Design verification strategies, chip testing and ATPG
- Low Power Design: design measures for reducing dynamic power consumption

BM2 Technology

- Reconfigurable Hardware: CPLD, FPGA and SOPC
- Semiconductor memories: DRAM, SRAM, Flash
- CMOS production technology: from mask making to wafer production
- Low Power Technology: Reducing static power consumption in nanometric CMOS-processes

B3 Optional subjects (Chose 4 out of 8)

- ASIC-prototyping
- Automotive microelectronics
- Mixed Signal Chip Design with TannerTools
- RFID
- LabView
- Process- and factory automation
- Robotics
- Image processing

C1 System development by Software- and Hardware-Engineering

- Software-Engineering I
- Software-Engineering II
- Embedded Systems I
- Embedded Systems II

C2 Team-Project and Project Management

- Project management in theory (2,5 CPs)
- Project: Planning and realization of a technical project in a team (7.5 CPs, 36 contact hours, 150 hours self directed project work)

C3 Economics

- Foundations of Economics
- Business administration and entrepreneurship
- Marketing and Management
- Information management using enterprise resource planning tools (ERP)

D: Master-project, thesis and viva voce: thesis topic from industry or university, 9 month duration, 30 CP

This general overview shows that microelectronics is part of a more general engineering environment. The modules in the microelectronics specialization are focused on industrial electronics. Here circuit design with field programmable devices, power reduction and development methodologies are of central importance. Testing and verification is covered as well. In order to understand the limits and possibilities of system integration foundation lectures on CMOS-technology are given. Facultative subjects which may be selected contain lectures on ASIC-prototyping, automotive electronics and mixed signal chip-design.

The total amount of electronic-related subjects is 30 ECTS credit points, which correspond to a workload of 900 hours or roughly one third of the taught contents in the master course. As Fig. 3 shows the specialization phase is in the second and third semester, where the students either select the modules BM1 and BM2 for microelectronics or BA1 and BA2 for in depth training in automation.

Note that the 8 optional sub-modules (B3) are either related to automation and microelectronics, but more general topics of current interest maybe chosen as well (LabView, RFID, Smart grids).

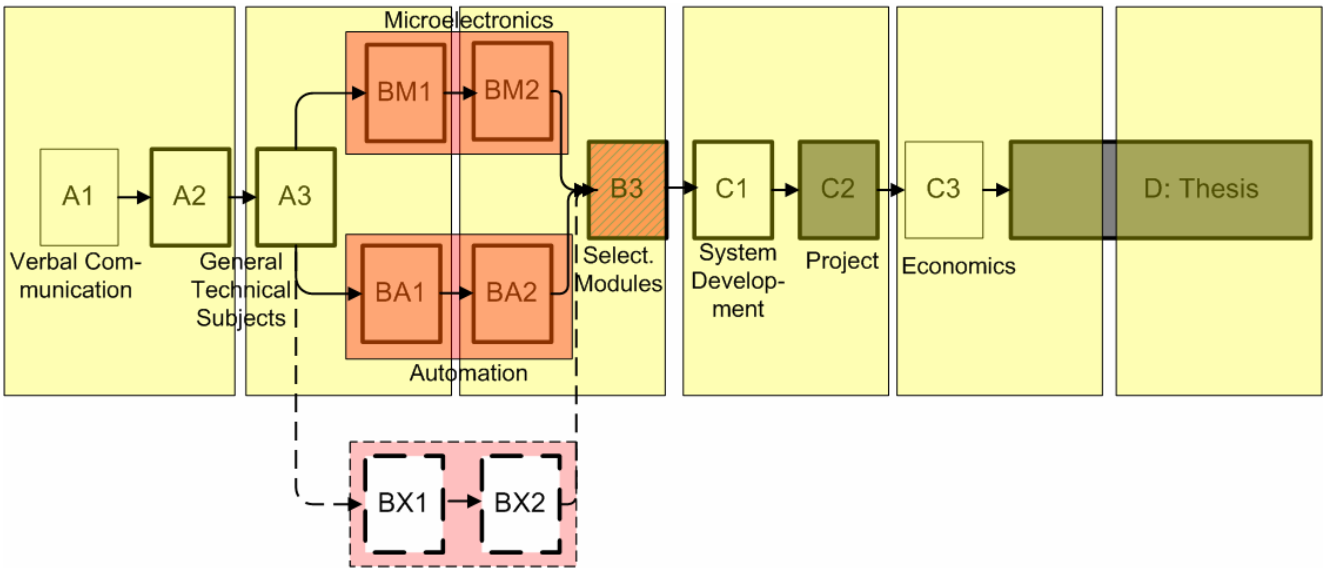

Figure 3. Course organization, semesterwise: 20 CP workload (i.e. two modules per semester). Students start with the general subjects A1 to A3, then they split up into 2 batches for automation and microelectronics respectively, select their topics of special interest in B3 and then come together for the software and poject modules (C1 and C2). Economics (C3) is the last theory module.The thesis (D) completes the studies. Potential extemsion of the programm with other fields of specialisation (BX1, BX2) are indicated by figures with dashed lines at the bottom of the graph.

IV. TEACHING AND LABORATORY WORK

Distance learning has its own challenges. In microelectronics tool usage and hands-on laboratory work is of special importance for the applicability of the knowledge gained in postgraduate education. In order to train these particular skills, we included practical exercises during contact hours at the weekends. EDA-tools are rather complex to handle. Since contact time is limited, this has to be made efficient by offering training during the learning and preparation phases of the students. So we provide students with instructions to use freeware or commercial tools for which student or trial versions are available. Hence the students can work at home on particular design problems in preparation of the contact periods.

In particular we supply a full commercial student version of MATLAB. MATLAB is the standard computer tool for automation and the student version covers all relevant toolboxes for this field. We use SystemVision from Mentor Graphics for VHDL, VHDL-AMS and SPICE modeling and simulation. Recently we recommend using the free version of Smash Dolphin since there are some problems with the current SystemVision trial version. For all these simulation tools we have full versions in our laboratories available. Chip-layout can performed at home with Microwind in order to introduce students into concepts and methodologies of the subject and in order to prepare exercises with professional tools at the university. In our labs we use the Tanner-Tools for Schematic Entry, SPICE-simulations and Layout exercises. For Logic Synthesis the ISE-Tools of Xilinx were found appropriate. ISE is available free of charge and includes a customized version of the HDL-simulator Modelsim which maybe used for VHDL-modeling. In the lab-sections during contact phases we also employ the EDA-toolset from Synopsys. In particular for testing we use ATPG generation and the ASIC-testing facilities of our partner university in Aschaffenburg.

V. LEARNING ORGANIZATION

To organize the studies we apply a blended learning concept with a strong emphasis on face to face teaching in weekend sessions. The reason for this approach is that in general students quit distance learning courses with a relatively high probability. Drop outs of 50% of each student batch over the program duration are not exceptional. If one investigates the structure and teaching concepts commonly used in other (commercial) distance learning courses, we see that for cost reasons and for reducing the organizational overhead most of the course work is done online and remote. Students are isolated and do not share and solve their problems and difficulties with others in a student team. We think that the standard remedy for such problems is an enhanced percentage of classroom teaching and laboratory work. This brings the students into classroom situations, which they are familiar with from their previous studies and solutions and assistance develop almost automatically. Internet platforms like Moodle, which we also use extensively for supporting the printed material, do not provide a similar open and interactive atmosphere, as nonverbal communication is suppressed by technicalities. Moreover after knowing each other personally from the contact phases the students find it easier to keep in electronic contact (chat rooms, e-mail) between the contact weekends. As we start with a soft skills module A1 where communication methods are discussed, the process of team formation is fostered by lots of practical exercises.

Figure 4. Students and staff in a classroom situation

VI. THESIS

Presently the first batch of students has passed the theoretical subjects and is in the concluding phase of their thesis project. It was found remarkable that only 40% of the students were offered a topic from their company. This is very untypical for universities of applied sciences, where almost every thesis (Bachelor-, Diploma-, or Master-Thesis) is performed in an industrial environment under mostly local supervision. In the distance learning course students had problems to allocate thesis topics in their company, as their department quite often had too much work to let an engineer work mainly on his thesis over a longer period. Research for other departments even in the same company was also not possible for various reasons.

So the university had to supply interesting and challenging research projects. This was done successfully as papers submitted to conferences and patent applications indicate.

However the thesis phase was found by the students to be the hardest part of the course. Continuous work on the project was found nearly impossible, since company requirements and commitments had to be met and also private life could not be disrupted for a nine month period. So the academic supervisors had to closely check for meeting the agreed schedules. Finally, all students submitted their thesis in time and at present the marking and the viva voce presentations take place.

VII. FURTHER DEVELOPMENTS

A distance learning course is never static but develops in order to keep up the interest of potential students. At present we work in two directions. As mentioned above we develop a third area of special interest, Electric Energy. There will be two new modules in part B (BE1 and BE2) focusing on Energy Conversion and production and on energy distribution and storage. These two modules will replace BA1,2 and BM1,2 for a third batch of students in the second and third semester. Optional sub-modules for B3with focusing on issues of electric energy will be developed as well.

The second way of addressing new students is the usage of the modules or parts of them as separate training modules for engineers, who do not want to go through the complete program, but need training in special fields of engineering or want to improve their non technical knowledge. This activity will be launched this summer by special marketing events and advertisements on the internet or technical journals. Each training is completed by an examination and hence individual training units may be granted later if the student wants to go for the Masters degree.

VIII. Summary and Conclusions

We presented the course structure and the course content of a distance learning part-time Master of Science course in electrical Engineering, which started three years ago at the Hochschule Darmstadt in cooperation with the partners: ZFH for organizational issues, Hochschule Aschaffenburg, and Hochschule Darmstadt for providing content. The program runs for six semesters and has 120 CPs as workload and hence is equivalent to a full time program in 4 semesters. Specialization is possible in either automation or microelectronics. At the moment 81 students are enrolled. The first bath of students (11) handed in their thesis recently and will leave the university in May.

It is noteworthy that only 4 students out of eighty left the program without a degree, which is an excellent figure for a distance learning course. Part time studies are very challenging, in respect of balancing the competing requirements of professional work, private life and the workload of a master's course. It is found interesting that most of the topics for thesis research are not related to the company which employs the students but focus on ongoing research in Aschaffenburg and Darmstadt.

It should be noted as well that 30% of the students are financed in full by their employer and most of the students are supported financially or by adapted working hours by their company. So we are convinced that this course meets not only the demands of postgraduate education but also these of the professional community. We will continue to add additional subjects to the curriculum. Presently, as a third specialization, Electrical Energy is in preparation.

What is new in our concept? Firstly, the inclusion of a substantial amount of contact phases at the university to avoid student isolation and in order to integrate laboratory work in a distance learning environment. For all the computer labs we provide free software versions of our commercial tools for the students to train themselves at home in order to be effective in the limited time frame available in the laboratories. Secondly, the inclusion of a larger amount soft skills and economics to balance the advanced technical content with subjects of immediate applicability in the professional environment. Thirdly, the modular structure allows for easy extensions to new technical fields if required, e.g. electrical energy.

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