# Research on Digital Logic Circuit Teaching for Training System Abilities in Computer Science Majors

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**Abstract.** This paper focuses on the positioning and course objectives of the digital logic circuit course in system ability training for computer science majors. Research has been conducted on the reform of theoretical teaching and experimental teaching of the digital logic circuit course from aspects such as course content and teaching methods. Taking into full consideration the professional characteristics of computer science that are different from other IT majors, as well as the overall needs of system capability cultivation, a set of teaching content and methods that make extensive use of computer simulation technology is proposed. This provides a feasible scheme for the teaching of digital logic circuits aimed at the cultivation of system capabilities.

**Keywords:** Digital Logic Circuit, System Ability Training, Computer Science Majors

## 1 Introduction

In 2019, Academician Wu Jianping pointed out in his special report titled "Cultivation of Computer System Capabilities" that the development of the national computer industry has changed the demand for computer professionals. It is clear that the positioning of computer professional talent training has changed, and the cultivation of computer system capabilities has become one of the most important contents in computer science education [1]. Computer system capability training refers to the ability to use the basic principles at the computer system level to build application systems centered on computer technology, and the ability to solve practical problems. This is one of the directions of computer teaching reform supported by the Computer Teaching Guidance Committee of China's Ministry of Education [2].

The goal of computer system capability training is to enable students to understand the interrelationship between hardware and software in computer systems based on their mastery of basic principles, thereby equipping them with the ability to solve complex engineering problems [3].System capability training requires that course instruction starts from a system perspective, meaning that the teaching of computer system hardware and software related courses should possess integrity, relevance,


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hierarchy, dynamism, and openness [4]. Digital logic circuits, principles of computer organization, operating systems, and compilation principles are designated by many universities as core courses that run through hardware and software teaching in the system capability training process [5].Among them, the digital logic circuit course is responsible for the design and implementation of the most core and fundamental underlying hardware in computer systems, occupying the primary link in computer system capability training. Therefore, in order to better achieve the goal of cultivating computer professional system capabilities, it is particularly important to explore the teaching research of digital logic circuit courses for computer majors by using computer simulation technology.

## 2 Course Positioning for Capability Cultivation in Computer Science Majors

The digital logic circuit course is a hardware related course for IT related majors, especially the core hardware course for electronic information engineering, automation and other majors. Therefore, its teaching content is relatively wide, including traditional circuit design methods and design methods based on EDA (Electronic Design Automation) technology.

For computer science majors, the number of software-related courses in their curriculum far exceeds that of hardware-related courses, and the quantity of hardware courses is significantly less than that of similar courses in majors such as electronic information engineering and automation, which focus on hardware talent cultivation. Moreover, the requirements for students' depth and breadth of hardware knowledge in the computer science major curriculum are lower than those in other majors that emphasize hardware talent training. Therefore, starting from the hardware knowledge needs of the computer science major curriculum aimed at teaching computer system capabilities, we have repositioned the status of the digital logic circuit course in computer science, serving the requirements for cultivating computer system capabilities and helping students establish a solid foundation in hardware.

## 3 Course Objectives for System Capability Cultivation

The goal of the digital logic circuit course aimed at cultivating system capabilities is to develop students' comprehensive abilities in digital logic design and EDA technology. Specifically, it includes the following objectives:

(1) Mastery of the basic theory of digital logic circuits.

(2) Mastery of the development process of EDA technology and the usage methods of EDA development tools.

(3) Mastery of the syntax knowledge of Verilog HDL language, and be able to proficiently use Verilog HDL language to describe commonly used digital circuit systems.

(4) Understand and master the EDA design and implementation methods of commonly used combinational and sequential circuits.

(5) Ability to flexibly apply EDA technology to complete the design and implementation of various complex digital systems.

(6) Be diligent in thinking, possess the ability to independently debug programs, analyze the causes of errors, and correct them, thereby enabling independent development of circuit systems.

# 4 Curriculum Reform Measures

## 4.1 Optimization of Theoretical Teaching Content

Regarding the positioning and course objectives of the digital logic circuit course mentioned in the above sections in the cultivation of system capabilities in computer science majors, it is necessary to refine and optimize the theoretical teaching content of the course in actual teaching. The overall principle for optimizing the theoretical teaching content of the course is to aim to master the design and implementation of digital logic circuits based on computer simulation technology EDA, deeply and precisely explain the basic theoretical knowledge related to digital logic circuits associated with EDA technology. Specifically, the theoretical foundations such as logic algebra basis, combinational logic circuits, semiconductor storage circuits, and sequential logic circuits, as well as the VerilogHDL language, should be thoroughly explained. In terms of the implementation of combinational logic and sequential logic circuits, emphasis should be placed on the design and implementation methods of EDA. However, topics such as semiconductor diode based gate circuits, CMOS gate circuits, TTL gate circuits, ECL integrated circuits, Schmitt trigger circuits and monostable circuits, traditional digital-to-analog and analog-to-digital conversion circuits, and traditional circuit design and implementation methods can be omitted. Students only need to independently understand these topics outside of class.

In summary, the theoretical teaching content of the digital logic circuit course aimed at system capability cultivation mainly includes the following chapters：

Chapter 1: Introduction. In this chapter, development history of digital Logic circuits, EDA Technology such as the EDA Software Development Environment, the Hardware Development Circuit Board, and EDA Development Process will be introduced.

Chapter2: Fundamentals of Logic Algebra. The main contents of this chapter include basic logic operations, logic algebra formulas and theorems, logic functions and their description methods, and simplification methods for logical functions

Chapter 3: Combinational Logic Circuits and EDA Technology. The main contents of this chapter include introduction to combinational logic circuits, analysis methods for combinational logic circuits, design methods for combinational logic circuits, FPGA/CPLD devices, Verilog HDL syntax, principles and EDA implementation of common combinational logic circuits.

Chapter 4: Semiconductor Memory Circuits. The main contents of this chapter include logic functions and logic symbols of basic Flip-Flops, characteristic tables, characteristic equations, and waveform diagrams of basic Flip-Flops, Verilog HDL syntax related to clocks, EDA implementation of basic Flip-Flops.

Chapter 5: Sequential Logic Circuits and EDA Technology. The main contents of this chapter include introduction to sequential logic circuits, analysis methods for sequential logic circuits, design methods for sequential logic circuits, principles and EDA implementation of common sequential logic circuits, design of finite state machines.

### 4.2 Reform of Teaching Methods for Theoretical Courses

The digital logic circuit course aimed at system capability training includes both the theory of digital logic circuits and computer simulation EDA technology. Typically, digital logic circuit theory and EDA technology are offered as two separate courses in many universities. Digital logic circuit theory mainly covers basic theories and traditional design and implementation methods, while EDA technology primarily discusses the EDA development software environment, hardware environment, development process, hardware description language, and EDA design and implementation of circuits. Digital logic circuits serve as a prerequisite for EDA technology. In principle, the teaching of the digital logic circuit course aimed at system capability training can adopt a sequential approach: first covering the theory of digital logic circuits, followed by the content on EDA. However, the limitations of classroom lecture hours and the sequential approach in explaining the design and implementation of circuits based on EDA technology require time to re-review relevant digital electronic theory basic knowledge. This often leads to issues of tight teaching hours and lack of conciseness in the teaching content. Therefore, the teaching method we adopted is a blended approach of interspersing explanations of digital electronic theory and EDA technology knowledge.

In the specific implementation, all content is explained with the theory of digital logic circuits as the main thread, and corresponding EDA content is interspersed and supplemented where EDA knowledge is needed. In the arrangement of theoretical teaching content for digital logic circuit courses aimed at system capability cultivation in Section 3.2.1, the first chapter, an introduction, mainly intersperses the introduction of digital logic circuits and related EDA technology. The second chapter primarily explains the fundamentals of logical algebra. The third chapter covers combinational logic circuits and EDA technology, explaining basic knowledge, analysis methods, and design and implementation methods of combinational logic circuits based on the foundation of logical algebra in the second chapter. Specifically, the design and implementation part of combinational logic circuits mainly discusses methods based on EDA technology, that is, implementing circuits using hardware description languages. Therefore, following the illustration of design methods for combinational logic circuits, there is an immediate interspersion of EDA technology topics such as programmable devices and VerilogHDL syntax, which is then followed by a discussion on the implementation of combinational logic circuits using VerilogHDL. The fourth chapter is about semiconductor storage circuits, which, building upon the foundation of combinational logic circuits in the third chapter, basic flip-flops are derived and clock flip-flops are introduced to address the shortcomings of basic flip-flops. After explaining the relevant theoretical content of flip-flops, Verilog HDL syntax related to clocks was interspersed, followed by discussions on the EDA implementation of various flip-flops. The fifth chapter is about sequential logic circuits and EDA technology. Based on the foundation laid in the second, third, and fourth chapters, it first introduces the basic content, analysis methods, and design and implementation methods of sequential logic circuits. Then, based on the VerilogHDL syntax explained in the third and fourth chapters, EDA methods is used to design and implement sequential logic circuits. Finally, further explanation will be given on an efficient method for designing and implementing control circuits—a method based on finite state machines.

From the above analysis, it can be seen that this interspersed explanation method makes the overall teaching content coherent and seamless. The results of multiple rounds of theoretical teaching indicate that students have a high acceptance of this explanation method and the classroom teaching effect is good.

### 4.3 Reform Measures for Experimental Course Teaching

The experimental course adopts a progressive teaching method based on knowledge and difficulty, as well as a student-centered autonomous exploration model mainly based on computer simulation technology. The overarching design principle of the experimental course is to commence with tasks of utmost simplicity, enabling students to gain proficiency in the experimental software, hardware environment, and experiment workflow. At this stage, teachers need to explain and demonstrate first, followed by hands-on practice by students. Based on this, students can gradually carry out subsequent experiments according to the knowledge learned in theoretical classes and their previous mastery of the experimental environment and procedures. Subsequent experiments are mainly conducted by students' hands-on practice, with teachers providing hints and answering questions as supplementary methods.

The first chapter of the experimental course is aim to enable students to master the use of Quartus II integrated development environment and DE2-115 development board, as well as the EDA development process, through simple experimental tasks such as half adder design, one-bit full adder design, design and simulation of a 24-bit directional controllable counter based on IP cores, and controlling an LED light with a switch.

The second chapter of the experiment focuses on the design and implementation of combinational logic circuits. The objective is to enable students to proficiently master the design and implementation methods of these circuits, as well as result verification methods. This is achieved through the design and implementation of 4-7 BCD code decoders, 4-bit full adders, and other combinational logic circuits, building upon the experimental content learned in the first chapter. The result verification process involves waveform simulation or debugging on the DE2-115 development board. In terms of hardware resource utilization, this chapter requires students to further master the use of seven segment digital tubes, building upon their already established proficiency with toggle switches and LED lights from the first chapter experiment. Figures 1 and 2 show the correct debugging results of the 4-7 BCD code decoder and 4-bit full adder on the DE2-115 development board, respectively.


**Fig. 1.** Debugging Results of the 4-7 BCD Code Decoder on the DE2-115 Development

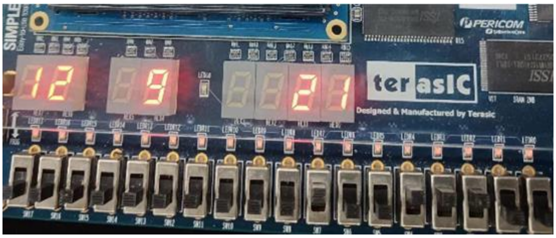


**Fig. 2.** Debugging Results of the 4-bit Full Adder on the DE2-115 Development Board

As illustrated in Figure 1, upon the input of the binary value 0111 via the toggle switch, the seven-segment digital display yields a decoding output of 7. Similarly, in Figure 2, when the addends 12 and 9 are input separately, the output of the full adder is 21.

The third chapter of the experiment focuses on the design and implementation of sequential logic circuits. The objective is to enable students to proficiently master the design and implementation methods of these circuits, as well as result verification methods. This is achieved through the design and simulation of a modulo-200 binary addition counter, a 10 frequency divider, and a common anode seven segment digital tube display decoding circuit with a flashing function. This function requires the seven segment digital tube to display digits 0-9 in a cyclic manner, with each digit on for 0.25 seconds and off for 0.25 seconds. This task builds upon the experimental content from the first two chapters. Notably, the common anode seven segment digital display decoding circuit with a flashing function presented in this chapter represents an advanced version of the 4-7 BCD code decoder discussed in Chapter 2. Figure 3 shows the correct simulation waveform of the 10 frequency divider.

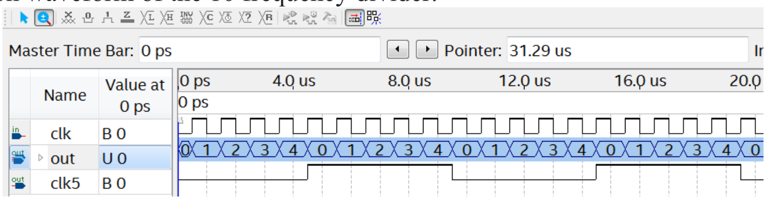


**Fig. 3.** The correct simulation waveform of the 10 frequency divider

In Figure 3, 'clk' represents the input clock signal, 'clk5' represents the output clock signal which is the result of dividing the 'clk' clock by 10.

Chapter four of the experiment focuses on the design and implementation of finite state machines, aiming to enable students to master this skill through the creation of an 8-channel color light controller, a 1101 sequence detector, and a seven-segment digital tube decoding control circuit for cyclic scanning display, based on a comprehensive understanding of the experimental content covered in the preceding chapters. Figure 4 shows the correct simulation waveform of the 1101 sequence detector.

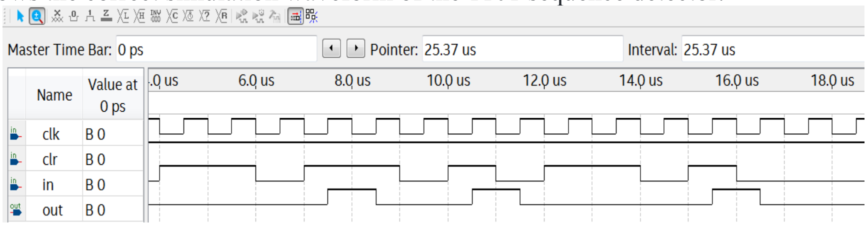


**Fig. 4.** The correct simulation waveform of the 1101 sequence detector

In Figure 4, 'clk' represents the clock signal, 'clr' signifies the high-level effective reset signal, 'in' denotes the input binary sequence, and 'out' indicates the output result of detector 1101. Upon detection of 1101, 'out' is assigned a value of 1; otherwise, it is assigned a value of 0.

Chapter five of the experiment focuses on the design and implementation of complex systems, aiming to equip students with the necessary skills through the creation of circuits such as intersection traffic light controllers and vending machines, building upon the foundational knowledge acquired from previous chapters. The ultimate goal is to significantly enhance their capacity to address practical engineering challenges.

The results of rounds of experimental teaching indicate that students generally evaluate this type of knowledge and progressively difficult teaching content and teaching methods very favorably. Students have a strong interest in independent exploration during the experimental classes, and their learning enthusiasm, practical skills, and problem-solving abilities have all significantly improved.

## 5 Conclusion

This article initially delineates the positioning and objectives of the digital logic circuit course within the context of system capability cultivation in computer science. Subsequently, taking into account the unique characteristics of the computer science major and the overarching requirements for system capability development, with a focus on computer simulation technology, the teaching content and methodologies of the digital logic circuit course are reformed and examined from both theoretical and experimental teaching viewpoints. The outcomes of numerous teaching iterations suggest that the approach proposed in this article has yielded positive teaching results in both digital logic circuit theory instruction and experimental teaching, and has been widely acknowledged by students.

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