Teaching Reform of Microcontroller Unit Based on Experiment

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***Abstract*—"Principle and Application of Microcontroller Unit" is the core course in Circuits and Systems. Microcontroller Unit is widely used in industrial production. Students with basic design ability of MCU system will have good prospects. The teaching of MCU is mainly based on two simulation softwares, Proteus and Keil. They are very helpful in teaching MCU, but the shortcomings are obvious. The simulation can only test the functionality of the circuit and the correctness of the program, and cannot verify the reliability and practicability of the designed system. This paper proposes an experiment-based MCU teaching method, which combines theory with practice to improve students' practical ability and comprehensive ability.**

***Index Terms*—MCU, Experiment-based Teaching Method, Practical Ability, Comprehensive Ability**

I. Introduction

With the rapid development of integrated circuit technology and microelectronics technology, the application of microcontroller technology has penetrated into all aspects of life. As a branch of microprocessor, microcontroller unit has become one of the most important tools in modern electronic systems. In cutting-edge technology and modern industry, such as military, communications, energy, robots, transportation and IT, they are inseparable from the MCU. Therefore, the "Principle and Application of Microcontroller Unit" course has a special status in Circuits and Systems and other professional teaching programs of colleges and universities[1]. The application of MCU is very extensive, so learning how to use MCU is very helpful for the employment of students. The traditional MCU course teaching in universities has fallen behind the times in both content and teaching methods. This paper proposes a new teaching method to improve the shortcomings of traditional MCU teaching methods, that is, teaching the principle and application of MCU on the basis of experiments. The teaching steps of the proposed teaching method are shown in Fig. 1. In order to achieve good teaching results, teachers must teach students in accordance with their aptitude, creatively choose the best teaching methods and approaches to train students[2], [3]. Compared with traditional teaching, the new teaching method pays more attention to practice, so that the quality of teaching can be greatly improved.

II. Teaching theoretical knowledge

Before learning MCU, students must first learn the basic theoretical knowledge, which includes digital circuit, analog circuit and C language. Analog and digital circuit are the foundation of electronics. Solid knowledge of analog circuit and digital circuit will greatly improve the efficiency of learning MCU. MCU belongs to digital circuit, if students master the basic knowledge of digital circuit, they can easily understand the hardware structure and principle of MCU, can lay a solid foundation for the study of microcontroller, students' learning confidence will gradually build up. On the contrary, if the foundation is not solid, the more students learn, the more question they will have.

Analog circuit is the most basic subject of electronic technology. Learning analog circuits is to understand the working principle of the basic components of the circuit and how to analyze the circuit. The knowledge of analog circuit is not only applied in circuits and systems specialty, but also in other electronic technology specialty. It's the basic knowledge that the students of circuits and systems specialty must master.

C language is a general computer programming language, which is widely used in the development. C language is the foundation of MCU programming. Learning C language well lays a solid foundation for learning MCU. At present, most MCU teaching materials are based on assembly language, because assembly language has the advantages of compact code, short execution time, timely control and it is easy to remember, teachers also spend a lot of class time on assembly language, and C language is rarely mentioned[4]. However, in practical application, the programming of MCU mostly uses C language[5]. Compared with assembly language, C language has obvious advantages in function, structure, readability and maintainability, and C language has rich function library, which can effectively reduce the programming workload,

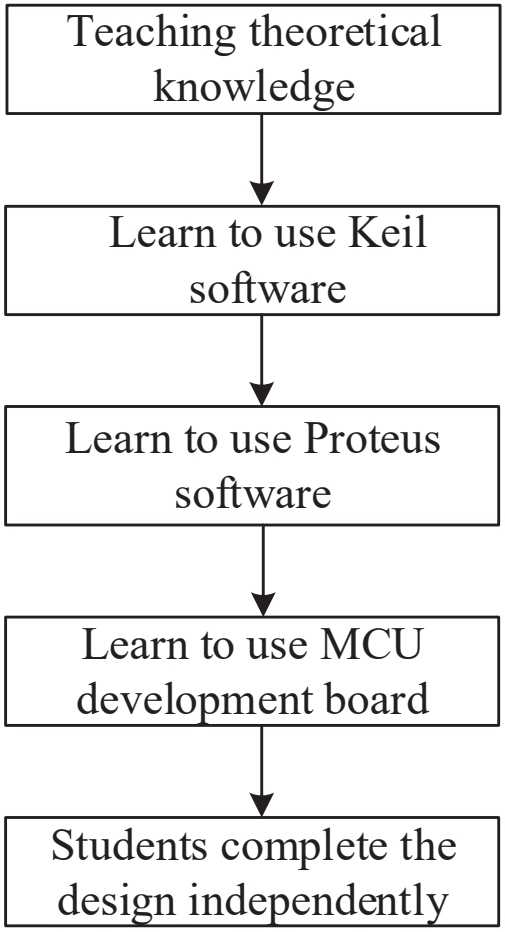

Fig. 1. The teaching steps of the course

especially the register allocation and addressing methods of C language are automatically completed by the compiler system. Using C language to program MCU will greatly improve work efficiency and shorten the project development cycle, so a lot of company's products are basically using C language to develop[6], [7].

Proteus simulation software is a simulation system which contains a large number of system resources and rich hardware interface circuit. It has a powerful debugging function and a combination of software and hardware[8]. It plays an important role in the development of MCU application system. In class, teachers can use Proteus software to build the circuit of the experiment, and then load the program code into the simulation. During the running process of the simulation system, students can see the same execution effect as the actual circuit board, which makes the hardware and software design of the microcontroller easy to understand. Students not only learn the construction of the application circuit of MCU in class, but also learn the debugging process. In addition, the teacher explains the knowledge in detail, which undoubtedly makes the students strengthen the understanding of knowledge and the perceptual understanding of the application, at the same time, they are familiar with the process of the debugging program of simulation software[9]. Fig. 2 shows an example of Proteus simulation, which is a simulation of 16X16 dot matrix display. From the figure, we can see clearly the composition of the hardware circuit. After loading the compiled program into the circuit, it can be clearly seen that the 16X16 dot matrix display will dynamically display Chinese characters through the parallel port P1-P3 of MCU. Through this example, students can visually and intuitively see the process of the microcontroller controlling the operation of the peripheral through the interface circuit.

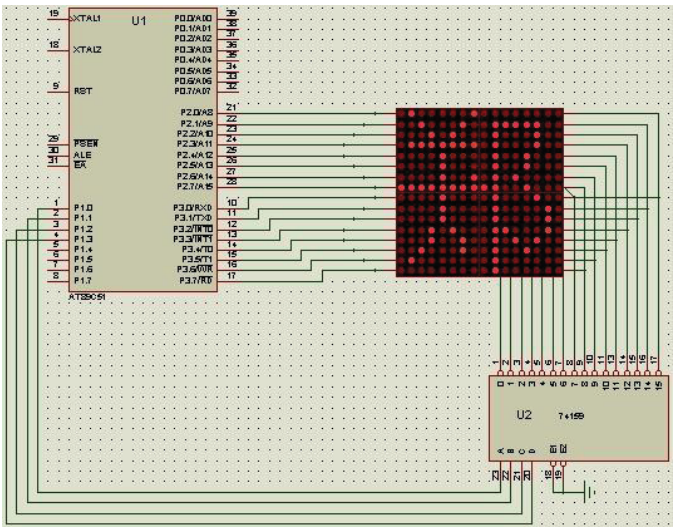

Fig. 2. Simulation of 16X16 dot matrix display

KEIL is the most commonly used software in MCU application development. It supports assembly, C language, and mixed programming. It combines editing, compiling, and simulation functions with powerful software debugging functions. Keil software and Proteus software can realize the joint simulation of software and hardware. KEIL can download the compiled program to the MCU development board, and then you can observe whether the development board works according to the programming.

The hardware of the MCU development board. The teaching method proposed in this paper is based on experiments. Students are required to complete various MCU design experiments, these experiments are all completed on a STM32 MCU development board, so students should first know the hardware of the development board, such as what kind of MCU is used, the circuit diagram of the development board, what resources are integrated in the development board and so on. After the class begins, the teacher will provide a document with these information to the students, and students can check them whenever they have problems.

III. Teaching how to use MCU based on experiments

This paper presents a new teaching method, which is based on practice and takes MCU experiment platform as a learning

platform. It breaks the original boundaries, regardless of the hardware structure, instructions, programming sequence, the knowledge of each part is decomposed into a knowledge point and merged into an example program. Teachers use assembly and C programming languages to provide reference source code, so that beginners can understand the programming style of the two languages, and also guide the students to learn the microcontroller with the learning materials of the microcontroller. Students can clearly understand the development process of MCU by completing the first experiment, and students are able to write their own programs after completing the second and third experiments. The learning process is a process of constantly completing experiments and realizing programming functions. When students complete all experiments, they naturally master the knowledge they need to acquire. Even if some students only complete some experiments, they will be able to do some design on their own. In fact, it is not necessary to learn all the knowledge to do development job, it can be said that this method is a shortcut to the development of MCU.

In the experiment, according to the principle of connection and hardware circuit, the teacher puts forward some questions, not just the questions in the experiment instruction book. This lets students have more thoughts and students can review the learning content in theoretical class. Students can deepen the impression and know the specific application of MCU. For example, the teacher puts forward some questions such as the function of an instruction in the program, the function of a chip, the function of a connecting wire and how the MCU controls it. At this time, even if the students are not very familiar with these problems, they pick up the textbook and browse again, the memory of knowledge is deepened.

IV. Improving students' ability through experiments

After the teacher introduces the software and hardware, the code of the experimental program is provided to the students with detailed notes and explanations, so that the students can quickly understand the meaning of each function. The experiments cover most of the resources of the experimental development board. Here are a few experiments to illustrate how to improve students' abilities to use MCU through experiments.

The first experiment is a MCU LED experiment, as shown in Fig. 3. The experiment required students to program the LEDs on the microcontroller development board to flash alternately. Through this experiment, students can master the circuit diagram and know the resources of the microcontroller and the I/O port assignment, and initially grasp the initialization function of the MCU, the I/O port enable function, the input level read function, the output level read function and output level set function. It helps students open the door to the world of microcontrollers.

The second experiment is the clock system experiment of MCU. Through this experiment, students can understand the clock system of MCU and learn how to use the clock system.

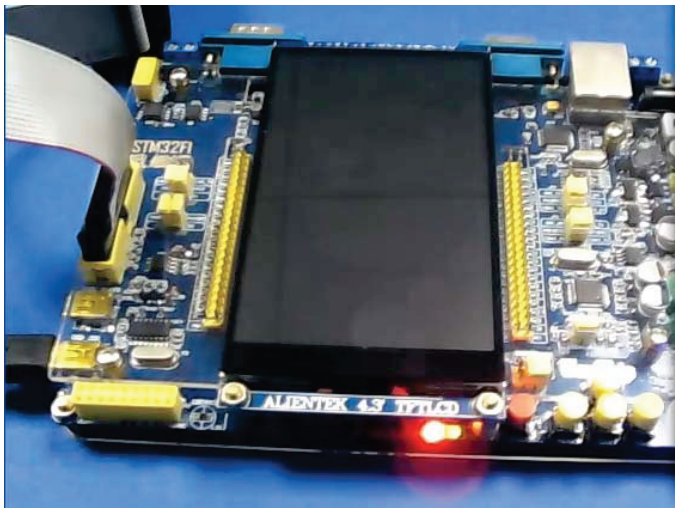

Fig. 3. MCU LED experiment

The third experiment is the interruption priority management experiment of MCU. Through this experiment, students can understand the concept of interruption and learn to set interruption channel of MCU, learn to use interruption initialization function, interruption enable function, interruption priority grouping function and set interrupt priority.

The fourth experiment is the experiment of MCU serial communication. The MCU receives the information sent by the host computer through the dialogue between the serial port and the host computer and then sends the information to the host computer without error. Through this experiment, students will master the basic principles of MCU serial communication.

Experiment 5 is a PWM experiment. Students are required to master the configuration of the PWM register of the MCU. The PWM function of the timer 3 of STM32 MCU is used to output the PWM wave with variable duty cycle which is used to drive the LED lamp, so that the brightness of the LED will change from dark to light, and then from light to dark.

Experiment 6 is the input capture experiment. Students are required to complete the input signal capture with the channel of the timer of the MCU, capture the pulse width of the high-level signal on the channel, and then output the time and frequency of the high-level pulse width through the serial port.

Experiment 7 is the ADC experiment. Students are required to master the basic principles of ADC and know how to use the ADC function of STM32 MCU. Experiments require students to use STM32's ADC channel to sample external signals and display them on LCD.

In addition, there are many experiments step by step to guide students to learn MCU. Through these experiments, students gradually master the knowledge of MCU and can run their own code on the experiment board. The quality of teaching has been greatly improved.

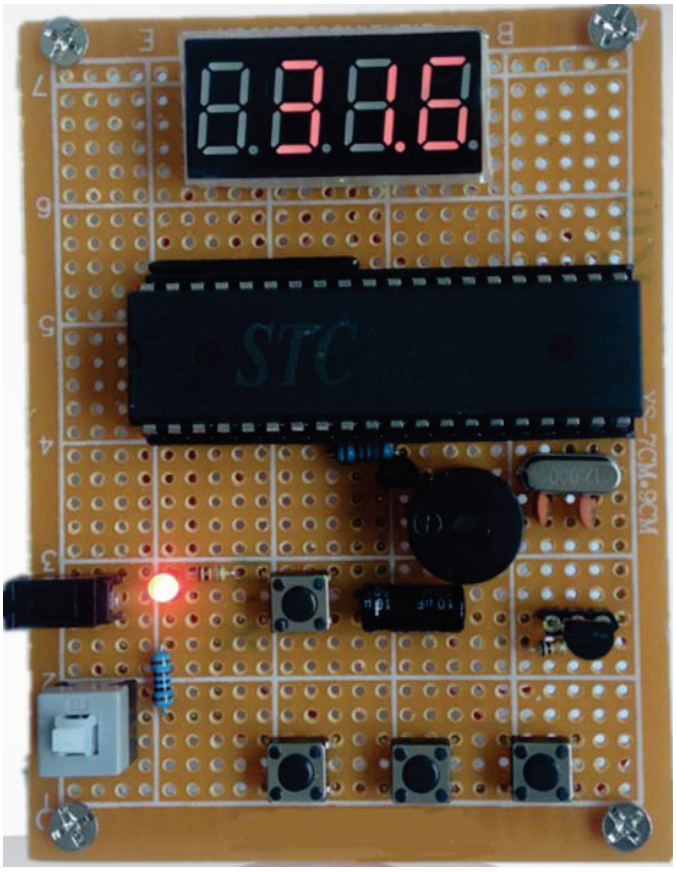

Fig. 4. Digital thermometer based on MCU

V. Improving students' design abilities by modifying experiments

Most of the above-mentioned MCU experiments are carried out by students according to the experimental instructions. In the experimental process, students are in a passive acceptance of experimental learning and operation, and the experimental results are not satisfactory[3], [10], [11]. Therefore, students trained in this way do not know how to design the system, derailed from the actual application, let alone the further development of the system[10]. In order to prevent students from copying the program according to the textbook, some key sentences (one or more lines) can be deleted from the program of the instructions for validation experiments, but the annotations are added so that students can complete the program. Students must understand the program before they can know how to add the missing sentences. If the instructions can not be deleted, the students will be asked to do some experiments by analogy. For example, after students complete the LED experiment, students are required to change the flashing time of LED or teachers will ask students to independently complete the buzzer experiment according to the LED experiment. Through these modificaitons, if students can complete the experiment, they basically master the principles of this experiment.

At the end of the course, students are examined with a comprehensive MCU design, such as a digital thermometer based on MCU, as shown in Fig. 4. This design is to integrate the teaching content of each chapter. The digital thermometer is made up of several independent modules. These modules correspond to the main knowledge points of MCU: keyboard control, LED display, serial communication, parallel communication, ADC converter, and timer. This design tests the comprehensive design ability of students. As shown in Fig. 5, students need to simulate in Proteus to verify the correctness of the program and circuit, and then build the actual circuit.

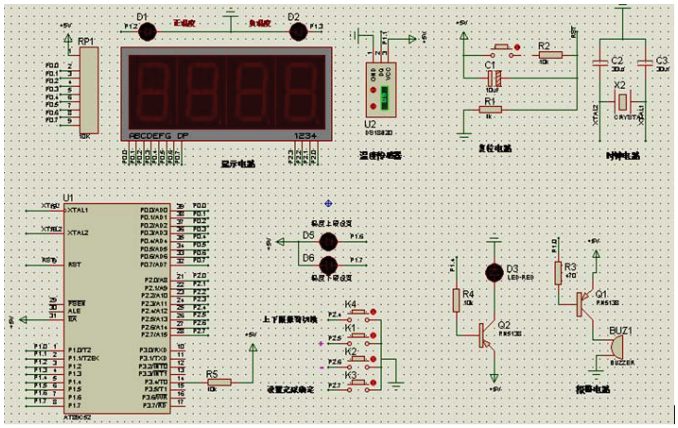

Fig. 5. Simulation in Proteus

VI. Conclusion

Through this experiment-based MCU teaching method, students' interest in the MCU has been improved, and their development ability has been significantly enhanced. The teaching method also trains students' practical ability, scientific research ability and innovation ability. Students are the biggest beneficiaries, it not only provides students with the opportunity of self-learning, self-development, practical training, but also greatly stimulates students' interest in learning.

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