Industrial Feedback for a Microelectronics Curriculum

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Abstract
This paper addresses the question of sufficient breadth and depth for undergraduate engineering curriculum in the area of microelectronics, based on input from an industrial panel. This panel was formed as part of a NSF Course and Curriculum Development (CCD) grant to help define the appropriate mix between specific skills, fundamentals, and exposure to current technology. Their input calls for curricula with broader coverage of the entire design cycle from concept to manufacturing. The panel lists specific concepts that are increasingly important for today’s chip designers and manufacturers, as well as timeless fundamentals that must continue to be emphasized in undergraduate programs. Suggestions on how to incorporate the growing demands of industry into over stretched engineering curriculum and courses are discussed.

1. Introduction
With the changes in the ABET 2000 criteria, universities will have considerably more freedom in defining “sufficient” coverage in their curricula. This paper concentrates on defining sufficient breadth and depth in the field of microelectronics for undergraduate engineering students which meets the demands of today’s industry.

To find the appropriate mix between engineering fundamentals and current technology a panel was formed consisting of engineers from companies related to the integrated circuit industry including: Intel, Advanced Micro Devices, National Semiconductor, Motorola, Hewlett Packard, Digital Equipment Corporation, Silicon Graphics, Altera, Cadence Laboratories, and Mentor Graphics. The panel was designed to incorporate engineers at different stages in their careers and in different areas of the IC industry[1]. The panel was formed as part of a NSF Course and Curriculum Development (CCD) Grant entitled “Teaching Integrated Circuit Design in a Simulated Corporate Environment”. This project included conducting an undergraduate VLSI design course with a heavy professional component emphasizing team work, communication, presentations, and project based learning [2,3].

2. Discussion
During the day-long workshop on November 8, 1996, the industrial representatives first defined their ideal engineer and then moved on to identify the skills and knowledge base critical to the microelectronics area. Toward the end of the day, they prioritized these qualities which allowed the author to develop the breadth and depth requirements shown in Table 1.

The interpretation of the data in Table 1 is as follows:
1) Only those skills or experiences specifically requested by the industry representatives (and not academicians) are included, 2) All material in the “Core” section are intended to be taken by every student seeking employment in the microelectronics area; 3) The doted lines in the depth column attempt to separate a digital/analog or process/manufacturing emphasis 4) Students would likely pursue depth in more than one area; 5) Prerequisites to the skills are not specified; 6) No course framework is implied, but could be developed using this skill list.

By examining Table 1, and in discussions with panel members, there was a real cry for increased breadth! Industry desires students with exposure to a much broader set of skills which emphasizes the entire product design cycle from concept to manufacturing (even if it is at a more surface level). For instance, every student should be exposed to system level design, hardware and software integration, and basic architecture, even if their specialization is solid state. And likewise, every student in digital design should understand basic CMOS fabrication process and manufacturing IC’s.

The panel deemed that hands on experience with appropriate simulation tools is essential, but student's should concentrate on the limitations and abilities of each tool, rather than mechanical use of a system. Particular software packages were discussed, but dedication to one package was discouraged. It was agreed that C++ is the language every student should know today, while
Assembly language can be left to electives, or students with a software emphasis.

The panel also placed particular importance on the student's professional development in non-technical areas, which are increasingly important in today's workplace. When defining the "ideal engineer" the panel's comments mimicked recent engineering education literature [4,5,6] which stresses the need for an engineer who is innovative, a mentor, a team player/leader, a good communicator, and of course technically competent. Further details of this panel's discussion of the general qualities desired in today's engineer is published elsewhere[7]. Overall there was increased emphasis for universities to take a more active role in the "professional development" of the student, as defined in Table 1.

<table>
<thead>
<tr>
<th>Breadth (Core)</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software</td>
<td>Algorithms (optimization, AL list-based interfaces), Programming environments (X, Motif, Visual), Programming tools (shell scripting, sed, awk, m4 perl), Assembly language, Client/Server, Documentation.</td>
</tr>
<tr>
<td>Digital/Analog Design (Hardware)</td>
<td>FPGA/ ASIC tradeoffs, CAD tools (Schematic capture, static &amp; dynamic timing tools, Place &amp; Route, DRC, back annotation), Verification methodology, Designing for test, Simulation environments, Memory design, Project experience from start to finish.</td>
</tr>
<tr>
<td>Process/Manufacturing</td>
<td>Technology tradeoffs, Process modules (diffusion/ implant, dry &amp; wet etching, deposition, lithography), Fluid dynamics, Material science, Fabrication, equipment, Contact issues, Exposure to new technologies (SOI, new memory structures, optoelectronic interconnects), Operations management (plant optimization), Yield improvement methods (wafer level tests, short loop monitors, statistical process flow), Process evolution (scaling and modeling issues).</td>
</tr>
<tr>
<td>Professional Development</td>
<td>Legality and intellectual property rights, engineering economics, time management, cross cultural interaction, career planning.</td>
</tr>
</tbody>
</table>

Table 1. Concepts and experiences divided into breadth and depth for undergraduate engineers in the field of microelectronics as dictated by industrial panel.

3. Implementation

3.1 Curriculum Level Implementation
Table 1 serves as a starting place or check point for an educational institution’s curricular or course review process. To accomplish the increased breadth that is dictated here, many courses once viewed as electives would be required. Since programs are already at the breaking point in terms of units, requiring additional courses in their present form is unrealistic. To implement a curriculum with increased breadth without additional course requirements the following steps are suggested and are currently being taken at the University of the Pacific. 1) A broader definition of the "core" and streamlined curriculum which would reduce the repetition of material in "depth" courses, and reduced prerequisite sequences for advanced courses. 2) By identifying computer usage in each course, and monitoring design experiences throughout the curriculum, a broader exposure to software languages and tools can be incorporated. 3) Seeking out science and engineering electives that incorporate more of the manufacturing end of the design cycle outside the Electrical Engineering curriculum and working with those departments to incorporate more IC process examples in their courses. 4) Encompass more of the professional component listed in Table 1, through selected general education classes and a more structured
capstone design project including manufacturing, legal, and project management issues.

3.2 Course Level Implementation

Of course the heart of the microelectronics curriculum lies the VLSI course sequence. These courses cover the depth required and provide the project experience desired by industry. Input from the industrial panel was also used to mold the project-based component of the CCD grant. As part of this grant, project material including simulations, physical layout, and fabrication data, are being created for use in a first semester undergraduate VLSI design course. The goal of these materials is to cover the main concepts emphasized by this panel, stressing physical layout and design choices, along with team work, and communication skills.

In these projects, students work as part of a team with a fabricated chip from a previous design team with which they have the Spice and timing simulations, fabrication data, and physical layout. Students then measure the actual fabricated chips to discover how physical layout affects performance. Significant course material is introduced through the projects instead of through lectures, and students discover the reasons for differences between predicted and actual performance. Based on their measurements, students decide how to redesign part of the chip to satisfy new project specifications or a change in the fabrication process. Problems are open-ended, so tradeoffs between size, speed and power become apparent. Students create designs ready for submission to the MOSIS fabrication service, documenting all changes to the existing design. More details about the development and availability of the chip layouts, simulation, and laboratory exercises are available at http://www.uop.edu/eng/courses/elec/elec136/pacificsi.html. It is the hope that these materials will add to other project based materials to better prepare students for today’s microelectronics industry [8,9].

4 Summary

Input from industry is valuable to ensure that a curriculum is developing engineers that have the needed skills and knowledge base to be productive in today’s workplace. However, incorporating everything that industrial representatives desire in a graduate is not the way develop a curriculum. Their input must be balanced with the student’s overall education. This panel was very in tune with this need and emphasized that the general and professional development component of a student’s education, as listed in Table 1, as being critical to their ultimate success and longevity in the microelectronics field.

5 Acknowledgments

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References