

Research and Teaching Practice on Experiment Course of STM32-Embedded Microcontroller

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Abstract—The experiment course of STM32 embedded microcontroller is very comprehensive and practical. The traditional teaching method can no longer meet the requirements of the course, and it is not conducive to cultivating application-oriented and innovative talents. According to the features of STM32 embedded microcontroller experiment course, the authors set up a comprehensive experimental equipment platform to effectively carry out basic experiments, design experiments and comprehensive experiments. In this paper, several improved teaching methods are put forward, including the effective use of multimedia and network, the introduction of project-based teaching, and the improvement of assessment methods. Practices show that these measures improve the initiative of students' learning and effectively improve the quality of teaching.

Keywords—curriculum reform; practice teaching; project-based teaching; STM32-embedded microcontroller

I. INTRODUCTION

With the rapid development of social economy, the application products related to embed system are constantly being developed [1]. In these applications, the STM32 series products become the mainstream microcontroller products due to its high performance, low power consumption, low cost and many other advantages. STM32 series chips have been widely used in real-time control, handheld devices, motor drive and other fields [2]. There is a great demand for talents to master the application of STM32 embedded microcontroller. In order to keep up with the rapid development of technology, many colleges and universities in China transform the course of MCS-51 microcontroller which has been taught for nearly 30 years into the course of STM32 embedded microcontroller [3]. The embedded system has been listed as the core course in the CC2004 computer curriculum system developed by the IEEE Computer Association and ACM [4]. Practices in recent years have shown that STM32 embedded microcontroller course has a great role in promoting students to participate in various electronic design competitions and increasing their employment opportunities [5].

The STM32 embedded microcontroller course has a wide range of knowledge and practicality and pays more attention to engineering and application. If the traditional teaching method is still adopted and there are only a few experimental courses,

the teaching effect will certainly not be ideal. According to the features and teaching goals of experiment course of STM32 embedded microcontroller, the authors reformed the traditional teaching method in experimental teaching. Better teaching results have been obtained by improving teaching methods.

II. FEATURES OF STM32-EMBEDDED MICROCONTROLLER EXPERIMENT COURSE

Many colleges and universities in China selected MCS-51 series microcontroller for teaching 20 years ago. Due to low integration degree and simple peripheral circuit, the 51 series microcontrollers are easy to understand. However, the 51 series microcontroller has low performance, low on-chip resources, low development efficiency, and the code is not easy to reuse. Therefore, more and more colleges and universities have turn to STM32 embedded microcontroller, which is rich in resources and high in development efficiency [6]. However, the STM32 embedded microcontroller is very comprehensive, and it is impossible for students to fully grasp all the functions of STM32 by the time of the class alone. Through the experiment courses, students can master the general development process of STM32, which will lay the foundation for further learning about embedded system technology. In view of these, the teaching goals of the experiment course of STM32 embedded microcontroller developed by Institute of Electrical Engineering of Yanshan University are as follows:

- Based on the basic concept of electronics and embedded microcontroller, students can select the corresponding theory and analysis method, master the microcontroller hardware structure principle and applications.
- The standard C language and embedded microcontroller software design method can be used to establish the software flow of the embedded system and compile the corresponding software program.
- Be able to select the type of microcontroller reasonably for engineering application problems and carry out the scheme design of basic system circuit, program and other application.
- Be able to master the test and evaluation methods of embedded microcontroller application system, and have

the basic abilities of corresponding experimental scheme design, data collection, analysis and processing.

Through the study of this course, students are required to build an experimental platform of embedded system and master the software and hardware design methods. If students want to learn this course well, it is not enough to rely only on reading books. They must understand the relevant principles of embedded system technology thoroughly through a large number of experimental operations and specific application examples. Such high teaching goals also pose challenges to experimental teachers. How to make efficient use of the experimental platform, design experimental items reasonably, and improve the teaching methods to help students gradually master the development technology of the embedded system is the subject that the experimental teachers should study.

III. FORMATION OF EXPERIMENTAL EQUIPMENT PLATFORM

Many colleges and universities take laboratory boxes or embedded development boards provided by manufacturers as teaching equipment. Although these devices have powerful and complete on-board functions and abundant teaching resources, they expose some problems in experimental teaching. The first is the contradiction between rich teaching resources and limited teaching hours. The experiment course of STM32 embedded microcontroller taught by the authors only has 16 class hours. This limited time is not enough for students to master the development of STM32 embedded technology. Many functions of laboratory boxes provided by manufacturers can't be fully utilized in teaching process. For colleges and universities, this brings about the increase of equipment cost and the difficulty of students' use. Secondly, the teaching cases provided by development boards mainly focus on individual functions, and the connection between them is not obvious, which can't show the comprehensive processing ability of STM32 embedded microcontroller. In the teaching process of colleges and universities, facing the requirements of a large number of beginners' alternate use, development boards also exposed many maladaptive conditions.

In view of the above situation, the STM32 embedded microcontroller experimental course taught by the authors adopt the self-developed experiment board [7] and self-developed experiment box as the equipment platform of the overall experiment course. With STM32F103ZCT6 as the core, the self-developed experiment board adopts modular building block structure, including LED, button, buzzer, serial port, I²C interface and other parts. It supports JTAG/JLINK debugging and meets needs of the basic experimental teaching of embedded system. The board was welded by the students themselves in the previous EDA course, and each student had one board to avoid damage caused by cross-use. The experiment board is easy to carry and can be used by students in their spare time. In experiment class, students mainly use self-developed experiment box. The self-developed experiment box is compatible with the self-developed experiment board, with richer functions and some protective designs, which is easy to maintain and manage. The components and function modules used in the experiment box are in compliance with the general standard. If it is damaged during the experiment, it is only necessary to replace the damaged module or component,

which will not cost too much maintenance cost and time. The experiment can be guaranteed to proceed normally. If students do not finish the experiment on time when they encounter problems in the class experiment, they can use the self-developed experiment board to continue their study in their spare time. This experimental platform can help students overcome the bad influence of putting more emphasis on theory than on practice and greatly improve their practical ability.

IV. EXPERIMENT CONTENT

According to the teaching goals of experiment course, the authors designed three kinds of experiment items in the course of practical experimental teaching, namely, basic experiments, design experiments and comprehensive experiments.

A. Basic Experiments

The basic experiments include two experiments. One is STM32 project establishment and GPIO control LED flashing, and the other is external interruption experiment.

1) *STM32 project establishment and GPIO control LED flashing*: Students are required to complete the experiment in two class hours, which is very tight. Therefore, students are required to preview before class and set up STM32 project on their own computers according to the steps in the experimental instruction. In the experiment class, students add library functions, write source code, and create object files in the project that have been built.

2) *External interruption experiment*: Students are required to review the external interrupt of STM32 embedded microcontroller before the experiment. Through the experiment, they should master the programming method of the interrupt configuration and realize the control of LED light on and off with key.

B. Design Experiments

The design experiments include four experiments, which timers are timing at any time, USART serial communication, DMA reading on-chip flash, and ADC voltage acquisition.

1) *Timer timing at any time*: STM32 universal timer is used for accurate timing to control LED on and off. Students are required to preview STM32 universal timer before class. Through the experiment, they should master the working mode of the timer and the configuration of the timing constant, and write the program to realize the LED light to turn off in seconds.

2) *USART serial communication*: The communication between the serial port of computer and the USART of STM32 is realized. The computer sends characters to the serial port of STM32 through the keyboard. STM32 transmits the received characters back to the computer, and displays the results through the serial port debugging assistant on the computer. Students are required to preview the STM32 universal synchronous/asynchronous transceiver USART prior to the experiment. Through the experiment, they should

master the serial communication function and usage of USART, master the design and code writing of the corresponding program of STM32.

3) *DMA reading on-chip flash*: The contents of the 32-bit data buffer in the processor's on-chip Flash are transferred to the buffer defined in the RAM using the DMA channel. Students are required to preview the DMA of STM32 before the experiment. Through the experiment, they should master the DMA setting and DMA interrupt.

4) *ADC voltage acquisition*: The voltage on the potentiometer is collected by ADC of STM32, and the collected results are sent to the computer through USART. The collected results are observed by serial debugging assistant. Students are required to preview the ADC of STM32 before the experiment. Through the experiment, they should master the use method of ADC on chip, and realize the collection and transmission of voltage signal.

C. *Comprehensive Experiments*

Completing the basic experiments and design experiments of prescriptive topic, students have mastered the basic development method of STM32, but they can't link various experimental items organically, and the knowledge is not systematic. The design of practical equipment through the comprehensive experiments can't only strengthen the students' knowledge of circuit design and program design, but also arouse the students' enthusiasm of learning and cultivate their innovation ability.

The comprehensive experiments require students to design a practical device by completing the circuit design and program design of STM32 embedded system. The teachers will no longer specify the topic. Students consult relevant materials according to the basic knowledge they have learned and complete the project independently. When the project completed, students record the results of the project by video and prepare PPT for defense. The teachers will check and assess the experimental results.

In the course of comprehensive experiment, the teacher will not assign topics, and students will consult relevant materials and complete the project independently according to the basic knowledge they have learned. Students can consult teachers when they encounter problems in the design process. The comprehensive experiment mainly relies on students to make the initial design with the experiment board before class. In laboratory experiments, experiments designed by the experiment board can be transplanted to the experiment box to make better effects. Students record the results of the comprehensive experiment by video and prepare PPT for defense. The teacher will check and accept the experimental results.

V. TEACHING METHODS AND ASSESSMENT METHODS

A. *Making full use of multimedia and network for teaching*

STM32 embedded microcontroller experiment course is a course that integrates many kinds of technologies. The traditional teaching method can't achieve the teaching goal.

Therefore, in the process of teaching, the authors make full use of multimedia and network to improve teaching efficiency and get satisfactory teaching effect.

At the beginning of the whole course, various embedded devices developed based on STM32 can be demonstrated by video, and the application products can also be given to the students for personal operation experience to guide the students to have a strong interest in learning. At the beginning of the course of basic experiments and design experiments, the video related to circuit interface and program design is played. The teacher prompts and analyzes the key content in the video playing process, so that students can make clear the experiment process and experiment objectives. During the defense of comprehensive experiments, each group of students plays the recorded project result video, which is helpful for the teacher to evaluate the project completion and promote the communication between students.

The STM32 embedded microcontroller experiment course require various forms of teaching materials, including video, software, documents and other forms of materials to meet different needs of students in the learning process. The Xue Xi Tong (XXT) network teaching tool is applied to the teaching of experimental course. The teacher distributes a variety of learning materials through XXT. Students can ask questions online and teachers can answer questions online. Students can exchange learning experience and share learning experience to improve learning efficiency.

B. *Introducing the project-based teaching method*

The project-based teaching method is a new teaching mode, which is based on theoretical knowledge, project-centered, student-oriented and teacher-centered [8]. This method decomposes the contents of the course into several small projects. In the teaching process, students are the main part and teachers are the auxiliary part, so as to train students' practical ability and ability to transform knowledge into skills.

In the STM32 embedded microcontroller experiment course, debugging is an essential part of teaching. For beginners, there will inevitably be a variety of mistakes in the process of the experiment, and they must be modified repeatedly to meet the requirements of the experiment. Students need a lot of practice time to explore and summarize more effective debugging methods. In the course of teaching, the authors pay attention to allowing students to carry out their own design and development so as to improve students' problem-solving ability. Teachers only give guidance, suggestions and evaluation in the process of students' design practice.

C. *Setting different teaching objectives according to students' aptitude*

For students with poor foundation and failing to complete the experiment in class, they should be urged to use the experiment board to complete the experiment after class and be checked in the next experiment class. For students who have the ability to learn more, some extended learning tasks are arranged in each class, so that students can learn the required knowledge by themselves through different learning tasks. Students can discuss with teachers about problems they

encountered in the process of learning through XXT. Students change from passive learning to active learning, and their learning efficiency and interest are improved.

There are two common ways to develop STM32 series microprocessors, which are library functions and register oriented programming. For students who have spare efforts, they can use register oriented programming mode to directly operate Cortex-M3 kernel, and learn embedded development technology from a deeper level. For students with poor foundation, they can use library function programming without knowing the working mechanism of STM32 kernel in detail.

D. Improving assessment methods

In the process of STM32 embedded microcontroller experiment course, the authors adopt the whole process assessment method. The assessment contents mainly include the following aspects:

- The situation of the preview experiment, accounting for 20%. Students are required to preview relevant theory before class to ensure that they are familiar with them during the experiment.
- Experimental operation performance, accounting for 40%. Students are required to upload their project situation to XXT immediately when they complete the prescribed project, including hardware photos and functional realization photos, so that teachers can better grasp the progress of students' learning.
- The situation of extended projects, accounting for 20%. Students are required to upload the extended projects they completed to XXT. The teachers give scores of this part by students' answering question performance.
- The quality of the experimental report, accounting for 20%. It mainly examines the structural clarity of students' writing experiment reports, the correctness and completeness of their contents.

VI. CONCLUSION

Due to the wide application of embedded systems in various fields and the strong demand for embedded talents in the market, universities in China have successively opened embedded microcontroller courses. The contents of STM32 embedded microcontroller course have a wide range, from

software programming to hardware design. Only traditional teaching method can't achieve the teaching goal. According to the features of the STM32 embedded microcontroller experiment course, the authors set up the STM32 experimental equipment platform which combines the self-developed experiment board and the self-developed experiment box, so as to making full use of the students' time in and out of class. In the process of teaching, three kinds of experimental items are designed to guide students mastering embedded system knowledge in experimental practice, namely basic experiments, design experiments and comprehensive experiments. In the experiment course, the authors adopted a variety of teaching methods and improved the course assessment method. Through learning of this experiment course, students' development ability of embedded system has been cultivated and improved.

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