Research on Computer Organization and Design Laboratory Teaching Based on the New TDX-CMX System

Yong Wang[a], Zhihao Cao[*]

College of Information Science and Engineering, Zaozhuang University, Zaozhuang, China

[a]wangyong_uzz@163.com, [*]zhhacao@gmail.com

Abstract. Addressing the deficiencies in traditional laboratory teaching of computer organization principles, the integration of the TDX-CMX experimental system into the laboratory teaching of computer organization and design introduces a novel experimental model combining component circuits and FPGA design. This model starts with foundational experiments based on component unit circuits, enabling rapid mastery of the working principles and structural details of components such as arithmetic units. Subsequently, various model computers are constructed from these component unit circuits, facilitating comprehensive understanding of the working principles and structural intricacies of computers as complete systems. Once a thorough grasp of the principles and structures is achieved, detailed design of components and model computers can be undertaken using FPGAs, allowing for the replacement of existing components with newly designed ones. Practical operations demonstrate that the TDX-CMX system significantly enhances experimental teaching effectiveness and plays a crucial role in fostering students' innovative capabilities.

Keywords: The TDX-CMX System; Principles of Computer Organization; Experimental Teaching

1 Introduction

The experiment of computer composition principle is the core experiment of computer science[1-3].The TDX-CMX, standing for "Principles of Computer Organization and System Architecture Laboratory Teaching System," is an educational experimental software developed by Xi'an Tangdu Company, as shown in Figure 1. Utilizing the TDX-CMX system, students can gain an in-depth understanding of the composition and operational principles of a computer's internals. The TDX-CMX experimental system encompasses computer component experiments, bus design experiments, and model computer experiments. Within the TDX-CMX system, general circuits are pre-connected and encapsulated within the system, requiring minimal manual wiring by students during experiments[4-6].

Y. Kuang et al. (eds.), *Proceedings of the 2024 5th International Conference on Education, Knowledge and Information Management (ICEKIM 2024)*, Atlantis Highlights in Computer Sciences 22,
https://doi.org/10.2991/978-94-6463-502-7_83

The main interface of the TDX-CMX experimental system is composed of sections for instructions, output, graphics, circuit layout, a menu bar, and a toolbar. Specifically, the circuit layout area includes components such as the power supply, system units, timing and operation console units, the Central Processing Unit (CPU), system bus units, main memory, and peripheral units. During experiments, students wire according to the experimental circuit diagrams[7]. They observe the working status of each component and the timing relationships between signals in real time through data path diagrams and timing diagrams, conducting experimental verifications to determine if the experimental objectives can be achieved.

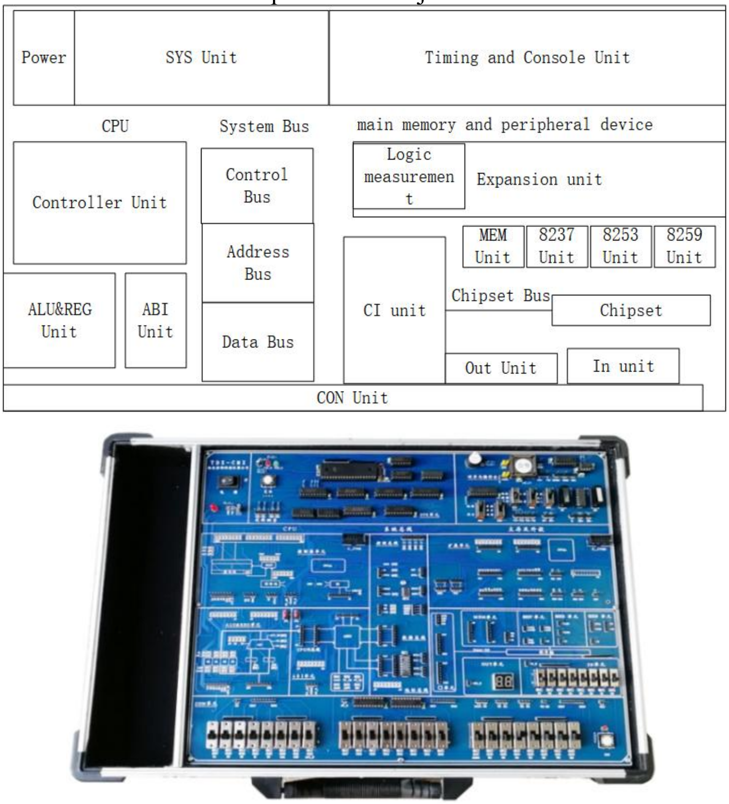

Fig. 1. The TDX-CMX experimental system

2 Introduction of TDX-CMX

The TDX-CMX experimental curriculum encompasses a multi-tiered instructional approach, including basic, intermediate, and advanced experiments that cover most knowledge points of the theoretical course and offer scalability. The detailed design of the multi-stage experimental teaching is as follows:

3 TDX-CMX Experimental Design

3.1 Basic Experiments

Basic experiments encompass arithmetic unit experiments, controller experiments, and memory experiments. Specifically:

Arithmetic unit experiments require mastering the working principles of arithmetic operations, shift operations, and logical operations, with eight-bit binary inputs being processed to verify the accuracy of the results.

Controller experiments aim to understand the operational process and principles of microprogrammed controllers, by designing and running four microinstructions and observing the correctness of the operational results.

Memory experiments focus on grasping the working principles of Static Random Access Memory (RAM), using the 6116 chip as an example to verify the read/write process[8].

3.2 Intermediate Experiments

Intermediate experiments include bus design and Input/Output (I/O) design experiments. Specifically:

Bus design experiments demand an understanding of bus functionality and characteristics, establishing a data path between the memory and the arithmetic unit, and accomplishing corresponding functionalities through microinstruction programming.

I/O design experiments necessitate mastering the working principles of external devices, I/O interfaces, and device controllers, connecting external devices and corresponding components through I/O interfaces, and programming microinstructions for data interchange.

3.3 Advanced Experiments

Advanced experiments are divided into simple and complex model machine experiments. Specifically:

Simple model machine experiments require students to design a basic model machine atop the CPU, write corresponding microinstructions based on machine instructions to achieve specific computational functions, thus fostering a comprehensive system perspective.

Complex model machine experiments demand that students design a more complete computer system based on prior knowledge, create microinstruction code as per the instruction system requirements, and execute corresponding operations on the model machine, gradually instilling a holistic view of computer systems.

When formulating the experimental teaching plan, it's possible to flexibly adjust the lecture hours for each experimental content, gradually cultivating students' practical abilities and overall system perspective from component experiments to complete machine experiments.

4 TDX-CMX System in Laboratory Teaching

The CPU primarily consists of components such as the arithmetic unit, registers, and the controller. Under the influence of the controller, the data pathway facilitates data exchanges between internal CPU registers, and between registers and the arithmetic unit, allowing students to directly observe the interaction and operational states among various components. Furthermore, timing observation diagrams display the sequential logic of data and control signals within the circuit, illustrating the temporal relationships between various signal points. This enables students to clearly perceive the operational details and outcomes of each signal.

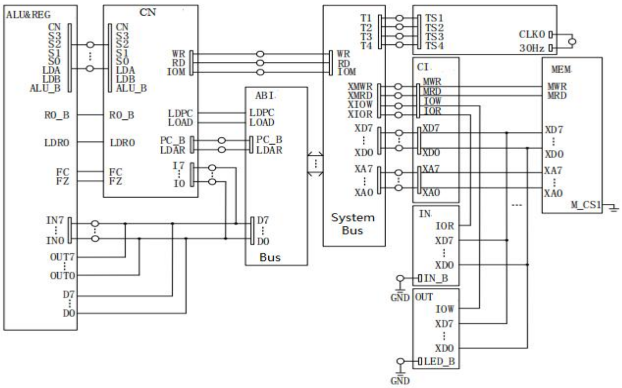

Fig. 2. Experimental Wiring Diagram

Taking the microprogrammed controller experiment as an example, by adding memory and I/O components to the CPU foundation, and through the data pathway and timing observation, students are tasked with writing microinstruction programs. This builds a simple model computer system, aiding in the establishment of an integrated system concept, and laying a solid foundation for conducting more complex model computer experiments later.

Firstly, the wiring results are as shown in Figure 2. Subsequently, the microinstructions are loaded into the TDX-CMX system, allowing for the execution of one microinstruction with each clock pulse. After executing a microinstruction, the correctness of the data in the data pathway diagram is observed to determine whether the microinstruction has successfully performed its intended function and operation. Finally, the operation of various signals during the arithmetic addition is examined through the timing observation diagram, providing insights into the internal signal dynamics of the arithmetic addition operation.

The timing observation diagram reveals that the control signal for Register A, LDA, becomes active at the T2 moment of the first machine cycle, with Register A's data subsequently changing to 65H at the T4 moment. The control signal for Register B, LDB, becomes active at the T2 moment of the second machine cycle, with Register B's data then changing to A7H at the T4 moment. This timing diagram displays the operational details and outcomes of each signal during the experiment, confirming the validity of the arithmetic addition result and achieving the experimental goal to deepen the understanding of theoretical knowledge further.

5 Analysis of Course Objective Achievement

Guided by the academy's talent development objectives, the curriculum syllabus for this course has been established, encompassing three main goals: Firstly, to grasp the fundamental concepts, components, and operational principles of computer hardware. Secondly, to compare and analyze the working principles and basic methods of the five major components, and, in the context of specific application problems, combining the theory and practical issues of computer hardware systems for analysis and computation, thereby selecting appropriate design methodologies. Thirdly, to be able to analyze and design computer hardware according to project requirements, use the Verilog language to simulate and emulate the operational principles of computer hardware, and propose solutions[9].

Aligned with the college's talent training objectives and teaching quality requirements, the achievement standard for the Computer Organization and Design course is set at 0.6. Taking the Computer Organization and Design course in the first semester of the 2023-2024 academic year as an example, the average achievement of Course Objective 3 exceeds the achievement standard of 0.6,meeting the achievement target requirements, and are presented in Table 1. This indicates a significant enhancement in students' practical operational abilities and autonomous innovation capabilities, demonstrating the effectiveness of the experimental teaching reform in the Computer Organization and Design course, which can further improve teaching quality[10].

Table 1. Comparison of Traditional and New method

Final evaluation grades	2022 (Traditional method)	2023 (New method)
90and above (excellent)	4.55%	22.25%
80-89points (good)	27.70%	32.91%
70-79points (good)	43.05%	35.69%
60-69points (passing)）	22.20%	9.15%
Below 60 points (failing)	2.50%	0.00%
Total	100.00%	100.00%
Course Objective 3 Achievement degree	74.96%	80.83%

6 Conclusions

The TDX-CMX experimental system boasts commendable intuitiveness, flexibility, and scalability, making it an excellent solution to the challenges faced in traditional experimental teaching. Its application has yielded positive results, significantly enhancing students' comprehension of theoretical knowledge and fostering their practical skills along with a comprehensive and systematic perspective.

References

1. Patil, S. S., Kulkarni, S. S., & Patil, S. K. (2020). Toward Outcome Based Education (OBE): An Impact of Active Learning Approach for'Computer Organization'Course. Journal of Engineering Education Transformations, 45-53. https://doi.org/10.16920/jeet/2020/v34i2/138793
2. Zhang, Y., Chen, K., & Liu, W. (2020). Online judge for fpga-based lab projects in computer organization course. In Proceedings of the ACM Turing Celebration Conference-China (pp. 15-20). https://doi.org/10.1145/3393527.3393531
3. Liu, X., De Vaulx, C., & Yuan, J. (2020). Experiment design for teaching digital logic and computer organization principle. ACM SIGAPP Applied Computing Review, 20(1), 24-35. https://doi.org/10.1145/3392350.3392353
4. Cao, Z., & Meng, F. (2021). Research on online teaching of ZigBee programming during the COVID-19 pandemic. In 2021 2nd international conference on education, knowledge and information management (ICEKIM) (pp. 208-211). IEEE. https://doi.org/10.1109/ICEKIM52309.2021.00052
5. He, F., Wang, W., Miao, X., & Hu, X. (2021). Course Ideological and Political Website Oriented to the Computer Organization and Architecture Based on Java. In 2021 2nd International Conference on Big Data and Informatization Education (ICBDIE) (pp. 236-239). IEEE. https://doi.org/10.1109/ICBDIE52740.2021.00060
6. Ham, Y., & Myers, B. (2019). Supporting guided inquiry with cooperative learning in computer organization. In Proceedings of the 50th ACM Technical Symposium on Computer Science Education (pp. 273-279). https://doi.org/10.1145/3287324.3287355
7. Xu, Y., & Chen, Y. (2021). Research on the Classified Teaching and Evaluation Mode of Computer Organization. In 2021 IEEE 3rd International Conference on Computer Science and Educational Informatization (CSEI) (pp. 191-194). IEEE. https://doi.org/10.1109/CSEI51395.2021.9477717
8. Zuo, D., Cheng, W., & Luo, J. (2021). A Practice Approach to Teach Computer Organization and Interface Technology. In 2021 2nd Information Communication Technologies Conference (pp. 338-342). IEEE. https://doi.org/10.1109/ICTC51749.2021.9441661
9. Margi, C., & Silveira, R. (2022). From face-to-face to online learning: performance and perceptions in a computer organization and architecture course. In EDULEARN22 Proceedings (pp. 2026-2033). IATED. https://doi.org/10.21125/edulearn.2022.0528
10. Estriegana, R., Medina-Merodio, J. A., & Barchino, R. (2019). Student acceptance of virtual laboratory and practical work: An extension of the technology acceptance model. Computers & Education, 135, 1-14. https://doi.org/10.1016/j.compedu.2019.02.010