EXPERIENCE WITH BLOCK COURSES IN DIGITAL LOGIC DESIGN AND VERIFICATION

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The fast development of technology poses new challenges to higher education. This applies in particular to emerging countries that have a smaller basis of industry and national research centers. In scientific and technical disciplines that evolve very fast, there is a high demand for university graduates.

Gordon Moore noted about the development of chip technology that the integration density increases at an exponential rate, which has enabled chips with over a billion transistors and several 1000 pins. As the one-time cost for the production of a new chip is very high, also the effort in logic design and verification for new chips is very high. Consequently, because new technology generations appear in short intervals on the market, the development time for a new chip has to be as short as possible. Both factors together, a short development time and a high effort, create a high demand for skilled engineers.

To address these needs I have taught two block courses at the Transport and Telecommunications Institute (TTI), Riga, Latvia. This paper summarizes the experiences and insights for future courses.

Keywords: VLSI, VHDL, Verification, CRC, System-C

Introduction

Following a presentation on advanced Cyclic Redundancy Check Methods in December 2003, TTI asked for a closer cooperation in the domain of programmable logic and digital design using VHDL. As IBM Research is expanding its cooperation with university partners in Eastern Europe, it was possible to offer a first course on “Advanced VLSI design” to a group of third-year students of both electrical engineering and computer science directions. The course was intended as a seed for further activities. For instance, the students were provided with a CD-ROM that contained reference material, example code, and articles for further reading. Accordingly, the course placed more emphasis on overview, organization, work flow and similar aspects than on the details of language constructs or algorithms. The students, however, were much more interested in the actual algorithms, and, for instance, performed the suggested homework with enthusiasm.

Based on this experience, a second course was offered in March 2009, which had more algorithmic content and also included projects to be implemented by teams of four students each. The students of the second course were at an earlier stage in their education (the second year). In view of their less advanced knowledge, the technical content turned out to be challenging. It was also found that what was lacking was not so much insight into the individual steps of a given problem, but the overview over the problem.

Both courses were organized as one-week-long block courses, with daily lectures. The second course required a short examination on the last day. At the end of both courses, follow-on projects were proposed, for instance as Bachelor-thesis projects, but to this date none has been started.

The paper is organized as follows: In the next section, the two past courses are described in more detail. In Section 3, the requirements for a remote course are analyzed. Section 4 contains the conclusions and an outlook.

1. Past Courses

The first course (May 2006) covered the following topics and content:

- Overview (technologies, definitions, Gajski diagram, verification and testing, abstractions, timing analysis, parallelism, Moore's law and Makimoto's wave, design flow).
- VHDL (programming language for the design of digital computer chips), with the following examples: population-count circuit in several variants, an on-chip bus, and McKeown's crossbar scheduling algorithm iSlip.
- Programmable Logic Devices (FPGAs and CPLDs), configurable computing, coarse-grained configurable logic (CRC).
- SystemC (C++ library for the simulation of chips or systems of multiple chips).

These topics were chosen in a view of enabling new projects at TTI in this technical field with little investment cost. Design environments for FPGAs, including simulation tools, are available free of charge and educational institutions can also apply for the hardware. SystemC can also be used with free tools, and allows the simulation of new architectural and algorithmic concepts. At that time, several students at the IBM Research – Zurich lab (ZRL) were working with SystemC.

TTI provided an interpreter during the course in case language problems would arise, but her service was needed only in few cases. There was not much long-term impact from this course, neither did a student from the course apply later for an internship at ZRL nor were any of the proposed bachelor projects carried out. The feedback of the students was twofold: the first problem was that the timing of the course was inconvenient because it was a short time before examinations. Because of that they could not devote much time on the assigned homework or preparative reading. The second comment related to the course content and asked for more technical content, such as algorithms. The example used of the course, the population count, was appreciated.

In line with its new directions, the TTI inquired about the possibility of having the second course, which took place at the end of February/beginning of March 2009. This date already addressed the first problem, as the course took place early in the semester. Secondly, it was hoped that the course would also have more impact on the selection of thesis topics because students typically chose their bachelor topic in May.

The course was organized in a matrix format:

Table 1. Schedule of the second course

Monday	Tuesday	Wednesday	Thursday	Friday
High-level overview	Editor CVS	Bug tracking	Bug spray Project planning	Selection of groups
CRC Optimisation Algorithm	Study: Hierarchical state machines	Example study: Population count	FPGA technology	Examination
VHDL: I	VHDL II	Fusion/RTX	System-C	
Exercise 1: Stimuli file generation and simulation	Exercise 2: Group project I	Exercise 3: Group project II	Exercise 4: Testing of project (simulation and Implementation)	Feedback

Fusion/RTX is an IBM proprietary technology that is used for verification. The aspect of verification was added to the course because it was observed that there is a lack of verifiers on the global labour market. The exercises were demonstrated using the free edition of VHDL simili by Symphony EDA. The exercise was a common task on the first day (Gaussian elimination) and split up between the groups on the subsequent days. The tasks for the groups depended on each other; hence a part of the task was to define the interface between the groups. This is a typical situation in larger academic projects, be it in software or hardware. At this point it already became clear that the reduction of teaching high-level concepts in favour of presenting more technical examples is problematic. For example, it was not understood by the students why a memory layout of intermediate data was needed and what it meant to invent one, even though they had examples from the Gaussian elimination example. This might have been a language problem as well. The students showed great interest and engagement, and quickly discovered and shared a web site with frequently asked questions about VHDL in Russian. On the subsequent days, the teams demonstrated continued intensive work and dedication, but it also turned out that the given tasks were a big challenge. Therefore, some teams decided to implement their assigned task in C++ instead of VHDL.

Beside the implementation of a given function, the teams were required to prepare a presentation and talk to the other teams about their results and insights on the final day of the course. These presentations were all of good quality.

The students could also borrow two text books ([1,2]), which they did.

The examination showed, however, that the technical level was too high for the students. This was partially caused by a communication problem prior to the course, as it was not clear during preparation that the students would be at an earlier stage in their education than those from the first course. At the request of the students, a list of project proposals was presented as the conclusion of the course. The project proposals ranged from small-scale designs that might be shared over the internet and presented at workshops to combined software-hardware projects that might be turned into a commercial product.

2. Options for a Remote Course

As it was found in a funded research project, many students have to earn money in parallel to their education. Therefore, a course with weekly lectures would give the students more freedom to read supplemental material and work on home assignments. As such a course would have to be given remotely (distance teaching), several problems have to be overcome.

If the lectures (as the one from 2009) are to be complemented with practical exercises, support for the installation of the tools and advice for the students is needed on-site if they encounter problems.

Secondly, the work schedule at ZRL makes a compact course more attractive than a constant load level over a half a year.

The third aspect is a language barrier. It was noted during the course that the students initially hesitated to ask questions or answer, and that if they intended to so, they often discussed the question first among themselves before a selected student came forward. It is feared that this communication hurdle would be even higher with the increased distance.

Conclusions

Although currently the moment even non-graduated students with information technology skills might find attractively paid employment, for the long-term technological development of Latvia and similar countries, courses in cooperation with industry are important.

This can be a win-win situation: while the academic institutions in these countries could benefit from state-of-the-art know-how and attractive opportunities for their students, the industry partners could influence the topics of the student theses and also attract talented applicants. Whether for the latter goals a remote course would be as attractive as on-site teaching remains to be seen.

References

1. Wile, B., Goss, C., Roesner, W. (2005). *Comprehensive Functional Verification*. San Francisco: Morgan Kaufmann.
2. Bergeron, J. (2003). *Writing Test benches: Functional Verification of HDL Models*. New York: Springer.
3. Moore, G. Cramming. (1965). More Components onto Integrated Circuits. *Journal on Electronics,* Vol. 38, No 8.
4. McKeown, N. (1999). iSLIP: A Scheduling Algorithm for Input-Queued Switches. *IEEE Transactions on Networking*, Vol. 7, No 2.

Doering, A. SPECIALIZĒTO KURSU PIEREDZE DIGITĀLĀS LOĢIKAS PROJEKTĒŠANĀ UN VERIFICĒŠANĀ

Strauja tehnoloģiju attīstība izvirza sarežģītus uzdevumus augstākajai izglītībai. Tas ir īpaši aktuāli valstīs ar pārejas ekonomiku, kurām nav plašas nozaru un valsts pētniecības centru bāzes. Zinātnes un tehnikas jomā šīs valstis attīstās ļoti strauji un tām īpaši nepieciešami augstskolu abiturienti.

Gordons Mūrs ir teicis, ka mikroshēmu integrācijas blīvums palielinās, ļaujot tās izmantot miljardos tranzistoru un tūkstošos kontaktu. Vienreizējie jaunu mikroshēmu ražošanas izdevumi ir lieli, jo lieli ir loģisko shēmu projektēšanas un verifikācijas izdevumi. Turklāt, tā kā jaunās paaudzes tehnoloģijas tirgū parādās ļoti ātri, jaunu mikroshēmu izstrādes laiks ir ļoti īss. Šie abi faktori, ierobežotais laiks, kas atvēlēts izstrādei, un lielās pūles mikroshēmu izstrādē, rada lielu pieprasījumu pēc augsti kvalificētiem inženieriem.

Speciālistu nepieciešamība ļāva šī raksta autorei docēt divus priekšmetus Transporta un sakaru institūtā Rīgā (Latvija). Raksts apkopo iegūto pieredzi un tās eventuālo izmantošanu nākotnē.

Atslēgvārdi: VLSI, VHDL, verifikācija, CRC, System-C.

Доеринг, А. ОПЫТ СПЕЦИАЛИЗИРОВАННЫХ КУРСОВ В ОБЛАСТИ ЦИФРОВОГО ЛОГИЧЕСКОГО ПРОЕКТИРОВАНИЯ И ВЕРИФИКАЦИИ

Быстрое развитие технологий ставит новые сложные задачи перед высшим образованием. Это особенно актуально для стран с переходной экономикой, не располагающих обширной базой отраслевых и общегосударственных исследовательских центров. В общенаучных и технических отраслях эти страны развиваются очень быстро и испытывают большую потребность в выпускниках вузов.

Гордон Мур говорил, что плотность интегрирования микросхем растет по экспоненте, давая возможность использования микросхем с миллиардами транзисторов и тысячами контактов. Единовременные расходы на производство новой микросхемы высоки, поскольку высоки расходы на проектирование логических схем и их верификацию. Кроме того, поскольку новые поколения технологий появляются на рынке очень быстро, время для разработки новых микросхем очень ограничено. Оба эти фактора, небольшое время, отводящееся на разработку, и большие усилия по разработке микросхем, рождают большой спрос на высококвалифицированных инженеров.

Эта потребность в специалистах сделала возможным для автора этой статьи преподавание двух дисциплин в Институте транспорта и связи в Риге Латвия. Статья обобщает полученный опыт и его возможное применение в будущем.

Ключевые слова: VLSI, VHDL, верификация, CRC, System-C