VLSI CURRICULUM IN AN INDIAN UNIVERSITY: AN ANALYSIS & PRESCRIPTION

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Abstract

In this paper, we review the general motivation and requirements of establishing an effective VLSI oriented curriculum at an undergraduate and a postgraduate level. We first discuss about such curriculums being followed at our institute. Next, we touch upon the environment and human related issues, keeping away from the debate on issues related to imparting & balancing fundamental knowledge & application oriented knowledge in a VLSI curriculum. Thus, manuscript focuses on issues related to effective VLSI teaching, laboratory development & faculty research; and strategies for possible solutions.

1 Introduction & requirements analysis

The element of evolution is driven by the needs of society & environment and by capability & desire of change agents. There is a definite shift of impetus towards digital media and computation for communication. The students' knowledge and desire for latest electronic and computer technology is ever higher, paving the way for evolution of systems and system design techniques for multimedia, computation and communication. Lee and Messerschmitt (1998) and (1999) provide a peek into futuristic education environment. According to a report from ministry of communication and IT, Govt. of India as well as according to an industry prediction, the demand of engineers for IT sector especially IT hardware is nowhere matched by the supply, from education domain. The short term strategies employed by industry is to impart VLSI design education-cum-training either in-house or at a hired academy. Alternately, fresh or practicing engineers pursue postgraduate studies in VLSI design specialization. Long-term strategies imply including VLSI design related course at undergraduate level. The latency of undergraduate course is much more than PG and hence we need to act urgently for improving and orienting the UG curriculum.

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In today's environment, knowledge is centered on Internet and students become aware of at least current technology and to some extent future of technology. The desire to learn and contribute is there. Views compiled in Martin (2003) and Ross (1997), represent industry viewpoint on requirements of VLSI education.

In this system-on-chip era, systems as well as electronic design automation (EDA) tools are becoming complex due to system integration issues related to physical effects at deep-sub-micron geometry. What's needed is a blending of basic electronics engineering courses with new required courses, which also require joint electrical/electronics and computer engineering/science programs. But the larger question is who can do it? We as faculty should posses required depth of the field for which we intend to impart instructions and courses are already so specialized that it is truly a multi-disciplinary effort.

Many of the Engineering colleges, deemed universities and IITs now have formal programmes leading to postgraduate degree with specialization in VLSI Design or a very closely related area. As many of the postgraduate subject-courses are offered as an elective to undergraduates, there is a definite penetration of teaching of VLSI related subjects to UG students.

The rest of the manuscript is organized as follows. In the Section 2, we present the programmes, we are currently offering at National Institute of Technology, Jaipur and the corresponding course structure. Next, we present the relative weightage of each of the courses. This would bring forth the total weightage of courses, which are oriented towards VLSI design in general. In Section 3, we summarize the identified issues and the strategies to address them, which evolved at a discussion during a work-session. We conclude in Section 4.

2 VLSI curriculum at NIT, Jaipur

Postgraduate programme in Microelectronics is being offered for past eight years at our institute, Malaviya National Institute of Technology, Jaipur. Acquiring a status of deemed university and having own senate for past two years, has given us a chance to swiftly revive our curriculum for undergraduates as well as for postgraduates. In the present analysis, we consider two programmes of our department of Electronics & Communication Engineering- (i) M. Tech. (ECE) with specialization in *Microelectronics* Stream, and (ii) B. Tech. In Electronics & Communication Engineering. The credit wise break up of a M. Tech. Curriculum's credit total of 88-96, is presented in Table 2. Similar break-up for undergraduate programme with credit-total of 206-214 is given in Table 1.

Table 1 M. tech. Curriculum's credit wise breakup: Major specialization carries a weightage of about 72-80% including weightage of dissertation

Institute Core	8-12	9-13 %
Departmental core	4-8	4-9 %
Engineering major electives	70	77 %
Engineering minor electives	8	9 %
Total	***90***	***100 %***

Table 2 B. tech. Curriculum's credit wise breakup: Minor specialization carries a weightage of about 10 %

Basic sciences	27	14 %
General engineering	47	23 %
Humanities & social sciences	16	8 %
Departmental core- Engineering major specialization	86-90	42-44 %
Departmental electives- Minor specialization	16-20	8-10 %
Total	***206-214***	***100 %***

In the M. Tech. Programme about 70% of credit weightage can be devoted to a specialization, whereas such is not the case with B. Tech. Programme. In a B. Tech. Programme, only 10% of credit-total is available for instructions into specialization courses, which by credit weightage seems sufficient, i.e. about 20 credits or 5 full courses.

2.1 Course structure

The courses in our postgraduate programme are shown in Table 3. A candidate entering the programme is supposed to have gone through few courses like analog circuits, digital design, digital signal processing, computer architecture etc during his undergraduate studies. The digital system design course leads him to the understanding of synchronous as well as asynchronous digital logic design fundamentals and algorithmic state machine based hardware realization. The device behavior and modeling aspects are covered in Microelectronic devices & circuits course, whereas fabrication fundamentals including study of individual processing steps are covered through VLSI technology. Circuit based design aspects are dealt with in two courses- Analog integrated circuits and CMOS VLSI Design.

Table 3 Postgraduate Microelectronics programme courses

I Semester	*II Semester*	*III & IV Semester*
Advanced Maths	VLSI Technology	Seminar & Dissertation
Simulation & Modeling- Microelectronic devices & Ckts.	Analog ICs	
Digital Systems design	Advanced DSP	
CMOS VLSI Design	FPGA based design	
VLSI Physical Design	Embedded systems	
Synthesis of digital systems	CAD Lab	

The courses that provide exposure to CAD related aspects of a typical design flow are – Embedded systems design, synthesis of digital systems, VLSI Physical design, FPGA based design. The hands on design experience is gained through CAD Lab where tools for layout design to high level synthesis are available viz. Tanner tools, Mentor graphics FPGAvantage, Cadence and Synopsys tools' sub-set. As participating institute in Ministry of Comm. & IT, Govt. of India sponsored project on VLSI manpower development, we are recipient of these industry standard CAD tools, which we wish to utilize to their full potential. Students have been quite enthusiastic about further exploration, consequently many of the public domain tools are also part of laboratory experimentation set up such as SpecC, Trimaran ASIP design exploration, SMV etc. Table 3 lists the courses, our students go through prior to their dissertation.

In B. Tech. Programme, we utilize weightage of 16 to 20 credits for giving them a freedom to choose either of the specialized streams' electives- communication OR VLSI Design. The dependence diagram is shown in Figure 1. The CAD laboratory venue serves commonly to undergraduates and postgraduates.

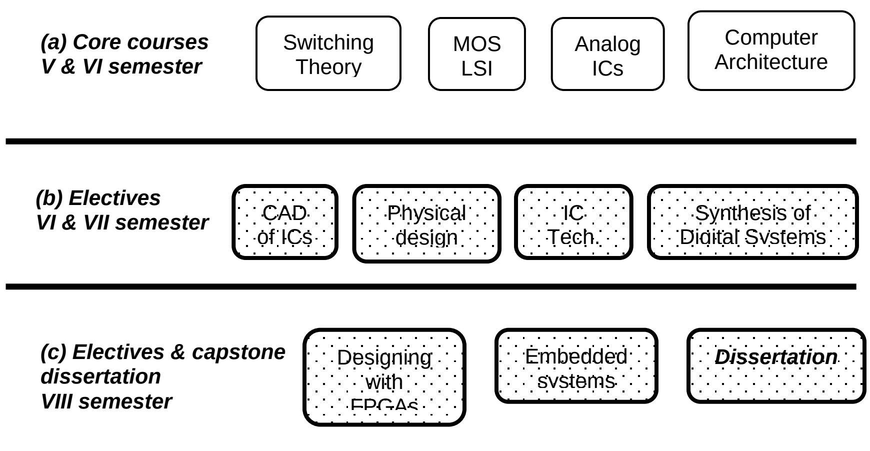

Figure 1 Dependency diagram- VLSI specialization B. Tech. courses

2.1.1 Courses oriented towards VLSI education

Setting an undergraduate curriculum is a difficult exercise due to need of balancing it with respect to fundamental and specialization courses. The breadth of coverage for major specialization like Electronics & Communication Engg. or computer Engg. should be matched with depth into minor specialization courses demanded by current technological advancements.

In a B. Tech. programme, the departmental core courses are supposed to provide a student with sufficient footing into fundamental and broad knowledge for his B. Tech. major. In order to cater to present demand from industry and research domain, we have attempted to impart instructions for VLSI design education. We could utilize the 20 credits for it, where all of the 6 courses are elective courses, refer to (b) and (c) in Figure 1. The prerequisite courses, refer (a) in Figure 1, are usually falling into previous semesters i.e. sophomore years. In pre-final and final years of undergraduate education, 6 courses along with capstone dissertation project form the basis for students being recognized as having been specialized in VLSI Design. These courses impart them with the knowledge which spans a system designing process based on a typical VLSI Design flow- (i) two courses on high level design aspects, (ii) two more on logic synthesis and FPGA based CAD and implementation; and others covering (iii) physical design aspects & (iv) manual RTL and logic level design and HDL based verification. We have also included a course on fabrication, which covers not only the study of individual process steps, but process integration aspects also.

The curriculum design activity is usually followed by self-evaluation by faculty members. The feedback from various quartets like industry, students and peer faculty about the contents, their suitability and quality of instructions is desired and quite useful. In the next section, we present inferences from such a workshop attended by teaching faculty, persons from industry and students; organized to identify issues and strategies for initiating, improving and imparting quality VLSI Education.

3 A prescription

The present manuscript is, in part, the outcome of a work session organized during a teacher-training course. The course was about Reconfigurable computing using FPGAs held in February 2004 at NIT, Jaipur. About 30 teachers from various engineering colleges around and outside Rajasthan and about 20 students brainstormed in the session. The inferences, evolved during the session, are presented in this section.

3.1 Work session objectives

The agenda of the work-session was to brainstorm and identify issues along with strategies for possible solutions related to following activities in VLSI education.

- Effective teaching
- Developing laboratories
- Faculty research
- Students' dissertation/projects

Four groups were formed to take up each of the four activities for discussion. Each group were to discuss the specific topic assigned to them and evolve ideas related to present status, prepare a wish-list (things to do), highlight the ways to implement and finally identify, what help may be expected of others, viz. (a) educational institutions, (b) industries, (c) VLSI society of India, and Government bodies. The group leaders were asked to summarize and present the top candidate ideas from the consolidated ideas evolved within their group.

3.2 Issues and Strategies

3.2.1 Effective teaching

Teaching spans curriculum design, content delivery and evaluation etc. For UG curriculum, the following subjects were identified as necessary in electronics engineering as well as computer engineering - (i) MOS/CMOS based circuit design, (ii) Theoretical aspects of VLSI design, algorithms and graph theory, and (iii) advanced digital design supplemented by FPGA based prototyping laboratory. The term project and assignment based evaluation must form the part of a taught course.

The significance of hands-on designing cannot be over-emphasized in VLSI design teaching. The teachers should keep themselves updated and be in touch with changing technological aspects by attending short term training programmes, conferences and workshops.

3.3 Lab development

The laboratory courses should not only cover the front-end design aspects but also stress on back-end design skills. A completed design should find a way to implementation- at own prototyping lab OR at fabrication lab e.g. SCL, Chandigarh and ITI, Bangalore which provides support to academic institutions; and MOSIS which provides worldwide support to such fabrication runs at very low cost.

Looking at the importance of laboratories, there is need to have short term training courses organized for teachers. In the laboratories, the knowledge through legacy should be preserved. This can be achieved by developing good demos on various aspects of designing as well as on CAD tools capabilities. The access to lab should be more flexible in terms of time duration. Also, the labs must not only follow basic curriculum but also be able to support and promote research and consultancy work.

3.4 Faculty research

The faculty research at present is not up to the desired level in most of the institutions. Firstly, there is a complete lack of support in terms of technical literature and funds in most of the institutions. Every institute needs to have a mechanism to evaluate and reward research by faculty in order to promote research. Faculty members are expected to update themselves and utilize the vacation period especially for this purpose, attending conferences and visiting research labs.

3.5 Student dissertation

The dissertation of a student is important work, which prepares him to think and initiates him towards research and innovative development. Industries may opt for sharing their project-based problems and outsourcing them to institutes as dissertation projects. Lab up-gradation support from industry form an integral part of dissertation support.

Apart from it, industry-institute collaboration can span other activities too like (i) faculty collaborated research and (ii) curriculum development. Industries are expected to keep wider vision for interaction with institutes, so that more institutes across the country get opportunity of interaction.

It was perceived that VLSI society of India (VSI) has a significant role here. It can facilitate a common platform of meeting to industries and institutes. Student-seminars and workshops organized by VSI would go a long way in making student aware and motivated towards VLSI curriculum.

4 Conclusions

In general, having 2 to 4 VLSI design related subjects in a UG curriculum is highly desired. Across the region or country, the efforts should be made to have a common minimal VLSI related subject contents in curriculum. The institutes have to identify the resources required and should be willing to pool resources, they posses for shared utilization.

5 Acknowledgements

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