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# Design of Innovative Digital Electronic Technology Experimental Case Teaching

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**Abstract:** Due to the fact that the traditional Digital Electronic Technology (hereinafter referred to as DET) experiments bear sufficient reference material, elaborate design plan and complete design circuits (which makes it difficult for the students to design some experiments by themselves innovatively), but fail to bear enough experimenting methods, combined with the requirements raised by the competitions for experiment case teaching of elementary curriculums on electronic engineering and technique, in order to make some changes to the traditional experiment teaching, the paper innovated a new experiment case for the design of Rock-paper-scissors Game. In the design, two methods, Digital-integrated-circuit method and programmable-techniques method, are adopted to make it come true. When adopting digital-integrated-circuit method, right integrated circuit components will be employed according to the game-designing plan, using the software of Proteus to simulate it first, followed by debugging and testing of the hardware circuits on the bread board. The programmable-techniques method can describe the functions of the game on the development platform of the software of Quartus II by programming, adopting HDL (hardware description language). After right simulation, the programs will be downloaded onto FPGA experimental boxes or development board to realize the design of the game. The experimental case of Rock-paper-scissors Simulation Game is interesting and novel, which tends to stimulate the students to explore new world, study and innovate new things on their own. The adoption of the two methods will not only further enhance students' knowledge application ability and engineer practice ability, but also help them better understand the difference of an experiment between the traditional and modern method, which will, in turn, understand the significance and value of programmable techniques in digital system designing.

**Keywords:** Rock-Paper-Scissors Simulation Game, Experimental Teaching, Proteus Software, Programmable Techniques

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## 1. Introduction

Digital Electronic Technology (hereinafter referred to as DET), which is theoretical, practical and engineering, is a fundamental and core curriculum for electrical information majors in China's higher education, because it plays a pretty important role in the cultivation of students' basic qualities, practical ability and innovation ability [1]. DET experiment, an important part in the application of DET theories, is rather crucial in cultivating students' professional skills and innovation ability [2]. In order to cultivate students' engineering practice ability and their ability to analyze and solve problems, in the arrangement of experiments, other than the basic verification experiments, at least one comprehensive designing experiment will be in the students' list. To have such arrangement is to ensure that students can apply what they

have learned in theoretical teaching to design, wire and debug some circuits so as to meet the requirements of the experiments [3].

Taking into account the fact that in traditional DET comprehensive designing experiments, mainly frequency meters, digital clocks, responders, digital stopwatches, etc., are frequently used [4]. For such experiments, there are sufficient reference materials, elaborate design plan and complete design circuits, which makes it difficult for the students to design some experiments by themselves innovatively. But for the present, the Electrical and Electronic Basic Curriculum Teaching Steering Committee of the Ministry of Education and the Joint Committee of National Experimental Teaching Demonstrating Center hold a National College Electrical and Electronic Basic Curriculum Experiment Teaching Case Design Competition, which is

originally designed to promote the reforms in the study and exploration, engineering practice and self-dependent innovation of Experimental teaching contents of electronic basic course of electrical engineering, to promote the teaching level and quality of experimental teaching, to make people share excellent teaching materials among colleges and universities, and to arouse teachers' enthusiasm for experiment teaching construction and reformation [5]. Hence, an innovative experimental case design of rock-paper-scissors simulation game has been put forward. The experimental case is sort of innovative and interesting, but with few schemes to refer to, which means that students have to design it by themselves. At the same time, compared with those traditional DET designing experiments, which only requires the use of digital integrated circuit or programmable device design, this experiment requires the involvement of the integrated circuit and programmable techniques at the same time [6]. By comparing the two different methods, the students will better understand the difference between the traditional method and modern method used in one design project, and experience the significance and value of new programmable techniques in designing digital systems.

## 2. Proteus Software and Quartus II Software

The digital integrated circuit designing method used in the experiment case is a method realizing circuit after installation and debugging of the circuit constructed with wire and integrated circuit components on the bread board when the functional simulation is ensured to be correct. Before the simulation, according to the design plan, right digital integrated components should be adopted to design the Rock-paper-scissors game. And most of all, Proteus software should be used to simulate the designed circuit. The programmable technique realizing method of the experiment case is based on the development software Quartus II, adopting HDL (hardware description language) or schematic diagram input to realize the designed circuit. When adopting this method, the design can be carried out by different sub-modules according to functions of the circuit. After the simulation of each sub-module is correct, a top-level design document can be constructed to connect all the sub-modules to realize the whole design. When the compiled simulation of the whole design is correct, pin-locking method will be used. Then the whole design will be downloaded to FPGA (Field Programmable Gate Array) development board or experimental boxes to realize the functions of Rock-paper-scissors simulation game.

The simulation and development platform of Proteus embedded system, developed by British company Labcenter Electronics, is one of the most advanced and unbroken embedded system design and simulation platforms in the world. As an advanced EDA software, the system consists of two major programs, namely, ISIS. exe (used to electric schematic diagram design and circuit principle simulation)

and AREA. exe (used to print circuit board), which can be used to simulate independent components and circuit principle. By using arrows and colors to signify the directions and value of current, the software can simulate various PLD (programmable logic device) with CPU. Thus, Proteus can not only be used in the experiments of circuit principle, analog electronic circuit, and digital electronic circuit, but also in the simulation experiments of some comprehensive systems like SCM (single chip microcomputer) and interface. Proteus simulation software is with friendly human-computer interaction interface, and powerful designing functions, which make it convenient and easy to use [7].

Functionally speaking, logic devices can be divided into universal and specific devices. PLD (programmable logic device) is universal because it bears characters like self-defined logic functions, highly-integrated chips, excellent secrecy performance, etc. Therefore, it has been widely used in some complicated and fast-speed logic controlled circuits. At present, there are more than companies manufacturing programmable logic device CPLD/FPGA, among which, Altera, Xilinx and lattice are the three biggest companies. And Quartus II is the development software of Altera Company [7].

Quartus II, embedded with synthesizer, works well with many design imputing forms, like schematic diagram, VHDL, Verilog HDL, and AHDL, etc., which ensures the whole PLD designing process from design input to hardware configuration. Quartus II works well on the operating systems like XP, Linux and UNIX. Not only does it provide Tcl script to complete whole design procedure, but also it provides perfect GUI (graphical user interface) design method. Therefore, it bears such feathers like quick operation, uniform interface, intensive functions, user-friendly, etc. Quartus II also works well with IP core of Altera, including LPM/Mega Function library, making users sufficiently mature modules, which simplifies the design and speeds up the design process. The feature of Quartus II of excellent supporting third-party EDA tools makes it possible for the users to use their familiar third-party EDA tools at any stage of the design procedure. Apart from all the above-mentioned features, Quartus II can not only easily realize various DSP application systems by combining with DSP builder and Matlab/Simulink, but also works well with SOPC (system-on-a-programmable-chip) of Altera. Therefore, it is safe to say that Quartus II is a synthetic development platform with system-level design, embedded software development and programmable logic design [8].

## 3. Design Process of Rock-Paper-Scissors Simulation Game Experiment Case

### 3.1. Experiment Content and Task

The experiment requires the design of a simple rock-paper-scissors game to simulate the game in real life that people usually decide the winner by the gestures of rock, paper and scissors that they show through their hands. The experiment will include the following content:

- 1) Six switches or push-buttons will respectively represent the three gestures of rock, scissor and paper of party A and Party B. An encoder will be used to encode different gestures of Party A and Party B into two-bit binary codes. And a comparator control circuit will be used to compare two sets of two-bit binary codes, separately using a light emitting diode (hereinafter referred to as LED) to signify the win or loss. When the LED is on, the party on its side is the winner; the other party is the loser. When the LED on neither side is on, it means it is a draw or there is no game;
- 2) 7-Segment display devices should be used in the design to display the number of games each person wins. The Best of Nine Sets should be the least function that the simulation game should realize;
- 3) The circuit designed can be reset so as to start new matches;
- 4) Digital circuit integrated components and FPGA are respectively required to be used to realize the design purpose.

### 3.2. Experiment Process and Requirements

The experiment should be finished totally based on digital electronic technique and programmable technique.

- 1) Experimenters should know the design methods of combinational logic circuit and the use of some integrated devices like encoder, decoder, counter, etc.;
- 2) Experimenters should know well how to use some circuit simulation software like Proteus. Once the design plan gets set, simulation of circuit should be done first to ensure the rightness of the design;
- 3) Proper small and medium scale digital integrated devices should be chosen to construct the hardware circuit of the rock-paper-scissor simulation game according to the simulation circuit, so as to verify whether the experiment result matches the requirement of the design;
- 4) Experimenters should get familiar with VHDL or Verilog HDL and the development software Quartus II for FPGA. Because they will have to use hardware description language to make programs in FPGA development software so as to realize the design of rock-paper-scissors simulation game. After that, it will be downloaded into a FPGA experiment box or development board to verify the designed functions.
- 5) When the design is finished, a lab report should be written to report the plan and process of the two designing methods. And of course, the difference of the two methods and how they find the two methods should be included.

### 3.3. Experiment Purpose

The purpose of the experiment is to guide the students to solve some application problems with what they have learned by using the design process of the game project. In the project, the students have to grasp the design methods and steps of the project, and the knowledge in circuit simulation, assembling

and debugging. After the experiment, the students should know the functions and usage of integrated devices like encoder, display decoder, counter, etc., and the usage of LED, 7-segment LED display and switches or push-buttons. Meanwhile, the project can also make students get familiar with programmable design technique, grasp the design methods of module-designing and top-down design, use hardware description language and schematic diagram to realize designs based on FPGA. And most of all, it can make the students experience the significance and application value of digital system design based on FPGA.

### 3.4. Experiment Teaching and Guide

The experiment is a complete digital circuit design, requiring students to independently finish the design, simulation, testing of the digital circuit and the step-by-step design, simulation and testing of FPGA. The design consists of several steps like explanation of the plan, design of the plan, circuit simulation and debugging, etc.

- 1) Before the experiment, the teacher should explain the idea of the design, plus telling students to choose right logic gates, encoder, counter, display decoder and LED display. The teacher should guide the students to finish the design of each part step by step, reminding the students of the dealing of invalid states, the counting and clearing of the numbers of winning;
- 2) Before debugging on the bread board to verify the correctness of the game functions, the design should be simulated to get positive result;
- 3) The design based on FPGA should be designed and simulated on different modules before synthesizing all the modules to do whole design and simulation. The positive result of simulation will be downloaded onto FPGA experiment box or development board to verify the correctness of game function;
- 4) Attention should be paid to the debugging techniques and skills. Still, the circuit wiring should be orderly and normal;
- 5) Some aspects of the two design style, like the difference between the two design methods, the different logic resources they use, the speed and convenient degree of the design getting modified should be compared in and after the design;
- 6) When the design is finished, students will be organized to have an exchange, to know the pros and cons of the design, and to discuss what they have got from the two design method and how they find them.

### 3.5. Experiment Principles and Schemes

#### 3.5.1. The System Module Diagram

The system module diagram is as shown in figure 1. The system consists of four parts, namely, the encoding circuit used to mean push-button input signifying gestures of the two parties, the comparator control circuit used to decide the winner, the LED display circuit used to tell the winner of each round, the counter controlling circuit used to add one time to

the winner of that round when the player push down the button and win. The last circuit also works to display the counting

result on a 7- segment LED after decoding with display decoder.

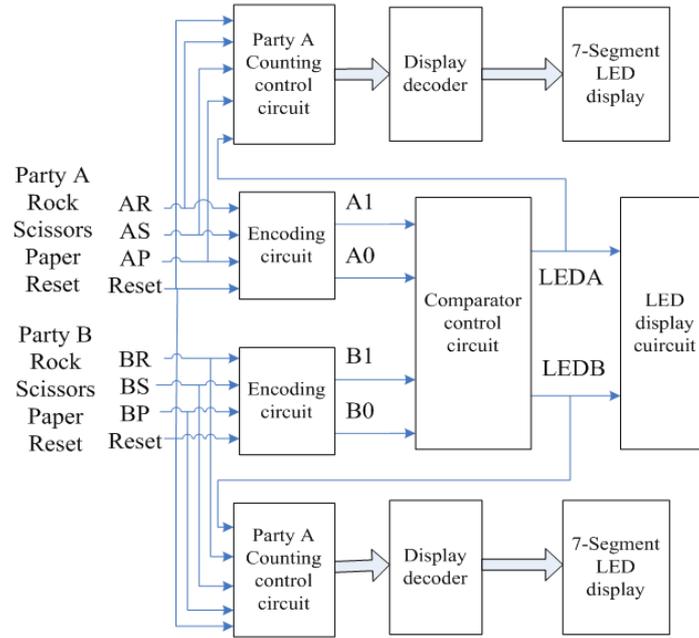


Figure 1. The system module diagram.

3.5.2. Implementation Plan

The experiment will be carried out in two ways, the digital circuit integrated components and FPGA.

- 1) Implementation through digital circuit integrated components
  - a) Encoding circuit

AR, AS, AP stand for the three gestures of rock, scissors, paper of Party A in the game, indicated with three push-buttons or three switches respectively. BR, BS, BP stand for the three gestures of rock, scissors, paper of Party B in the game, indicated with another three push-buttons or three switches respectively. Reset works on clearing all the encoder and counter in the whole circuit, indicated with one push-button or switch. The functional table of encoding circuit of the input of Party A is shown in figure 1. Gesture input is active low. A1 and A0 stand for the two-bit encoded outputs. The encoding circuit design of Party B is the same as that of party A. The gesture inputs of Party B are BR, BS, BP, while the encoded outputs are B1 and B0.

Table 1. Functional Table of Encoding Circuit.

Reset and gesture input				Encoded output	
Reset	AR	AS	AP	A1	A0
1	X	X	X	0	0
0	0	1	1	0	1
0	1	0	1	1	0
0	1	1	0	1	1
0	Others			0	0

The circuit can be realized through 8 to 3 bit binary encoder 74LS148 and inverter, or similar encoder. Reset works as the enabled-signal of the encoder.

- b) Comparator control circuit

By comparing two groups of code A1, A0 and B1, B0 of gestures of Party A and party B, two controlling signals, LEDA and LEDB, will be displayed on the two LEDs. When the controlling signal is at high level, the LED it is connected is on. When the controlling signal is at low level, the LED it is connected is off. When Party A wins, LEDA is at high level, LEDB is at low level. Vice versa, when Party B wins, LEDB is at high level, LEDA is at low level. When the result is a draw, both LEDA and LEDB will be at low level. And as long as there is no valid input of either party, both LEDA and LEDB will also be at low level. The functional table of comparator control circuit is shown as in Table 2.

Table 2. Functional table of comparator control circuit.

Input				Output	
A1	A0	B1	B0	LEDA	LEDB
0	0	X	X	0	0
X	X	0	0	0	0
0	1	0	1	0	0
0	1	1	0	1	0
0	1	1	1	0	1
1	0	0	1	0	1
1	0	1	0	0	0
1	0	1	1	1	0
1	1	0	1	1	0
1	1	1	0	0	1
1	1	1	1	0	0

Based on the functional table, the function expression of LEDA and LEDB will be worked out. And a logic gate can be used to realize the control of the circuit.

- c) Counting control circuit

In the game, when either Party wins that round, the corresponding counter will add one to the result, five of the

best will be the winner. When a new round begins, the counter will be reset. Taking into the fact that when the gestures keep unchanged, the counter should not keep counting. That means only when both parties input new gestures, will the counter move on. Then, it is necessary to use gesture input signal and the high level signal of the winner to run some logic operation to have a counting pulse signal each time. The counting of the counting pulse can be realized through a decimal counter with a reset controller, such as 74LS90.

d) Display decoder

The display decoder can adopt CD4511 or similar integrated decoder, which will decode the result of the decimal counters into output signals as a, b, c, d, e, f, g, so as to drive the seven-segment LED to display the result.

Proper digital integrated components should be used to finish the above-mentioned parts of the design. Proteus software should be used first to simulate the whole design in order to make sure of the correctness of the functions of designed circuit. Then, based on the devices used, the whole circuit will be constructed on the bread board or digital circuit experiment box to debug the whole design step by step.

2) Implementation through FPGA

According to this scheme, the whole design will be divided into three parts, namely, encoding module, comparator control module and counting decoding displaying module. The design idea of each module is same as that of the design with digital circuit integrated components. What makes the two schemes

different is that in FPGA scheme, the work principles of each module should be used to describe the function of each module with HDL in Quartus II, the FPGA development software, and to compile each module and simulate the modules respectively. Later, the top-level schematic input or component instantiation statement will be used to connect each module to realize the whole design [10]. After getting positive result in the simulation of the whole design, the whole design will be downloaded onto FPGA development board or experiment box to verify the functions of the whole system.

The schematic diagram of each module is shown in figure 2. In Encoder module, R, S, P stands for the gesture input of rock, scissors, and paper respectively of each party. Reset means clearing the controlling input. Y1 and Y0 stand for the two-bit code output of the gesture-input of each party. In Comparator module, A1, A0 and B1, B0 stand for the input of the gesture-input encoding of party A and party B respectively. LEDA and LEDB stand for the light-output of the winner between party A and party B. In Counter\_Decoder module, the names of the input signals should be consistent with the former two modules. The output signals, a, b, c, d, e, f, g, will drive the seven segments of LED correspondingly, so as to display how many games one party has won. After connecting these sub-modules and adding input and output ports, the complete top-level schematic diagram is set up [11]. This diagram is shown in figure 3.

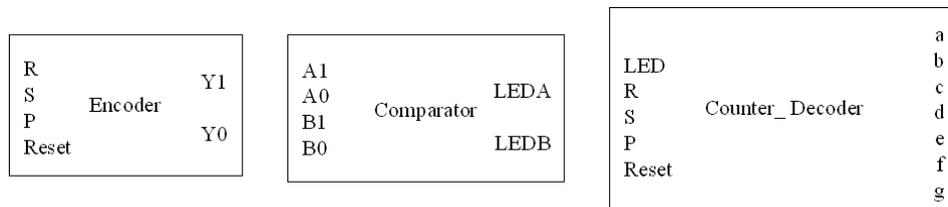


Figure 2. Schematic diagram of Encoding Module, Comparator Controlling Module and Counting Decoder Displaying module.

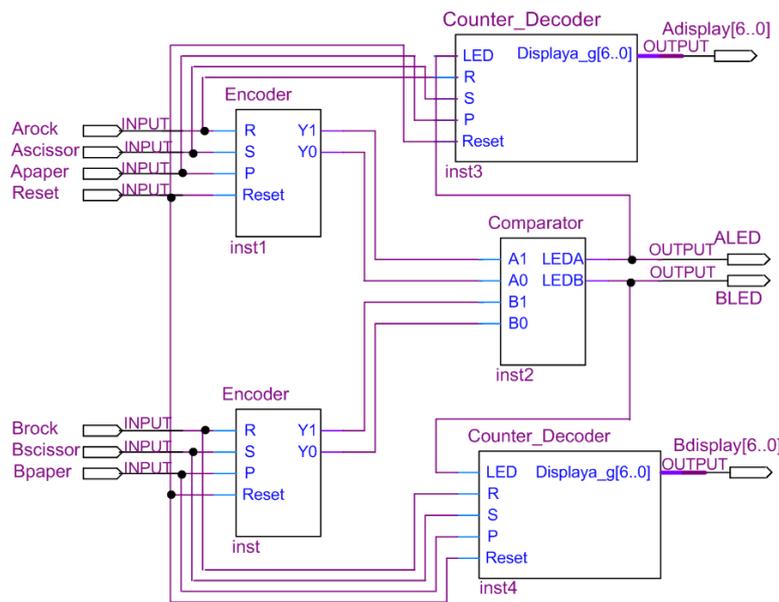


Figure 3. The complete top-level schematic diagram..

### 3.6. Experiment Reports

The experiment report should include the following parts [7]:

#### 1) Task and requirements of the project

First, the students should analyze the project and its corresponding schemes. When doing this, they should analyze the project seriously, understand it correctly and know the designing ideas very clearly. They should also introduce the design procedure of the two schemes.

#### 2) Choice of integrated circuit devices and other components

The students should choose proper integrated circuit devices and other components for the design, and name the pin figures, function table and main parameter values of the integrated circuit devices.

#### 3) Drawing and simulation of the schematic diagram

Both the schematic diagram simulation circuit in the scheme of the digital integrated components, and the schematic diagram of each module and its simulation waveform, the whole schematic diagram and its simulation waveform in the scheme of programmable techniques should be attached to the reports.

#### 4) Circuit testing, analysis and research

This part should include the list of experimental facilities, the introduction of installation, and debugging process, and the analysis of malfunctions and their solution, etc.

#### 5) Summary

In this part, the difference between the two design methods should be compared to find out the advantages of the scheme of programmable techniques. Apart from that, the students should summarize the problems coming from the project, point out better ideas, and figure out what they have learned in the project, how they have found it and what suggestions they would give to the future projects.

### 3.7. Requirement and Method of Assessment

The students are required to finish the design, simulation and testing of the two schemes within given time. They will be assessed according to the following parts:

- 1) The checking of the schematic diagram simulation circuit. Mainly in the following aspects: if the functions of each part match the requirement, if the simulation waveform is correct, and if all the functions have been achieved.
- 2) The checking of the hardware circuit. It is mainly about how and when the required function has been achieved.
- 3) Quality of the experiment. It is mainly about whether the circuit scheme is rational, and how the wiring is.
- 4) Independent innovation. It is mainly about if the conception about functions and the design of the circuit is innovative, and whether the students thought and practiced independently.
- 5) The experiment reports. It is mainly about how formal and complete the reports are.

## 4. Conclusion

The whole experiment designing process of an innovative experimental case, rock-paper-scissors simulation game, is introduced in this paper. The process consists of the students' understanding about the content and tasks, the experimenting procedure and purpose of the experiment, and the designing process of the rock-paper-scissors simulation game and its components.

In the experiment, two different methods to carry out the case have been adopted; one is with digital integrated components, the other being with programmable techniques. Both methods require the division of modules like encoding, comparison, counting and decoding display according to the functions of the game. After the division, it is required to design each module step by step in order to realize the functions. The method to realize simulation with Proteus in the adoption of digital integrated components to realize the design, and the basic steps using Quartus II in the adoption of FPGA are briefly introduced in the paper. The former method is direct because many integrated components are used in theoretical learning, which makes it easy for students to understand. But it's also not very convenient to extend the functions of the system, neither repeated amendment. The latter is comparatively more comprehensive as it can realize the design by programming the whole functions of the system, which is easy to extend and amend repeatedly. Each time when the functions of the system need to be changed, it only requires amending, compiling and downloading the programs, while it is not necessary to change the hardware circuit.

Due to the innovation and interestingness of the rock-paper-scissors simulation game experiment case, and the specificity of the employment of two methods to carry out the experiment, it is pretty good to be used as comprehensive experiment in DET, because at present, there is not much reference material for the students to use, which is likely to arouse their enthusiasm, initiative, and creativity. The case will also works well in guiding students to apply what they have learned in class to solve some real problems and grasp effective methods to gain useful material, according to the designing process of the game. Furthermore, the method to use FPGA to carry out the experiment will work well in helping students to grasp programmable techniques and verify the difference between the two designing methods with practice.

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