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Constructions and teaching practices of integrated circuit design and application courses for IC engineering postgraduate program

Jianping Hu*, Yeliang Geng, Haiyan Ni

Institute of Micro-Nano Electronic Systems, Ningbo University, Ningbo City, (CHINA)

ABSTRACT

This paper presents constructions and teaching practices of the integrated circuit (IC) design and application courses for IC Engineering Postgraduate Program at Ningbo University to meet strong demands for engineering designers of IC chips and electronic products. The course system of the IC Engineering Postgraduate Program is presented, which are constructed by referencing developing experiences of the Circuit & System Postgraduate Program at Ningbo University. The teaching content, teaching methods, and practice teaching modes are explored, which are developed by referencing advanced teaching experiences of the IC Design & Application Undergraduate Program. The teaching goals and contents of the core courses related on the IC designs and applications are presented, which include mainly Modern Circuit Theories, Advanced Algorithm Design and Optimization, Advanced Digital System Designs, Integrated Circuit Designs, Automatic Design of Digital IC, Mixed-Signal IC Designs, Special-Purpose Chip Design, Low Power IC Designs, Design Techniques of RF Circuits, Cadence High-Speed Circuit Board Design, and Advanced Embedded System Design courses. The constructions of the course system and teaching practice of the core courses for the IC Engineering Postgraduate Program have some value for other similar universities.

KEYWORDS

Engineering postgraduate education; Teaching practices; Integrated circuit design and application.

INTRODUCTION

Integrated circuits are the foundation and core of the information technologies. The technical level related on chips represents the key competitiveness of a country or region. In the next few years, there exist huge demands for integrated circuit design talents. The teaching of IC design and application specialties can help develop the national and regional information science and techniques, and has extremely vital significance for enhancing original innovation ability[1]. Therefore, the IC design and application program has been an important specialty in all over the world, although microelectronics related on IC has begun for decades of years[2]. In order to meet the urgent needs for IC design and application talents, Chinese Education Department approved “integrated circuit design and integrated systems” undergraduate program from 2001. However, the integrated circuit design undergraduate program was developed only a few of universities in China. From 2006, Ningbo University has being offered the IC Design & Application Undergraduate Program for the undergraduate students of the Faculty of Information Science and Technology, which is one of the earliest ones in China[2].

In order to meet further strong demands for advanced engineering designers of IC chips and electronic engineers, Ningbo University begun to offer the IC Engineering Postgraduate Program from 2010. The IC engineering postgraduate specialty is a recent new postgraduate specialty all over the world, although some courses have begun for microelectronic undergraduate and postgraduate program for a long time[3-11]. Therefore, course system, teaching contents, teaching methods and experimental modes of its core courses are not mature experience for reference. One of the keys of the specialty construction is how to set teaching contents, teaching methods and experimental modes of the core curriculums reasonably and effectively[2].

In this paper, the curriculum system of the IC Engineering Postgraduate Program is presented. The innovation practices of the core professional courses in the IC Engineering Postgraduate Program are also described. The project-driven teaching methods and innovation practice of the core courses are in detail given in this paper. Finally, our work of this paper is summarized in the last section.

CURRICULUM SYSTEM OF IC ENGINEERING POSTGRADUATE PROGRAM

The training goal of IC Engineering Postgraduate Program is ASIC design and application ability of electronic information systems. The students should be skillful at basic theory, principles and knowledge of IC design and application with integrated circuit design tools. The students can engage in research, design, and engineering applications of IC chips and electronic information systems with some innovation ability of engineering and technique.

The setting principles of the course system include systematicness, completeness, advancement, and practicability related on IC design and applications. To achieve the training target, the course system of the IC Engineering Postgraduate Program should cover all main theoretical knowledge and engineering ability related on IC designs and electronic information systems. In order to make students adapt to future work, the core courses of the IC Engineering Postgraduate Program should reflect the advanced knowledge related on IC and electronic product designs. The course system of the IC Engineering Postgraduate Program should also emphasize the engineering practice ability and team cooperation spirit of students, and trains students the capability of solving problems with the IC design knowledge that they can easily transfer to a future workplace.

The IC engineering postgraduate specialty is a recent new postgraduate specialty all over the world. Therefore, course system of the IC Engineering Postgraduate Program is not mature experience for reference. One of the keys of the specialty construction is how to set teaching contents, teaching methods and experimental modes of the core curriculums reasonably and effectively.

After careful thorough investigation and demonstration, the course system of the IC Engineering Postgraduate Program is constructed by referencing developing experiences of the Circuit & System Postgraduate Program at Ningbo University. To achieve the training target, we determine that the curriculum system of the IC Engineering Postgraduate Program is composed of four parts, named as public degree courses at Ningbo University, core degree courses, professional elective courses, and practice required courses, as shown in Figure. 1.

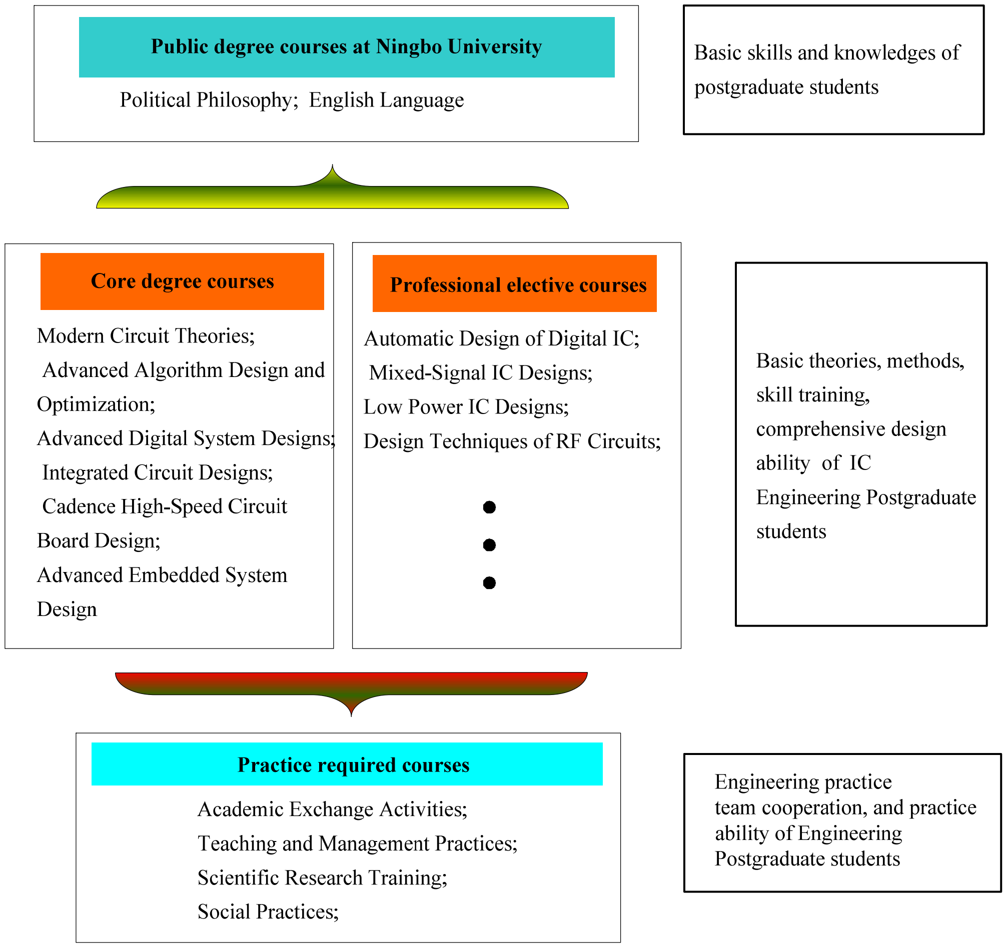


Figure 1 : The curriculum system of the IC engineering postgraduate program at Ningbo university

The basic skills and knowledge of postgraduate students such as political philosophy, English language, etc are covered by public degree courses at Ningbo University. The basic theories, methods, skill training, comprehensive design abilities of the IC Engineering Postgraduate students such as Modern Circuit Theories, Advanced Digital System Designs, Integrated Circuit Designs, Advanced Embedded System Design, Automatic Design of Digital IC, Mixed-Signal IC Designs, etc are included in the core degree courses and professional elective courses, which are especially constructed for the IC Engineering Postgraduate Program. The engineering practice, team cooperation, and practice ability of engineering postgraduate students such as Academic Exchange Activities, Teaching and Management Practices, Scientific Research Training, Social Practices, etc are covered by the practice required courses.

INNOVATION PRACTICE OF THE CORE PROFESSIONAL COURSES IN THE IC ENGINEERING

After careful thorough investigation and demonstration, the core courses of the IC Engineering Postgraduate Program is constructed by referencing developing experiences of the Circuit & System Postgraduate Program at Ningbo University. To achieve the teaching target, the organization structure of the core courses in the IC Engineering Postgraduate Program is composed of two parts, named as core degree courses and professional elective courses, which are constructed by referencing developing experiences of the Circuit & System Postgraduate Program at Ningbo University. The organization structure of the core courses in the IC Engineering Postgraduate Program related on the IC designs and electronic information techniques are shown in Figure. 2. TABLE 1 shows the lecture hours and experiment hours per week of these core courses. The core courses are used for the basic theories, methods, skill training, comprehensive design abilities, which are especially constructed for the IC Engineering Postgraduate Program.

As shown in Figure. 2, the core professional courses in the IC Engineering Postgraduate Program include mainly: “Modern Circuit Theories”, “Advanced Algorithm Design and Optimization”, “Advanced Digital System Designs”, “Integrated Circuit Designs”, “Automatic Design of Digital IC”, “Mixed-Signal IC Designs”, “Special-Purpose Chip Design”, “Low Power IC Designs”, “Design Techniques of RF Circuits”, “Cadence High-Speed Circuit Board Design”, and “Advanced Embedded System Design” courses.

The IC Engineering Postgraduate Program is a recent new postgraduate specialty in universities and colleges. The teaching contents, teaching methods and experiment contents in the above core professional courses are not mature experience for reference. By referencing advanced teaching experiences of the IC Design & Application Undergraduate Program[11], the teaching content, teaching methods, and practice teaching modes of these core professional courses in the IC Engineering Postgraduate Program have been explored to achieve the teaching goals. For these core courses, we have draw up course syllabus by referencing advanced teaching experiences of the IC Design & Application Undergraduate Program and developing experiences of the Circuit & System Postgraduate Program at Ningbo University. The teaching content, teaching methods, and experiment teaching modes are explored and developed at Ningbo University, which includes lecture notes, experiment guide book, etc.

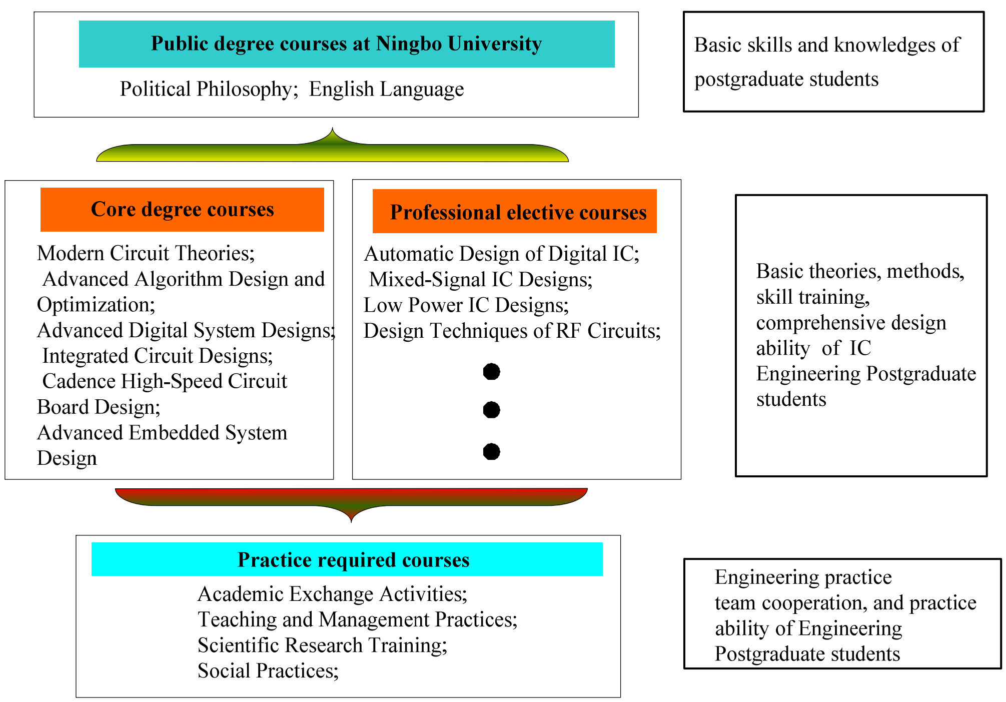


Figure 2 : The curriculum system of the IC engineering postgraduate program at Ningbo university

The “Modern Circuit Theories” course provides students with fundamental theories, analysis, and design methods related on the circuits. The course introduces the hot spots and frontiers of the modern circuit theory. The main contents of the course include circuit basic concept, second-order active RC filters, high-order active filters, switch network analysis, nonlinear resistance circuits, qualitative and quantitative analysis of dynamic nonlinear circuits, chaotic phenomena of circuits, fault diagnosis of analog circuits, and artificial neural network circuits.

TABLE 1 : The core professional courses of the IC engineering postgraduate program at Ningbo university

Course name	Lecture hours per week	Experiment hours per week
Modern Circuit Theories	2.5	1.0
Advanced Algorithm Design and Optimization	2.0	2.0
Advanced Digital System Designs	2.0	2.0
Integrated Circuit Designs	2.0	2.0
Automatic Design of Digital IC	1.0	3.0
Mixed-Signal IC Designs	2.0	2.0
Special-Purpose Chip Design	2.0	2.0
Low Power IC Designs	2.0	2.0
Design Techniques of RF Circuits	2.0	2.0
Cadence High-Speed Circuit Board Design	2.0	2.0
Advanced Embedded System Design	2.0	2.0

The “Advanced Algorithm Design and Optimization” courses provide students with fundamental theories, analysis, and design methods related on algorithm design and optimization. The main contents of the course include algorithm analysis foundation, greedy algorithm, partition strategy, dynamic programming, network flow, NP, approximate algorithm, local search, and random algorithm.

The “Advanced Digital System Designs” course focuses on design methods and design skills by using the CPLD and FPGA chips. The course introduces the hot spots and frontiers of the modern circuit theory. “The models, structures, descriptions, and design methods of digital systems. The course provides students with fundamental theories, analysis, and design methods related on the foundation, basic theory, and realization of digital systems. The main contents of the course include modeling and structure of digital systems, algorithm description for digital system, design steps and skills of digital systems, detection and measurability design of digital systems, VHDL language description, typical EDA development tools, SOC technology, and DSP Builder design.

The “Integrated Circuit Designs” course includes the two parts, named as the “Integrated Circuit Basis” and “ASIC design” courses. The “Integrated Circuit Basis” is one of the professional core curriculums in the IC Engineering Postgraduate Program. The goal of this course is an understanding of IC fabrication process, semiconductor devices, layouts, transistors, and CMOS logic design. The course trains students to develop skills at analysis and design of CMOS logic gates, combination logic blocks, and sequential circuits, and use IC design tools for carrying out schematic input, simulation and optimization of IC digital circuits. The course also introduces design methods of basic digital modules including flip-flops, adders, shifters, etc.

The “ASIC Design” course introduces simulation, design, verification, and testing of IC chips, which are a professional core course in the IC Engineering Postgraduate Program. The goal of this course is an understanding of full-custom layout design and verification. The course trains students to develop skills at full-custom layout design and layout verification by using IC EDA tools such as Virtuoso Layout Editor, Diva verification, etc. The course also introduces design methods of basic digital modules including multipliers, memory, etc.

The “Automatic Design of Digital System and Its Practice” course is also one of the professional core courses in the IC Engineering Postgraduate Program. The goal of the course is an understanding of the cell-based IC design. The course introduces Verilog HDL hardware description language, logic synthesis, layout place and route, etc. The course trains students to develop skills at cell-based IC design and layout verification by using IC EDA tools such as DC, Encounter, etc.

The “Mixed-Signal IC Design” course introduces basic knowledge and skill of mixed-signal IC devices, CMOS operational amplifier, CMOS OTA, filter, ADC, DAC, mathematical model, mixed-signal IC design method, etc. The goal of this course is an understanding of fundamental theories, basic knowledge, and analysis and design methods of the mixed-signal integrated circuits. The course trains students to develop skills at layout design and layout verification of mixed-signal integrated circuits.

The “Special-Purpose Chip Design” course is also one of the professional core curriculums in the IC Engineering Postgraduate Program. This course is a comprehensive application training course, and it emphasizes the engineering practice ability and team cooperation spirit of students, and trains students to resolve the actual engineering problems with the comprehensive adoption of fundamental theories, basic knowledge and basic technical ability through several projects, and develop student’s team cooperation sprits. Through this course, the student should grasp full-custom ASIC design and cell-based ASIC design methods by using IC EDA tools.

The “Low Power IC Designs” course is also one of the professional core curriculums in the IC Engineering Postgraduate Program. The goal of the course is an understanding of the basic concepts and design techniques of low-power integrated circuits. The course introduces power estimation, low-power design technologies, micro-power IC, latest topic on low-power IC, etc.

The “Design Techniques of RF Circuits” introduces designs of radio frequency (RF) circuits, which are a professional core course in the IC Engineering Postgraduate Program. The goal of this course is an understanding of basic knowledge, analysis methods and design methods of radio frequency (RF) circuits. The main contents of the course include design basis of RF circuits, design of small signal amplifiers, RF power amplifiers, modulator and demodulator, RF mixer, phase lock loops, direct digital frequency synthesizer, etc.

“Cadence High-Speed Circuit Board Design” course focuses on PCB design process including the built of components library, designs of principle diagram, layout, wiring, rules set, report inspection, post-treatment, ect. The main contents of the course includes principle diagram input, integration management environment of the component libraries, PCB design tool, and the skills for later circuit designs, etc.

The teaching of the “Advanced Embedded System Design” course helps students to understand basic idea of embedded system design, and familiar with grasping the basic concept and development process of the embedded systems and embedded operating systems. The main contents of the course includes embedded system overview, ARM architecture, command system of ARM, The hardware and operating system related on ARM, Windows CE operating system, and embedded system experiments including memory controller, interrupt controller, UART, graphical interface, TCP/IP communications, uC/OS - II, uCLinux, WinCE operating system.

PROJECT-DRIVEN TEACHING METHODS AND INNOVATION PRACTICE OF THE CORE COURSE

Experiment related on IC designs is an important teaching step, which teaches actual operation ability, training, and scientific research methods. The experiment training provides students with powerful learning experiences that they can easily transfer to a future workplace. In the most courses related on IC designs, the experiment lesson is not less than theory ones. Taken as example, the experiment teaching contents of the “Integrated Circuit Design” course is shown in TABLE 2.

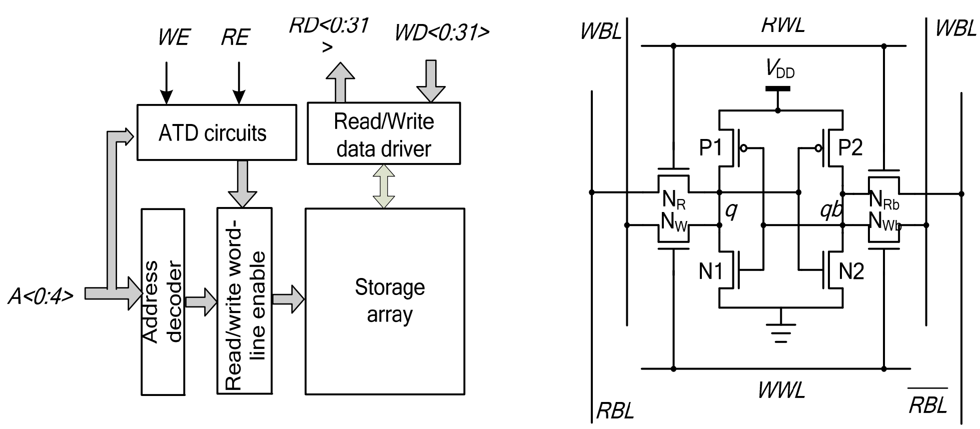
The main contents of the “Integrated Circuit Design” course include schematic input and simulation by using Cadence Composer and HSpice tools, designs and performance analysis of CMOS combinational logic gates, sequential logic circuits, and complex CMOS circuits, design of complex circuits, custom layout design, etc.

The experiment teaching contents are composed of six basic practices and five projects. The six basic practices are for “Integrated Circuit Basis”, while the five projects are used for “ASIC Design”, which strengthen design and practice ability of ASIC.

TABLE 2 : Experiment teaching contents of the "Integrated Circuit Design" course

Experiment content	Detailed content	Experiment hour
Cadence Composer and HSpice simulation	Simulation methods of the CMOS circuits by using Cadence Composer and HSpice tools	2
Circuit design style	Performance analysis and comparisons for circuit design styles by using HSpice simulations with Cadence Composer	2
Designing CMOS combinational logic gates	Device sizing optimization for CMOS combinational circuits based on complementary CMOS, DCVL, and CPL by using HSpice simulations with Cadence Composer	4
Designing sequential logic circuits	Device sizing optimization for static flip-flops by using HSpice simulations with Cadence Composer	4
Design of complex circuits	Designs, simulations, and comparisons for complex circuits by using HSpice simulations with Cadence Composer	4
Custom layout design	Schematic input, pre-simulation, layout design, and layout verification for the basic CMOS cell (Adder and flip-flop) by using Cadence Composer and Virtuoso Layout Editor with HSpice simulation tool.	4
16-bit parallel adder	First, complete schematic input and pre-simulation for CMOS modules by using Cadence Composer, then layout design and layout verification (DRC, LVS, and LPE), and post-simulation by using Cadence Virtuoso Layout Editor with HSpice simulation tool, and finally add I/O PAD.	16
32-bit serial adder		16
32-bit shift register		16
32×32 memory		16
10×10 counter		16

In the five projects, the students are demanded to complete schematic input and pre-simulation for CMOS modules by using Cadence composer, then layout design and layout verification (DRC, LVS, and LPE), and post-simulation by using Cadence Virtuoso Layout Editor with HSpice simulation tool, and finally add I/O PAD. First, the students are demanded to complete schematic input and pre-simulation for the projects by using Cadence Composer. Then, the students should complete layout design and layout verification (DRC, LVS, and LPE) by using Cadence Virtuoso Layout Editor and Calibre, and post-simulation with HSpice simulation tool. Finally, the students should add I/O PAD and complete layout verification and post-simulation for the whole chip including the core and I/O PAD.



(a) The structure of 32 × 32 SRAM (b) Storage cell

Figure 3 : SRAM design project based on the full-custom design in "Integrated Circuit Designs" course

For an example, the SRAM design project is shown in Figure 3. The students are demanded to complete the project using the full-custom ASIC design at Chartered Semiconductor 0.35um CMOS process (CHRT35dg_SiGe). The 32×32 SRAM is composed of Storage array, Read/Write data driver, Address decoder, Read/write word-line enable circuits, and ATD (Address Transition Detector) circuits. The schematic and layout of the SRAM design project with I/O PAD are shown Figure 4. The students are demeaned to complete the circuit designs and optimization of the SRAM, layout design and verification, and post-simulations.

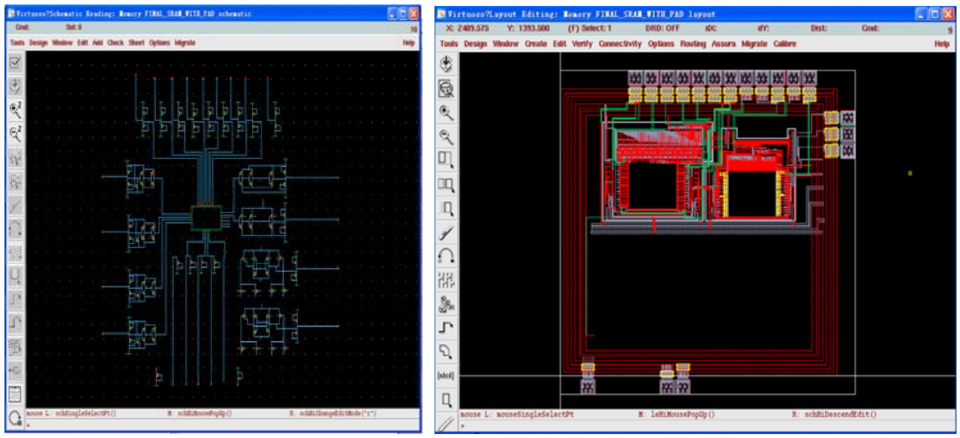


Figure 4 : Schematic and layout of the SRAM design project with I/O PAD in the “Integrated Circuit Designs” course

CONCLUSION

The constructions and teaching practices of the integrated circuit design and application courses for IC Engineering Postgraduate Program at Ningbo University have been carried out to meet strong demands for engineering designers of IC chips and electronic products. After several years of construction and practice, the teaching practices have obtained many innovation achievements in course system, teaching content, teaching method, experiment mode, courseware construction, and construction of IC design experimental platform. For content organization of the experiment teaching, we increased comprehensive experiment projects on the basis of basic experiment skills to improve students' design and practice abilities that they can easily transfer to a future workplace. The constructions of the course system and teaching practice of the core courses for the IC Engineering Postgraduate Program have some value for other similar universities.

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REFERENCES

[1] J.P.Hu, Y.S.Xia, H.Y.Ni; Advances in Intelligent and Soft Computing, **108**, 35–42 **(2012)**.
[2] J.P.Hu, Y.S.Xia, H.Y.Ni, L.Y.Wang; Advances in Intelligent and Soft Computing, **109**, 7–14 **(2012)**.
[3] Y.H.Dai, H.Li, J.P.Hu; Advances in Information Sciences and Service Sciences, **4(19)**, 571–579 **(2012)**.
[4] Y.H.Dai, Y.B.Wu, H.Y.Ni; Journal of Convergence Information Technology, **7(21)**, 9–17 **(2012)**.
[5] H.Q.Ren; Taiyuan Science and Technology University Journal (Social Science Version), **21(4)**, 88–89 (**2003**).
[6] U.Simsek; “Effects of cooperative learning methods on social studies undergraduate students' achievement in political science”, Energy Educ.Sci.Technol.Part.B, **5(1)**, 619-632 **(2013)**.
[7] W.Y.Xu, W.Feng; Journal of Electrical & Electronic Engineering Education, **23(6),** 79–84 **(2001)**.
[8] X.F.Sun, X.Z.Fang; Advances in Information Sciences and Service Sciences, **3(11)**, 124–131 **(2011)**.
[9] Z.Raud, V.Vodovozov; Przeglad Elektrotechniczny, **88(7b)**, 166–170 **(2012)**.
[10] Y.T.Qu, X.M.Li; Journal of Electrical & Electronic Engineering Education, **23(6)**, 23–24 **(2001)**.
[11] H.Li, J.P.Hu, H.Y.Dong; Procedia Engineering, **15**, 3154–3158 **(2011)**.