Application of IC EDA Software in Practical Teaching of Digital Electronic Technology

Ruifang Tie*, Yuan Xu, Ningye He, Fuwei Shen
Engineering Research Center of Power IC Anhui Province, Huangshan University, Huangshan, Anhui, China
**Corresponding Author.*

Abstract: It's of great significance to introduce IC EDA software into the practical teaching of theory course for integrated circuit majors. This paper expounds the teaching practice mode and teaching content design of digital electronic technology course based on IC EDA software. It takes NMOS and CMOS inverters as examples to explore the feasibility of teaching solutions. Through teaching practice, good teaching results have been achieved and students' practical application abilities have been enhanced.

Keywords: IC EDA Software; Digital Electronic Technology; Practical Teaching; NMOS; CMOS Inverters

1. Introduction

As predicted by Moore's Law, with the rapid development of integrated circuits, the scale of on-chip transistors has reached billions, and the complexity and scale of circuits are increasing. Digital Electronic Technology is an introductory technical foundation course for electronic technology related majors. The course mainly teaches the working principles of basic logic units, the basic concepts, analysis methods, and design methods of combinational logic circuits and sequential logic circuits. It is the foundation for students majoring in microelectronics, integrated circuits, and other fields to deeply study digital integrated circuits [1].

2. Research Background

With the transformation and upgrading of the electronic information industry, higher requirements are put forward for the practical innovation ability of electronic information engineering talents [2]. The course of digital electronic technology has a strong practicality, and the exploration of the teaching method and teaching mode reform of the course has never stopped [3-5]. With the development of information technology, Multisim, Proteus, Quartus and other EDA software can be applied in the course of digital electronic technology to circuit simulation, verify circuit functions, assist classroom theory teaching, and deepen students' understanding of classroom content [6-8]. However, the mature product model parameters given by these softwares, the device parameters of transistors in the circuit can not be changed. Especially for students majoring in integrated circuits, should focus more on the design of device and circuit parameters, and requiring students to master the use, design and analysis methods of IC EDA tools, such as Empyrean and Cadence. Taking the integrated circuit EDA training course in Huangshan University as an example, this paper explores the practical teaching mode of digital electronic technology course based on IC EDA software.

3. Design of Practical Teaching Content

Based on the 0.18um CMOS process and 3.3 V standard voltage MOS transistor model as the main device， the integrated circuit EDA training course of Huangshan University has designed five categories of experimental projects for the course of digital electronic technology, and the number of specific teaching routine circuits exceeds 30, as shown in Table 1. The course is carried out in the professional IC design computer room, The teachers explain around the teaching routine, students learn and practice on the computer. After class, students can use the campus network to log on to the training platform on the server on their own computers for training. so as to master the software operation method, be familiar with the circuit structure, consolidate the theoretical teaching, and improve the application ability. According to the application characteristics of students, combined with the OBE teaching concept, the experimental manual is uploaded to the training platform before class, and the teaching method of "student-centered, reverse promotion" is introduced to form a three-in-one hierarchical practical teaching mode of "independent practice, research and exploration, thinking innovation" for students, which redefines the practical teaching link and derives the two-hour isolated experimental class to the pre-class, after-class and extra-curricular.

Table 1. Table Example

No.	Teaching Projects	Teaching Cases
1	Basic characteristics of MOSFETs	NMOS& PMOS
2	basic logic gate circuit	NOT, TG, AND, OR, NAND, NOR (multi inputs)
3	combinational logic circuit	8-3 encoder, 3-8 decoder, data selector
4	trigger circuit	D trigger, SR trigger, JK trigger (level trigger, edge trigger, pulse trigger)
5	Sequential logic circuit	bidirectional shift register, counter

The teaching case design of the practice course starts from the understanding of the working characteristics of MOS devices, through the simulation reinforcement of the basic logic circuit, and finally to the analysis, design, simulation and verification of the specific functional module circuit. Through practice teaching, students can have a more concrete and profound understanding of the basic concepts, analysis methods and design methods explained in class, and master the use of IC EDA software, laying the foundation for the subsequent analog integrated circuit and digital integrated circuit design practice courses.

4. Introduction to Practical Teaching Cases

This paper introduces the teaching cases of NMOS device and CMOS inverter.

4.1 Simulation of NMOS

MOSFET is the most basic device in integrated circuits. From the point of view of digital circuit design, MOSFET, as a switch, has very good performance and is widely used in integrated circuits.

In this paper, NMOS is taken as an example to build simulation circuit as shown in Figure 1. The gate-source voltage V_{GS} and drain-source voltage V_{DS} are set as variables.

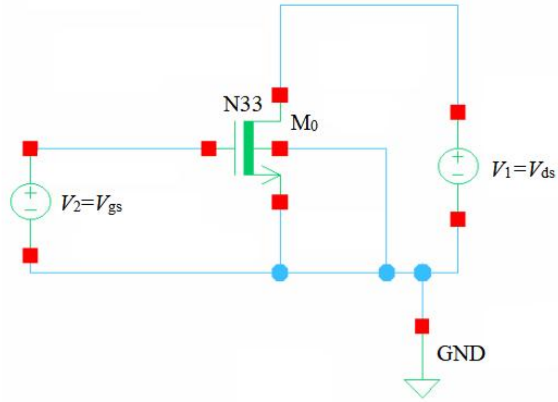

Figure 1. NMOS Simulation Circuit

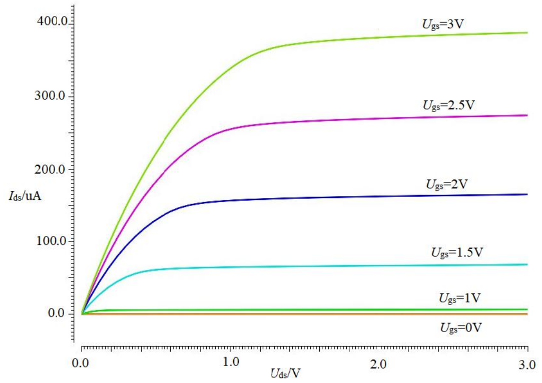

Figure 2. Output Characteristics of NMOS

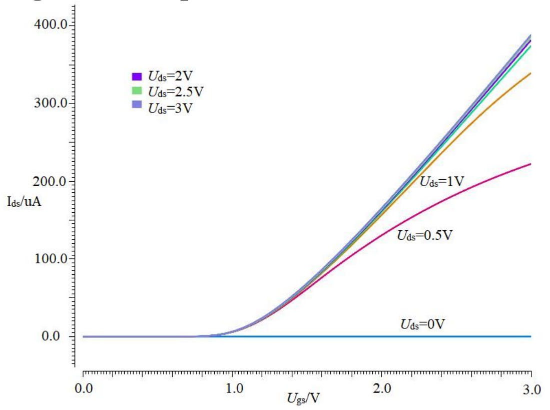

Figure 3. Transfer Characteristics of NMOS

The results of output characteristics are shown in Figure 2. When V_{gs} is constant, when V_{ds} is very small, the drain-source current I_{ds} is basically linear with V_{ds}, that is linear region; when V_{ds} exceeds a certain value, I_{ds} is constant and independent of V_{ds}, that is saturation region; when V_{ds} is constant, I_{ds} increases with the increase of V_{gs}. It also can be seen from Figure

3, when V_{ds} is constant, when $V_{gs} < V_{TH}$ ($V_{TH} \approx$ 0.75V in this example), $I_{ds} = 0$, that is cutoff region, and when $V_{gs} > V_{TH}$, it reflects the square law relationship between I_{ds} and V_{gs}. Through the simulation, students can understand the working principle of MOSFET, and have a qualitative analysis of the current and voltage equation.

The advantages of IC EDA software can change the device process parameters, such as W/L. Through the W/L adjustment simulation comparison of MOSSET, strengthen the students' understanding of the far-reaching significance of device parameter settings. The simulation shown in Figure 4 compared with Figure 2, the L of the NMOS is reduced but the W/L is unchanged. In Figure 4 I_{ds} in the saturation region is not always unchanged but slowly increases, which is caused by the channel modulation effect. That can guide students to understand the advantages of selecting long-channel devices and lay a foundation for subsequent integrated circuit design courses.

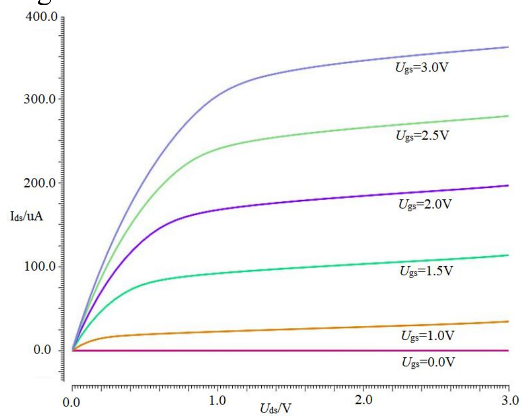

Figure 4. Output Characteristics of NMOS with Channel Modulation Effect

4.2 Simulation of CMOS Inverter

Inverters are the core of digital circuits. Through the simulation of the dynamic and static characteristics of the inverter, students can deepen their understanding of the concepts of the inverter, such as voltage transmission characteristics, noise margin, threshold voltage, delay time and so on.

By constructing the simulation circuit in Figure 5, and the voltage transfer characteristic (VTC) curve of the inverter is simulated as shown in Figure 6. Different colors represent different size ratios of PMOS and NMOS, denoted as β. From Figure 6, it can be seen that β=1, the threshold voltage of the inverter V_M= 1.42V; β=0.5, V_M=1.28V; and β=2, V_M= 1.55V. The noise margin of inverters with different size ratios is also different. Through the simulation of changing the size of the device, the students have a preliminary understanding of the factors affecting the threshold voltage. In reference [9], the anti-interference characteristics of the inverter can be simulated to verify the physical meaning of the noise margin, which will not be repeated here.

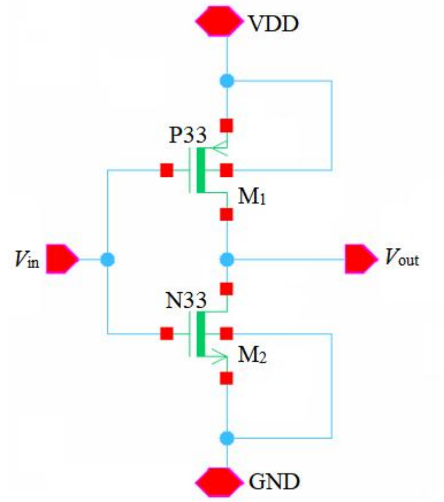

Figure 5. Simulation Circuit of Inverter

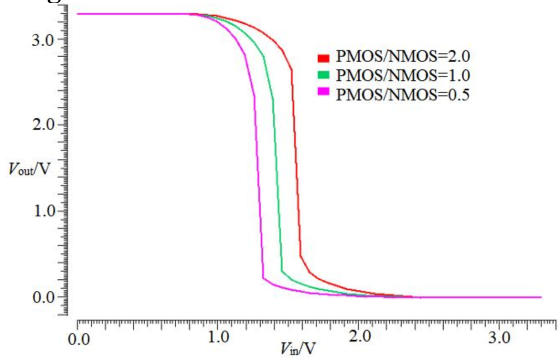

Figure 6. VTC Curves of Inverter

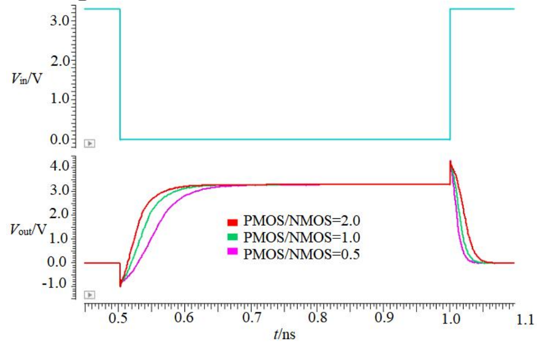

Figure 7. Transient Characteristics of Inverter

The transient waveform of the inverter is shown in Figure 7. When a square wave input signal is applied, the size ratio β of PMOS and NMOS will affect the delay time of the output waveform. With the increase of β, t_{PLH} (Delay time for the output to flip from low to high) decreases and t_{PHL} (Delay time for the output to flip from high to low) increases. Through simulation, students' ability to read graphs can be exercised, and their understanding of the dynamic performance indicators of gate circuits can be strengthened. At the same time, students can consider the difference of propagation delay from the perspective of device design, which lays the foundation for subsequent courses.

5. Conclusion

IC EDA software is the most commonly used software tool for students majoring in IC to study, research and work. By using the corresponding EDA software in the practice teaching of digital electronic technology, different types of process model parameters can be selected, and with its powerful simulation ability, through the simulation and verification of devices and basic logic gates cirtuits, students can master the basic circuit structure and deepen understanding of its working characteristics. Through the practical teaching of analysis, design, simulation and verification of functional circuits such as combinational logic and sequential logic, students can consolidate the application of theoretical knowledge in class, strengthen their understanding of specific combinational logic and sequential logic circuits. At the same time, it enables students to master the usage methods of EDA software for IC majors, and cultivate students' practical and innovative ability in circuit design. Through teaching practice, good teaching results have been achieved.

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