A new microelectronics curriculum created by Synopsys, Inc.

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Abstract: Rapid changes in integrated circuits (IC) technology and constantly shrinking process geometries demand a new curriculum that meets the contemporary requirements for IC design. This is especially important for 90nm and below technologies and the use of state-of-the-art EDA design tools and advanced IC design techniques. The creation of new curriculum is laborious and requires a combination of effort from many specialists from different countries to obtain the best quality. This paper describes the experience in developing a new microelectronics curriculum, based on using Synopsys EDA tools, that is successfully deployed in leading technical universities around the world.

Key words: microelectronics curriculum; Synopsys Armenia Educational Department; cooperation; 90nm and below technologies

1. Introduction

The transition into every new process technology, especially into 90nm and below, creates new challenges in IC design (K. Agrawal, et al., 2006). Second and third order physical effects become first order effects. That is, some phenomena which had minimal affect at 90nm and above became more important. For example, above the 130nm technology node, dynamic power considerably exceeded leakage power (for 0.25um technology leakage power was typically smaller than 5% of the power budget) and leakage power could essentially be ignored. For 90nm technology and below, the situation has sharply changed and leakage has now become a major consideration. Many other similar examples exist. IC design methodologies and the applied EDA tools are also continuously changing. To keep pace with these changes, there is a critical need to create new microelectronics curricula, which comes with its own set of challenges. The creation of new curricula requires:

(1) Significant time and effort to develop a large number of needed courses, which must include all the necessary materials—lectures, labs, course projects, homework, exams, etc.

(2) Expert knowledge of new design challenges and advanced IC design techniques.

(3) Experience in using best-in-class EDA tools in the designs of contemporary ICs and their components.

(4) Development of Educational Design Kits (EDK) and Process Design Kits (PDK) which must correspond

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to real technologies to reflect their specific attributes, available with little to no restriction to universities.

(5) Comprehensible presentation to enable trainees to easily master the capabilities of contemporary methods of IC design and their solution methods.

Existing experience shows (M. Törngren, et al., 2005) that the best curricula are created in the result of cooperation among the leading specialists of the area. For that reason, Synopsys, Inc. has teamed with leading academics in China to share a new microelectronics curriculum which is planned to be used in leading universities of China, Russia and the region.

The goals of this cooperation are to advance the understanding and knowledge of modern IC design, increase the quality in research and development, support the training of highly-qualified specialists, influence the Chinese and Armenian microelectronics industry, and increase the engineering talent pool of China and Armenia for many years to come.

2. The essence of developed curriculum

The new curriculum presented is compiled based on the experience of world famous, leading universities and the 7-year teaching experience of SAED. It is targeted for the study of state-of-the-art IC design for 90nm and below technologies and is based on using Synopsys EDA tools and advanced design techniques, such as low power design—multi voltage, multi threshold, clock gating, etc. (M. Keating, et al., 2007).

There are curricula for 2 specializations—VLSI Design and EDA. Students take common educational courses before studying with the curricula—mathematics, physics, etc., by which a necessary base is created for further study with the specialized courses. In fact, the new curricula includes only specialized courses of Bachelor (3rd and 4th years) and Master (1st and 2nd years) programs.

All the courses have full methodical materials—syllabus, lectures, labs, homework, exams, etc. The curriculum of VLSI design is oriented at training such specialists who will be able to design contemporary ICs, IPs, digital standard cell and I/O libraries as well as special I/Os (SSTL, HSTL, LVDS, MLVDS, USB, DDR, etc.) using Synopsys EDA tools. The EDA curriculum is oriented at training such specialists who will be able to create different types of EDA tools (for digital circuits—synthesis, simulation, place and route, physical verification, etc., for analog circuits—simulation, physical design, layout verification, etc. as well as design for manufacturing (DFM), design for test (DFT), etc.).

The number of weeks and hours for the specialized courses is shown in Table 1.

Table 1 Number of weeks/hours

Program	Year	Semester	# of weeks	# of hours
Bachelor	3rd	5th	17	24
		6th	17	28
	4th	7th	15	23
		8th	8	17
Master	1st	1st	17	14
		2nd	17	10
	2nd	3rd	17	16
		4th	13	20

The total number of hours in the Master program is smaller than in the Bachelor program as more attention is placed on individual student work such as the Master thesis. The curriculum includes basic and large volume courses as well as a number of elective courses for VLSI design and EDA specializations as outlined below.

The VLSI design specialization Bachelor program includes the specialized courses illustrated in Table 2.

Table 2 VLSI design, Bachelor program, courses

Course name	Semester	Total # of hours	Number of hours		
Semiconductor Devices	5th	68	68	-	-
Introduction to Circuits	5th	68	34	17	17
Digital Integrated Circuits	5th, 6th, 7th	232	147	51	31
Semiconductor Technology	5th	68	51	-	17
IC Design Introduction	5th	68	34	-	34
Microprocessor Systems	6th, 7th	192	113	17	62
Analog Integrated Circuits	6th, 7th, 8th	216	127	32	57
Logic Design	6th, 7th	162	81	15	66
IC Testing	7th, 8th	92	69	15	8
RF Circuits and Systems	8th	16	16	-	-
IC Fabrication	8th	16	16	-	-
IC Simulation Theory	8th	48	32	8	8

The VLSI design specialization Master program includes the specialized courses illustrated in Table 3:

Table 3 VLSI design, Master program, courses

Course name	Semester	Total # of hours	Number of hours		
Design of Special I/Os	1st, 2nd	85	51	-	34
PCB Design	1st, 2nd	68	51	-	17
RF IC Design	1st, 2nd	68	51	-	17
Mixed-Signal IC Design	1st, 2nd	85	51	-	34
Design for Test	2nd	34	17	-	17
VLSI Design	3rd	136	68	34	34
Digital Signal Processing	3rd	68	34	-	34
Crosstalk and Noise	4th	65	52	-	13
Modeling and Optimization of VLSI interconnects	4th	65	52	-	13

The EDA specialization Bachelor program includes the specialized courses illustrated in Table 4.

Table 4　EDA, Bachelor program, courses

Course name	Semester	Total # of hours	Number of hours		
IC Design Introduction	5th	51	34	-	17
Semiconductor Devices and Technology	5th	68	51	-	17
Discrete Mathematics	5th, 6th	119	85	34	-
EDA Mathematical Methods	5th, 6th	153	102	51	-
Computer Architecture	5th	68	51	-	17
Programming Languages	5th, 6th	136	85	-	51
Computer Networks	5th	68	51	-	17
Object Oriented Programming	6th, 7th	128	96	-	32
EDA Introduction	6th	68	51	-	17
Algorithms Theory	6th	51	34	17	
Analog Integrated Circuits	7th, 8th	69	46	-	23
Digital Integrated Circuits	7th, 8th	69	46	8	15
Data Structures	7th	45	30	-	15
Software Development Technology	7th, 8th	69	46	-	23
Hardware Description Languages	7th, 8th	69	46	-	23
VLSI Design Algorithms	7th	60	45	15	-

The EDA specialization Master program includes the specialized courses illustrated in Table 5.

Table 5　EDA, Master Program, Courses

Course name	Semester	Total # of hours	Number of hours		
EDA Mathematical Methods	1st	51	34	17	-
Software Verification and Validation	1st	51	34	-	17
VLSI Schematic Design Algorithms	1st	68	34	34	
Information Security	2nd	34	34	-	-
Advanced Operating Systems	2nd	68	51	-	17
Databases	2nd	34	17	-	17
VLSI Physical Design Algorithms	2nd	34	17	17	-
VLSI Design	3rd	119	68	17	34
Operational Research	3rd	34	17	17	
Artificial Intelligence Systems	3rd	34	17	-	17
VLSI Verification Algorithms	3rd	51	34	17	-
Modeling and Optimization of VLSI interconnects	4th	130	52	26	52

The Master program also includes special and mathematical elective courses, which can be selected by the student depending on the direction of the Master thesis. For example, possible elective courses included in the Master program for VLSI design specialization are as follows:

(1) Data Compression;

(2) Low Power Design;

(3) IC Critical Networks;

(4) Linear Algebra;

(5) Numerical Methods;

(6) Probability Theory;

(7) Fuzzy Logic;

(8) Complex Functions;

(9) Fourier Transformations.

Possible special elective courses included in the Master program for EDA specialization are as follows:

(1) Compilers Design;

(2) Low Power Design;

(3) IC Critical Networks.

Scientific seminars are anticipated in the last 2 semesters of the Master program, which allows discussion of the problems with accomplished faculty in the domain of their Master theses. All the basic and large volume courses include course projects and works which are carried out by the use of Synopsys EDA tools. VLSI design specialization has special projects for the following courses: IC Design Introduction, Digital Integrated Circuits, Analog Integrated Circuits, Logic Design, and Mixed-Signal IC Design. EDA specialization has special projects for the following courses: IC Design Introduction, Computer Architecture, EDA Mathematical Methods, Digital Integrated Circuits, Analog Integrated Circuits, VLSI Schematic Design Algorithms, and VLSI Design.

The curricula are based on using the following Synopsys EDA tools (Table 6).

Table 6 Used Synopsys EDA tools

Astro	Milkyway Environment
coreAssembler	Module Compiler
coreBuilder	NanoSim
Cosmos	PathMill
Design Compiler Ultra	Physical Compiler
Design Vision	Power Compiler
DesignWare Library	PrimeTime SI
DFT Compiler MAX	Saber
Formality	Star-RCXT
HDL Compiler	System Studio
Hercules	TCAD-Raphael
HSIM^{plus}	TCAD-Taurus
HSPICE RF	TCAD-Sentaurus
IC Compiler	TetraMAX
JupiterXT	VCS MX
LEDA	Vera Developers Kit
Library Compiler	

The curricula is combined with a corresponding 90nm Educational Design Kit (EDK) supporting a design flow of digital, analog and mixed signal ICs and IPs in universities. The EDK is free from intellectual property restrictions, and it is optimized for low power design and use with Synopsys EDA tools. It is not designed for fabrication. Contents of the EDK include:

(1) Technology Kit which includes a databook and user guide, symbols, .lib, Verilog and VHDL simulation models, DRC and LVS decks, HSPICE netlists, extracted C/RC netlists, GDSII layout views, LEF files, generic SPICE models, fram views, layout views and runset files;

(2) Digital Standard Cell Library which consists of 250 cells to optimize the IC design. The library includes typical combinational and sequential logic cells of different drive strengths. It has all the required deliverables for low power design including support for IC designs with different core voltages to minimize dynamic and leakage

power;

(3) I/O Standard Cell Library which consists of 50 typical I/O cells: digital, analog, power/ground pads for different loads and miscellaneous cells. The library is designed for 1.2V/2.5V operation with a process technology of 1P9M 1.2V/2.5V and an operating frequency of 100 MHz;

(4) Memories which include several static medium-sized RAMs (SRAMs). They are synchronous dual-port with write enable, output enable, and chip select on each port. They have the same architecture and vary in size;

(5) Phase Locked Loop (PLL) clock multiplier circuit which can generate a stable, high-speed clock from a slower clock signal. It has 3 operating modes: normal, external feedback and bypass.

The new curriculum meets the requirements of leading microelectronics companies and can be applied not only for students' study, but also for retraining specialists. It is published in 4 languages—English, Chinese, Russian and Armenian. The courses are modular in structure which means that they can be used in their entirety or selected components can be used to augment existing programs or used as the base to create a completely new course.

3. Results

The preliminary version of the curricula has been developed at SAED. In the last few years it has successfully been deployed in the following universities of Armenia—State Engineering University of Armenia (SEUA), Yerevan State University (YSU), American University of Armenia (AUA), and Russian-Armenian Slavonic State University (RAU). In addition, the content of individual courses included in the curriculum is serving as the base for local language textbooks to accompany the courseware in China. Professors from leading Chinese microelectronics universities are heading up the project.

In our experience, since developing and using the new curricula, we have seen a significant increase in the quality and experience of the trained specialists. In Armenia, over 60% of the latest graduates studying with this curriculum meet the necessary industry requirements and are now gainfully employed by Synopsys, Virage Logic and other companies. As a result of this success, other universities have expressed a desire to use this curriculum to help bring high-quality graduates to local industry. One in particular is the most famous microelectronics university in Russia—Moscow Institute of Electronic Technology (MIET), which has recently integrated the new curriculum into their Engineering Educational Center.

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