Research and Design of Digital Logic Virtual experiment system

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Abstract. The realization of the virtual laboratory includes the construction of the website and the design of the learning system. The design of the learning system is introduced in this paper. In the system, the popular EDA tool Quartus EDA ModelSim is used to construct the virtual experimental environment, and the virtual FPGA is used as the carrier. EDA is used to design, modify, debug and verify the circuit. As a learning tool for digital circuit design and experimental simulation verification, it has obvious advantages. The course, theory and technology involved in the teaching of digital circuits are integrated to form a virtual experimental teaching simulation platform for digital circuits which is rich in content, advanced in technology, theory, experiment and simulation, and enriches the teaching methods. The paper presents research and Design of Digital Logic Virtual experiment system.

1. Introduction
Digital circuit plays a very important role in computer teaching and computer application, and the study of digital circuit is restricted by experimental equipment, experimental materials, technical means and application environment. Because of the new technology and the new product, the new teaching idea, the teaching resources and the teaching means are required higher, and the existing experimental environment and resources can not meet the teaching needs.

Facing the pressure of upgrading, the renewal of equipment requires a large amount of capital investment, especially for colleges and universities, which are already short of funds for running schools [1]. This situation has affected the smooth progress of teaching work. The concept of virtual laboratory emerges as the times require. Virtual experiment is used to improve the teaching environment and improve the teaching quality. The virtual experimental teaching environment refers to the environment needed to carry out the virtual experiment teaching. EDA / Electronic Design Automation (Electronic Design Automation) tools are also widely used in the design of digital circuits. EDA is based on the computer large-scale programmable device development software and experimental development system as the design tool. Through the development of software, the realization of electronic system to hardware system is realized automatically.

On the basis of this, the reform and discussion of the teaching method of digital circuit virtual experiment are made, and the integrated and networked solution is put forward. Combining virtual laboratory theory with EDA tools and introducing EDA simulation technology to display the difficult language in theoretical courses in the form of graphics, numbers or curves, An extremely complex process of change in which words are expressed or difficult to understand. The curriculum, theory, and technology involved in the teaching of digital circuits are integrated to form a rich, technologically
advanced, theoretical, experimental, The digital circuit virtual experiment teaching simulation platform combined with simulation enriches the teaching methods.

Digital logic is the abbreviation of digital circuit logic design; its content is to use digital circuit to carry on the digital system logic design. The electronic digital computer is composed of logic parts with various logic functions. These logic components can be divided into combinatorial logic circuits and sequential logic circuits according to their structure.

Sequential logic circuit is composed of flip-flop and gate circuit with memory ability. With combined logic circuit and sequential logic circuit, reasonable design and arrangement are carried out. Boolean algebras use only 1 (true) and 0 (false) numbers, so that when binary addition, multiplication and other operations establish a corresponding relationship with Boolean algebra operations, Logic components can be used to achieve binary data addition, multiplication and other operations.

In electronic equipment, circuits are usually divided into analog circuits and digital circuits, the former involving analog signals, that is, physical quantities of continuous variation, such as changes in indoor temperature within 24 hours, and the latter involving digital signals. When the switch K of figure 1 is quickly turned on and off, a series of pulses (voltage, this is the digital signal) on the resistance R are generated. Electronic circuits that control or convert digital signals are called digital circuits [2].

The digital circuit is a kind of professional course with strong practical requirements. The digital circuit experiment is a kind of verification theory, and the course of simple application is carried out according to the knowledge. The experimental operation is helpful to the mastering and understanding of the course theory. It can basically verify the basic digital logic circuit and the function of the device, and can independently analyze and design the basic circuit. In order to realize this purpose, it is required to complete 6 - 8 experiments in the course learning period. The experiment should be completed in synchronization with the classroom teaching, and the concrete contents and requirements can be found in the text. In order to highlight the characteristics of the software college, the experiment of students in our college is mainly based on the virtual experiment, and the implementation of the circuit experiment adopts the way of laboratory open verification. The virtual experiment software used is the virtual laboratory experiment of the electrician electronic network developed by the Qingdao Branch of Naval Aviation Engineering College.

2. Application of Virtual instrument in Digital Logic experiment
At present, many colleges and universities also use the following teaching methods of digital circuit teaching, but often because of constraints to achieve good teaching results.

According to the contents and requirements of the experiment, the experimental circuit is designed, and the experimental circuit is built mainly with simple gate circuit, electronic component, wire, switch LED, with simple experimental board as carrier, and with different combinations of switches. The input signal is provided to the circuit artificially, the state of LED brightness and extinction is observed, and the design of the circuit is judged correctly or not.
Figure 1. According to the contents and requirements of the experiment, the experimental circuit is designed.

Because of the limited types and quantities of experimental materials such as electronic components and gate circuits, the design of experimental schemes is often restricted. Effective experimental schemes can only be realized through existing materials. Simple experimental schemes are more convenient to implement because they involve fewer materials. For complex experimental schemes, electronic components and gate circuits are involved. There are a lot of wires and so on. It is difficult and easy to make mistakes because of the manual layout of the elements on the experimental board, which leads to the rework or failure of the experiment, which affects the smooth progress of the teaching experiment and cannot guarantee the teaching quality.

Special experimental instruments, such as digital logic, computer principles, etc., have the advantage that most of the basic circuits have been designed in advance, and students can do experiments according to the circuits and materials provided by the instruments [3]. Experiment scheme to complete the verification experiment of teaching content. Fewer circuits are built by the students themselves, which reduces the chance of error, and can ensure the smooth progress of the experiment. It is precisely because most of the circuits have been designed. At the same time, the experimental circuit provided by the instrument is limited, so the design of the experiment content, scheme and circuit is greatly restricted, especially for the complex and large-scale experimental circuits, especially some innovative and open experiments can not be completed.

The basic circuit in a digital circuit is a gate or gate and a non-gate (inverters). There are two or more inputs and one output in the basic form of the gate and / or gate. Because the input and output can be "0" or "1" respectively, They are called basic logic circuits. The symbols (graphics) and main expressions of the three basic logic circuits are shown in the attached table, which may be difficult for beginners to understand. Once understood, they will find it easier than normal analog circuits.

| $A_3 A_2 A_1 A_0$ | $Y_a Y_b Y_c Y_d Y_e Y_f Y_g$ |
|-----------------|-----------------|
| 0 0 0 0         | 1 1 1 1 1 1 0   |
| 1 0 0 1         | 0 1 1 0 0 0     |
| 2 0 1 0         | 1 1 0 1 1 0 1   |
| 3 0 1 1         | 1 1 1 1 0 0 1   |
| 4 1 0 0         | 0 1 1 0 0 1 1   |
| 5 1 0 1         | 1 0 1 1 0 1 1   |
| 6 1 1 0         | 1 0 1 1 1 1 1   |
| 7 1 1 1         | 1 1 1 0 0 0 0   |
| 8 1 0 0         | 1 1 1 1 1 1 1   |
| 9 1 0 1         | 1 1 1 1 0 1 1   |
| A 1 0 1         | 1 1 1 0 1 1 1   |
| B 1 0 1        | 1 0 1 1 1 1 1   |
| C 1 1 0         | 1 0 0 1 1 1 0   |
| D 1 1 0        | 1 0 1 1 1 1 0   |
| E 1 1 1         | 1 0 1 1 1 1 1   |
| F 1 1 1        | 1 0 0 0 1 1 1   |

1) and the gate. The following and the gate are 2 input, which is designed for the multiterminal input and gate equally applicable to the .2 input and gate function: when the input AHB is both logical "1" state, The output $Z$ is the logical "1" state .2 the logical relationship between the input terminal and the gate can be described by the circuit in fig. 2. For fig. 2, it is stipulated here that when the switch K1N K2 is off, the "0" state of the input AHB is represented when the switch is switched on, and the "1" state of the input AHB is represented when the switch is turned on; The "0" state of the output $Z$ is represented
by the lamp L, and the "1" state of the output Z is represented by the light L light. The various combination states of the switch K1N K2 "on" and "off", and the output states resulting in the "light" and "extinguishment" of the lamp, are then listed in a table. The table is called the truth table, which is shown in the table. In order for the lamp L to be illuminated, the output Z must be "1", and the input AHB must be "1".

The logical relationship between the gate and the gate is as follows: if each input has a state of "1", the output is "1". The non-gate has only one input and one output, and its output state is always the opposite of the input state. Here we can also use the circuits to describe the functions of gates and non-gates respectively, or to make corresponding truth tables and draw logical symbols.

Human society has entered a highly developed information society, and the development of the information society cannot be separated from the progress of electronic products. Moreover, the pace of product upgrading is also getting faster and faster. The main reason for this progress is the development of manufacturing technology and electronic design technology [4]. The former, represented by micro-processing technology, has now progressed to the deep sub-micron stage. Tens of millions of transistors can be integrated on a few square centimeters of chips; the core of the latter is EDA technology. EDA is a combination of applied electronic technology, computer technology, and computer technology. The electronic CAD software package, which has been developed with the latest achievements of intelligent technology, can mainly assist in three aspects of design work: IC design, electronic circuit design and PCB design. There is no support from EDA technology.

It is unthinkable to complete the design and manufacture of the VLSI mentioned above, but in the face of today's rapidly developing electronic products market, designers need more practical and fast EDA tools, using a unified collectivized design of Huang Jing. To change the traditional design thinking and concentrate on the design ideas, the comparison of schemes and the search for optimal design, we need to develop excellent performance and first-class quality electronic products at the fastest speed. The future EDA technology will make new breakthroughs in the aspects of simulation, timing analysis, automatic testing of integrated circuits, design of high speed printing plate and expansion of development and operation platform, which will be powerful and easy to learn. Easy to use the direction of development.

The logic analyzer can record and display 16 logical signals synchronously. Therefore, when the input and output signals of the circuit is connected to the input end of the logic analyzer, the waveform of the input and output signals can be displayed synchronously. This can help us to analyze the logic function of the circuit.

3. Virtual Simulation instrument commonly used in Digital Circuits
A special FPGA (Field-Programmable Gate Array (Field Programmable Gate Array) experimental board, such as DE0DE2 of Altera, is adopted. Because of the programmable characteristic of FPGA, the experimental scheme, experimental circuit and circuit are designed by software, and the circuit is simulated by function, time sequence, and verified. According to the specific model of FPGA, manually distribute pins, determine the logical relationship between input and output, download the programming files of the circuit to the experimental board, and provide input signal through the switch on the experimental board. The correctness of the circuit design is verified by the output state of the LEDX LCD. Because of the different types of FPGA, the different types and the number of the internal logic units, and the limited resources such as the switch LED LCD on the experimental board, the design of the experimental scheme is made. The design of the circuit is also limited to meet the basic teaching needs, and can not meet the design and experimental requirements of large, complex, comprehensive digital circuit system.

The above methods all have common shortcomings, that is, experimental equipment, materials, and limited resources. With the continuous development of technology, the continuous updating of teaching theory and experimental contents, the existing equipment is facing the situation of being backward and eliminated. Failure to meet the teaching requirements will greatly affect the teaching work.
With the development of electronic technology and computer technology, electronic products have been closely connected with computers. The intelligence of electronic products is becoming more and more perfect, and the integration of circuits is becoming more and more high [5]. The electronic design automation (EDAA) technology enables electronic circuit designers to complete circuit function design, logic design, and performance analysis on a computer. Sequence testing to automatic design of printed circuit board. EDA is a computer design software system developed on the basis of computer aided design (CAD) technology. Compared with the early CAD software, EDA software has a higher degree of automation and more perfect function. Faster operation, friendly operation interface, good data openness and interchangeability.

The electronic work platform Electronics Workbench (now called MultiSims) software is a virtual electronic workbench software developed by Interactive Image Technologies Company of Canada in the end of 80s and the beginning of 90s.

![Figure 2. The electronic work platform Electronics Workbench](image)

1) creating circuit with visual graphic interface: simulating the workbench of real laboratory on the computer screen, drawing the components needed for circuit diagram, and selecting the test instrument needed by circuit simulation directly from the screen;

2) The control panel of the software instrument is similar to the real object in shape and operation mode, and can display the measurement results in real time.

The EWB software has abundant circuit component library and provides many kinds of circuit analysis methods.

As a design tool, it can exchange data with other popular circuit analysis, design and board making software.

EWB is also an excellent training tool for electronic technology. The virtual instrument provided by it can be used to carry out circuit experiments in a more flexible way than in the laboratory, to simulate the actual operation of the circuit, and to be familiar with the measuring methods of common electronic instruments.

The traditional design method adopts the bottom-up design method. Generally, the functions are divided according to the specific functional requirements of the electronic system, then the truth table is drawn for each sub-module, and the manual logic is used to simplify the function of the Carnot diagram, and the Boolean expression is written. Draw the corresponding logic circuit diagram, then select the components, design the circuit board, finally carry on the test and debugging, because cannot carry on the function simulation of the hardware system, if there is an error in a certain process, it is very inconvenient to find and modify. So this is a time-consuming, laborious design method, and modern electronic design technology is top-down and advanced and efficient. In terms of design concepts, design methods, system hardware components, design reusability, intellectual property rights, The design cycle and other aspects of EDA technology have some advantages, so the design of the emergency responder abandoned the traditional design method, and chose the mainstream EDA technology to design.
4. Research and Design of Digital Logic Virtual experiment system

Logic converter is a virtual instrument unique to Multisim, which is not in the laboratory. Logic converter can convert logic circuit into truth table and truth table into logic expression. The truth table is transformed into a simplified logical expression, a logical expression is converted to a truth table, an expression is converted to a logical circuit, and a logic expression is converted to a logic circuit with a gate.

In the platform, excellent EDA simulation tools such as Quartus II Quartus Model Simulator and so on are integrated, which can be used for the theoretical study of digital circuit, experimental scheme design, digital circuit design, and so on. The function and timing of the circuit provide a good simulation environment for learning and experiment. Through the study of these tools, students' digital circuit design and learning ability can be improved.

The design of digital circuit is not only described in the form of schematic diagram, but also in HDL hardware description language, especially in complex digital circuit. The platform provides the learning environment of hardware description language such as VHDL and Verilog HDL. A large number of language learning cases are established and simulation results are given to facilitate students' learning.

Figure 3. The design of digital circuit is not only described in the form of schematic diagram

On the basis of basic gate circuits in digital circuits, such as with, or, with, with, or with, or with, or with, or with, with, or or not, the same or the same or the like, students are provided with the basic knowledge, basic principles, and design methods of simple circuits for studying and designing digital circuits, Make it master the experiment, simulation and verification method of digital circuit, lay a solid foundation for the study of digital circuit.

On the basis of trigger, decoder, latch, register, counter, selector, distributor, comparator, arithmetic logic unit and so on in digital circuit, training students to analyze, design, design, etc. Realizing the ability of medium scale integrated circuit, deepening the understanding of digital circuit theory, laying a good foundation for the design of complex digital circuit.

The synchronous sequential circuit is composed of combinational logic and flip-flop. The concepts of clock and timing are introduced. Based on the basic structure of synchronous sequential circuit, the basic design steps, such as state diagram, state table, state assignment and simplification, are introduced. The selection of trigger, the determination of output state, the derivation of output function, etc. From simplicity to complexity, the design of synchronous sequential circuit is studied step by step, and the timing simulation of the design is carried out by EDA tool. To verify the correctness of the sequential circuit design, this module provides a variety of sequential circuits, such as register, counter, frequency divider, pulse generator, pulse detector, code block converter and so on.

The selection range of components is wide and the parameters are easy to modify. It does not damage the device and printed circuit board as many times as the actual operation. It makes circuit debugging fast and convenient. It can be applied to most circuits in Analog Electronic Technology basic course. It can be used not only to verify the characteristics and principles of a single circuit, but also for multistage combinational circuits.

The component library not only provides a variety of components such as discrete components and integrated circuits, but also is a fully open platform for simulation experiments and courseware making. Provides us with a comprehensive electronic technology laboratory with complete experimental
instruments. It can be used in any combination of experimental environments, The whole circuit is assembled by component replication or single stage circuit replication [6]. Therefore, it is also suitable for large scale design experiments.

Figure 4. The component library not only provides a variety of components such as discrete components and integrated circuits.

EWB (Electronic working platform) provides us with a good practical tool, so that we can provide experiments, demonstrations and circuit analysis at any time in the teaching process. Teachers can analyze the characteristics of various circuits in a multimedia classroom. Explain the influence of various parameter changes on the circuit. Students can combine the contents of their studies and conduct debugging and analysis close to the actual circuit, which is conducive to deepening their understanding of theory, especially in some colleges and universities and radio and television universities. Through the computer simulation experiment, the theory teaching and experiment teaching of electronic technology are organically combined.

The realization of the virtual laboratory includes the construction of the website and the design of the learning system. The design of the learning system is introduced in this paper. In the system, the popular EDA tool Quartus EDA ModelSim is used to construct the virtual experimental environment, and the virtual FPGA is used as the carrier. Design, emulate, verify the experiment scheme and experiment circuit. Use EDA to design the circuit, modify, debug, verify conveniently and quickly, as the digital circuit design, The learning tools proved by experiment simulation have obvious advantages. Quartus and ModelSim are excellent digital circuit simulation software. They are the first choice for circuit design based on FPGA. It needs integration and configuration to obtain the best results in the platform, including the installation of software. Environment variable setting, system parameters and return information processing.

The learning process of digital circuit design includes: analysis and determination of logic function, generation and simplification of logic function describing logic function, schematic design and optimization, gate circuit selection, establishment of optimal logic circuit, function verification, timing verification, The actual circuit is formed, and the realization process of the virtual experiment is as follows.
The learning process of digital circuit design includes: analysis and determination of logic function

1. According to the design.
   Determine the input mode of the digital circuit design document: schematic description, HDL description, mixed description.

2. Start the Quartus tool.
   Set up the project and select the model of FPGA. Because the Quartus provides a variety of virtual FPGA devices, it can satisfy the design of almost all digital circuit systems. It can fully meet the requirements of the virtual laboratory for the target devices.

3. Design document of input circuit.
   You can use schematic input / HDL language input, or a hybrid input between the two. For complex digital circuits, you can use a top-down or bottom-up hierarchical design method. The circuit is divided into several relatively simple sub-modules, the sub-module circuit design is relatively easy, the design, verification, after the combination of the complete circuit.

4. Compilation projects.
   After compiling the project, it generates the test incentive file TestBench. modifies the test file to add the input test signal, adds the test file to the project and recompiles, starts the function simulation and timing simulation, and automatically enters the ModelSim simulation environment. Observe the output waveform file to verify the correctness of the circuit design.

5. Download validation.
   If there is a FPGA experimental board, you can configure the specific type of FPGA according to the resources on the board, determine the input and output pin relationship. Specify the corresponding pin in Quartus, recompile and generate the program download file. The correctness of the circuit design is verified by changing the input signal and observing the state of the output signal. If there is no experimental board, the study and design of the digital circuit can be completely satisfied by virtual experiment.

5. Summary
   The whole platform includes the integration of EDA tools for website construction, the design of learning system, the integration of various EDA technologies, and the stability of the system. In order to meet the design requirements, special tests have been carried out. The establishment of the virtual laboratory, the design and implementation of learning systems, the enrichment of teaching methods, and the provision of a large number of teaching cases, The integration and optimization of many courses in digital circuits can meet the teaching requirements, achieve the purpose of distance learning through network access platform, save laboratory space, facilitate the implementation of teaching tasks, and have high application value.

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