Microcomputer Principle Virtual Laboratory for Smart Grid Specialty Practical Teaching

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Abstract. For the practical teaching of smart grid information engineering undergraduate specialty, carrying out the construction of microcomputer principle digital virtual laboratory is of great significance to cultivate compound engineering application talents for the smart grid industry. The constructed microcomputer principle virtual laboratory uses three kinds of 8086 visual assembler and debugging software (CLAB, STAR and EMU8086), as well as EDA software which supports 8086 simulation operation to carry out hardware and software system design. Based on the virtual laboratory, the topics of smart grid specialty's course design or graduation design can adopt the principle of combining with actual smart grid technologies. The practical application of the virtual laboratory is introduced by taking a design case of definite-time over-current relay protection. This teaching method of combining theory with practice can enhance students' cognitions of building strong smart grid and new-type power system in China. The teaching practice in recent years shows that the teaching effect of the microcomputer principle virtual laboratory is remarkable, and it has practical value in cultivating and improving students' practical innovation ability, which is worth further research and practice.

1.Introduction

"Microcomputer Principle and Application" is a basic course of engineering specialty [1], and it is also a core course of the new engineering specialty "Smart grid information engineering". Microcomputer is an important foundation for undergraduate students to learn and master power automation technologies.

Microcomputer principle course's teaching contents mainly include microcomputer computational basis, 80x86 MPU (microprocessor unit) and assembler instruction set, assembler language programming, memory system, I/O (Input/Output) interface and interrupt system technology, programmable I/O interface chips, and so on. The knowledge is scattered and complicated, the students are difficult to understand and apply skilfully within a short period of time, and the teaching process is easy to be trapped in the boring and difficult situation. In the above, 80x86 assembler language programming should be the hardest and the most important.

Through the course study, students should grasp the flexible application of instruction set and assembler language source program's writing and debugging, and in the course design link can combine the software and hardware to solve a slightly complex engineering practical problem, which is the course's core task.

Affected by COVID-19, the current teaching method in colleges and universities has changed dramatically, and a new way of online and offline hybrid teaching has emerged. However, it is difficult to carry out course experiments and course design normally during online teaching. For this reason, in response to the requirement of digital teaching construction, aiming at the characteristics of the microcomputer principle course that focuses on program reading and application programming, and considering the development of 80x86 assembler and debugging software and EDA software supporting 80x86 MPU, a microcomputer principle virtual laboratory is constructed, which is suitable for online teaching and at the same time can improve the students' manipulative ability and innovative ability.

2.Software selection for the virtual laboratory

Microcomputer principle virtual laboratory uses two types of software, one is 8086 assembler and debugging software, and the other is EDA software that supports 8086 MPU.

After years of teaching practice, the course team identified three kinds of 8086 visual assembler and debugging software for experimental use, respectively: 1) Tsinghua version of assembler software CLAB [2]; 2) STAR integrated assembler environment software that supports software and hardware experiment of 8086/8088 and 51/96 SCM (Single-chip), and 3) the assembler and microprocessor emulator EMU8086.

Among them, CLAB and STAR have the Chinese-language interface, and they are simple and easy to learn, but both software require the support of 32-bit operating system. Therefore, we suggest that students should install

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a 32-bit virtual machine (XP system) on their computers to support CLAB and STAR.

In teaching, EMU8086 has been widely applied [3–5]. EMU8086 software is an 8086 assembler and emulator with a good human-computer dialogue interface, and it also supports 80186. EMU8086 has a powerful emulator debugging environment, which can achieve single step debugging (single step and step back) and full-speed running (run), and can view the MPU internal general and segment registers, memory cells, stacks, variables and flags register, etc. It also supports Debug function.

EMU8086 can directly debug instructions and pseudo instructions, unlike CLAB and STAR, which must strictly abide by the segment structure. This gives a great convenience to the classroom teaching. At the same time, its emulator provides some commonly used virtual devices, such as traffic lights, stepper motor, robot, thermometer, LED and virtual screen, etc. Beginners can use these virtual devices to complete some simple applications. See Figure 1, this is the EMU8086 traffic lights system, at this moment the east-west passes, north-south stops, the operation effect is very vivid image.

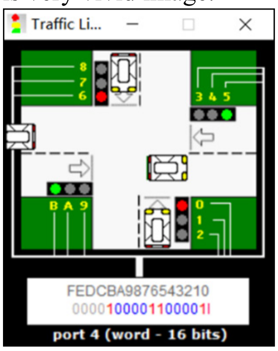


Fig. 1. Traffic lights system of EMU8086.

However, EMU8086 also suffers from a number of syntactic bugs that are less rigorous than CLAB and STAR, as shown in Table 1. These bugs should be avoided as much as possible when writing and debugging assembler source program using EMU8086. For example, the repeated definition of DUP (?) can be replaced by DUP (0). It should be noted that if we verify that a certain syntax is correct, we must use CLAB or STAR.

Although the virtual devices provided by EMU8086 can be used to carry out the design for some simple application systems, but it is far from being able to meet the course design and graduation design needs for the smart grid specialty practical teaching. It is necessary to choose an EDA software that can support 80x86, and Proteus software is a better choice [4]. Proteus is not only an EDA software, but also supports 8086, 51 series, ARM, DSP and other microcontrollers, as well as peripheral components. It can also achieve hardware and software joint debugging of 8086 application system.

Table 1. Bugs in the EMU8086

No.	Bugs
1	Data definition initial value indefinite symbol “?” is not supported.
2	Pseudo instructions “ORG” and “LABLE” are not supported.
3	Arithmetic operators “/”, “MOD”, “SHL” and “SHR” are not supported or cannot be very well supported.
4	Logical operators “AND”, “OR”, “XOR” and “NOT” are not supported.
5	Relation operators “EQ”, “NE”, “LT”, “GT”, “LE” and “GE” are not supported.
6	Value return operators “TYPE”, “SIZE” and “LENGTH” are not supported.
7	Property modification operator “THIS” is not supported.
8	Byte separation operators “HIGH” and “LOW” are not supported.
9	Instruction “PUSH src” can push an immediate into the stack

Figure 2 shows a typical hardware simulation experimental platform from the 8086 demo board of Proteus, containing 8086 MPU, programmable I/O interface chip 8255A, programmable timer/counter 8253A, programmable serial interface chip 8251A and other peripheral components. The simulation platform has a certain degree of universality and a more suitable platform can be gotten after a little modification. The executable file (.exe or .com) generated by either visual assembler and debugging software (such as CLAB) is embedded in the 8086 module, and software and hardware joint simulation debugging can be carried out.

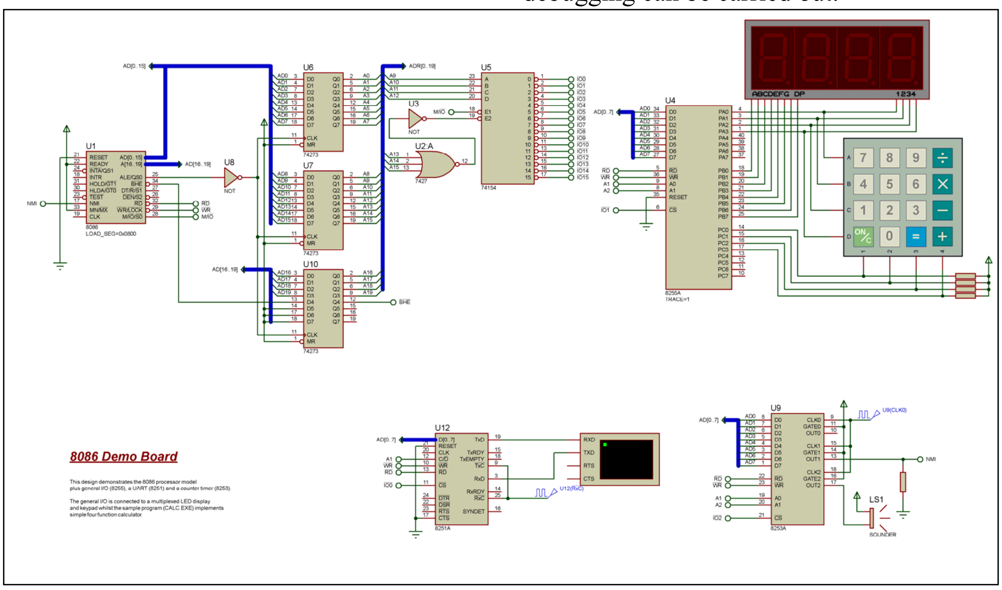


Fig. 2. An 8086 hardware simulation experimental platform (Proteus Demo Board).

The virtual laboratory can carry out the course experiment and course design based on 80x86, and some graduation design issues. Even if students synchronize online learning at home due to the epidemic, they can complete the task successfully.

3. Topic Selection of course design and graduation design based on the virtual laboratory

As stipulated in the syllabus, there are six in-class experiments in the course of "Microcomputer Principle and Application". They are respectively,

(1) Introduction to Debug,
(2) Observation of 8086 instructions,
(3) Sequential structure programming,
(4) Branching structure programming,
(5) Loop structure programming,
(6) Subprogram design.

These experiments are all basic skill training for program reading and programming, and the topic selection should focus on the commonly-used functions in the programming field of smart grid technology, such as table look-up, BCD code number display, seeking the maximum and minimum number, bubble method sorting and so on. Experiment is a pure software debugging, so it can be done using either of CLAB, STAR or EMU8086 software. However, it should be noted that STAR uses a fast assembler TASM, and CLAB and EMU8086 use the macro-assembler MASM, so in the preparation of the assembler source program, the characteristics of MASM and TASM should be taken into account.

The selected topics of course design and graduation design using the microcomputer principle virtual laboratory should be combined with the specialized characteristics of smart grid, and it is not recommended to adopt the traffic lights system as a general design topic. In the teaching designs, intelligent electricity technology can be selected as a direction of the topics, such as intelligent socket design, etc., and smart grid protection and control technology can also be selected as a direction, such as three-stage current protection design, low-voltage load-shedding design, etc. Analogously, smart distribution network monitoring technology is also a better topic selection direction, such as remote terminal unit (RTU) design, etc. The reference range of selected topics is shown in Table 2.

The above topics combine the specialized basic course "Microcomputer Principle and Application" and the specialized courses of smart grid, which can broaden students' engineering cognition of building strong smart grid and new power system, and can enhance their ability of hardware and software system design. In addition, there are various realization options for software program and hardware design of a specific topic, which is an open design. Each student can try to realize their own different ideas, which can help to cultivate students' autonomous and research learning abilities, and improve their practical innovation ability.

Table 2. Course design/graduation design reference topic selection based on the virtual laboratory

Technical direction	**Intelligent electricity technology**	**Smart grid protection and control technology**	**Smart distribution network monitoring technology**
Reference point 1	Smart socket design	Three-stage current protection design	Remote terminal unit RTU design
Reference point 2	Smart meter design	Overload protection design	Feeder terminal unit FTU design
Reference point 3	Electric vehicle DC charging post design	Load-shedding design [6]	Distribution transformer monitoring terminal TTU design

4.Design case of the virtual laboratory

Now, a course design case of microcomputer principle virtual laboratory titled "Definite-time limit over-current relay protection design" is introduced. Definite-time limit over-current protection is a basic knowledge point that must be mastered in the course "Power System Relay Protection" of smart grid specialty, and it is the third section protection in the stage current protection. The design is a typical case of using microcomputer principle and interface technology to solve the actual problem of relay protection engineering in the process of smart grid operation, which requires the application of relay protection principle (including action signals and alarm signals), A/D conversion and data acquisition technology, 8086 assembler language programming methodology, programmable interface chip and peripheral components application and other related knowledge and technology. The design involves software and hardware application system development of microcomputer device, computer simulation operation and other engineering concepts and methods.

Figure 3 shows the software flowchart of the definite-time limit over-current protection design, including the main links such as A/D sampling, comparison of the sampled value and the protection set value, protection start-up, protection timing and protection tripping.

Figure 4 gives the simulation debugging effects. When the measured value is less than the set value, the relay does not act. Once the measured value is greater than the set value, the protection starts. As soon as the definite time arrives, relay acts and motor works, and LED-red is on, LED-green is off. Simultaneously, buzzer alarms continuously. The above behaviors all simulate the protection action and tripping operation.

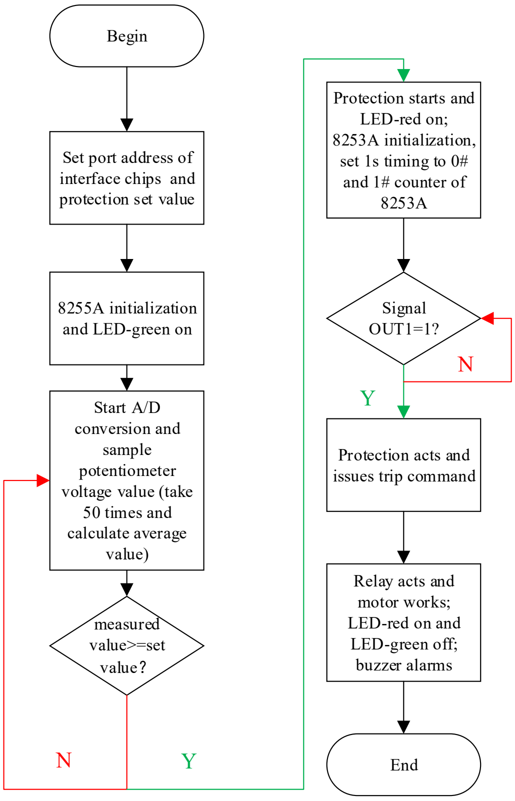
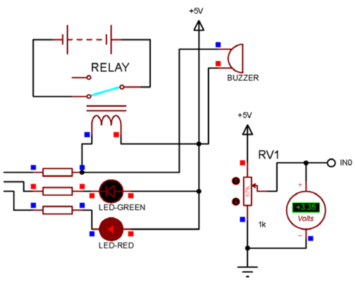
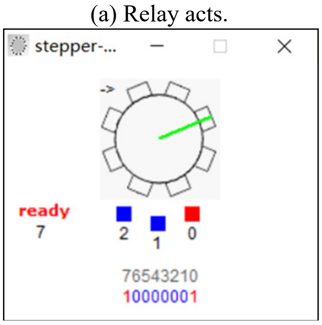


Fig. 3. Software flowchart.



(a) Relay acts.



(b) Motor works.

Fig. 4. Debugging effects.

The design case simulates the teaching of actual engineering problems in smart grid operation, and the course of students' psychology and behaviour in the experiment can be summarised as follows: feeling complexity - scheme thinking - programming modelling - debugging successfully - obtaining results - getting a sense of achievement. Practical innovation ability has been cultivated and enhanced unconsciously.

The design scheme of this case can also be used as a reference for other types of relay protection design, such as the design of a new-type overload protection.

5.Conclusion

The work of building microcomputer principle virtual laboratory for the specialty practical teaching of smart grid information engineering is interesting and beneficial, and the virtual laboratory can be practically applied in the online course teaching such as "Microcomputer Principle and Application" and "Computer Interface Technology". It can also be applied in the teaching of specialized courses such as "Power System Relay Protection", "Substation Monitoring Technology", and so on. In the graduation design of undergraduate and the project training of graduate student, the virtual laboratory can play an important role too.

The construction of the microcomputer principle virtual laboratory focuses on specialization and openness to broaden students' eye shot and cultivate their comprehensive quality, which is conducive to the development of "Theory and Practice Integration" teaching, and is significance to the cultivation of compound engineering talents for smart grid industry.

Acknowledgments

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