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VEPES：A Virtual Experimental Platform for Embedded System Course

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Abstract. In view of the problems in the traditional experimental teaching of the embedded system course, the experimental equipment is few, the experimental mode is boring, and the time and space are limited, the Proteus and IAR development tools are used to design a set of virtual experiment platform based on the ARM7 kernel. The platform is divided into 2 levels of the basic experimental module and the comprehensive experimental module. Take the project of pulse width modulation (PWM) waveform control and driving as an example, the design process of the platform is introduced in detail, including the requirements of the experiment, the hardware design, the software design and the joint debugging. Finally, the teaching effect of the experimental platform is analyzed by fuzzy comprehensive evaluation theory. The result shows that the overall evaluation level of teaching is excellent. The evaluation results verify the practicability of the platform.

1. Introduction

The embedded system is a kind of dedicated computer system. It is related to the detailed application requirements of advanced computer, controlling, electronic technology and other industry. The main hardware of the embedded system is the ARM micro-controller unit, which is designed by the Advanced RISC Machines (ARM) Company. This kind of embedded micro-controller unit, such as ARM 7, ARM 9, ARM 11, etc., has been promoting a series of emerging technologies, like internet of things, artificial intelligence, mobile communication and portable medical treatment, developing rapidly [1,2]. By working with Linux, Android and WinCE operating systems, it can meet all kinds of strict requirements including functions, reliability, costs, size and power waste of products from all professions and trades. With the continuous expansion of the application of embedded system, the relative courses become more and more popular in many universities. However, due to the short developing time, there are still some problems in the procedure of running the embedded system courses, mainly including: (1) The experimental conditions are limited [3]. Generally, students don’t have enough practical opportunities because of lack of experimental equipment. In the civil universities, one experimental box is shared by 2-3 students. If the number of a class is more, teachers have to divide students in batches. Besides, in this kind of embedded system course based on the ready-made experimental box, students are mostly doing the verifying experiments without the direct experience in designing and developing embedded system. Their requirements of self-study are hardly satisfied. (2) Students' participation is low [4]. At present, teachers usually show the operating process at the beginning of class and students repeat the experiment passively according to the experimental manual. Even worse, some of them download the program which is finished by teachers into the experimental box in order to complete the task quickly. In the procedure above, students lack the link of analysis and thinking, so the effect of exercising the students’ practical ability is not good. (3) The experimental operation is cumbersome [5]. The embedded system experiment usually needs to build a communicating development environment based on computer and experiment box. The preparation time is long and the operation is cumbersome. It increases the learning burden of students and affects the teaching effect.

In view of the problems above, this paper proposes a Virtual Experimental Platform of Embedded System course, VEPES. Using Proteus and IAR Embedded Workbench for ARM version as the development tools, with ARM7 series chip (LPC2138) as the control core, the VEPES makes students quickly grasp the basic knowledge and design method of embedded system development. The experimental design of VEPES is continuously from shallow to deep. Using computer simulation software to develop virtual experiment platform to solve the problems in experimental teaching has become a reality.

2. Design of the VEPES

The simulation software Proteus is very suitable for the design and development of ARM embedded system. Therefore, we chose Proteus as the main development platform, and the Philips' LPC2138 based on ARM7 TDMI-S core as the microcontroller chip. IAR Embedded Workbench for ARM version is used as software programming tool to realize code compilation, compilation and linking. Through simple configuration, the joint debugging of two software tools can be realized, and the debugging efficiency of the virtual experiment platform can be greatly improved. Combined with the teaching content of theoretical course, the virtual experimental platform, VEPES, includes two modules: basic experiment and comprehensive experiment.

2.1 Basic experimental module

The basic experimental module mainly focuses on the in-depth understanding and mastery of basic knowledge. Adhering to the principle of less and more refined, we designs 4 projects altogether, including: Minimum system design experiment, GPIO basic input / output experiment, interrupt control circuit experiment, UART configuration and data transmission experiment. All the programs are written by C language. The simulation circuit is shown in Figure 1.

(1) Minimum system design experiment. It mainly focuses on familiarity with the specific operation methods of virtual simulation software, so that students can master the link between simulation software Proteus and programming software IAR.

(2) GPIO basic input / output experiment. The port pin P0 is used as the output to drive a group of 8 bit LED light-emitting diodes to control the LED to be lit and extinguished to achieve multiple displays. The purpose of the experiment is to enable students to skillfully use the input / output function of the GPIO module, especially the port configuration method.

(3) Interrupt control circuit experiment. Timer 0 interrupt and external interrupt 0 are used to control each LED light emitting diode to change the status of LED to achieve the interrupt nesting. The external interrupt is triggered by an external key as input. The purpose of the experiment is to familiarize students with different interrupt types, interrupt priority, and grasp the basic programming method of interrupt nesting.

(4) UART configuration and data transmission experiment. For the standard serial interface, the P0.1 is multiplexed as the receiving port Rx0 of the serial interface, while the P0.0 is multiplexed as the sending port Tx0 of the serial interface. The virtual terminal of VEPES is taken as the console, which can receive and display the output data of the serial interface, and has the function of input data through keyboard. Through this experiment, students can master the configuration mode of standard serial interface and understand the influence of configuration parameters on data transmission process.

2.2 Comprehensive experimental module

After the students have mastered the basic knowledge of ARM embedded system development, the comprehensive experimental module can further expand the students' knowledge and strengthen the training of students' engineering practice ability. This module covers all the peripherals of the LPC2138 chip, including 8 experimental projects.

(1) Design of I2C interface circuit. The experiment is based on I2C interface to realize memory system design. The memory unit selects the memory chip 24C02C with I2C interface. P0.2 of the microcontroller is multiplexed to the I2C interface serial clock signal line SCL. P0.3 is used as a

serial data signal line SDA for I2C interface. The storage capacity of 24C02C is 256 bytes, which can store data such as boot password, network port number and so on.

(2) SPI circuit simulation. The experiment is based on the SPI interface for seven segments LED. The buffer chip 74HC595 with a 8 bit serial input and parallel output is used to drive a 8 bit seven segment LED. LPC2138 connects with 74HC595 through SH_CP interface, and multiplexes P0.4 as the clock signal of SPI interface. The port P0.6 is multiplexed as the data input signal DS of the SPI interface. P0.8 is used as the parallel output control switch ST_CP of the SPI. Students use the hardware SPI interface to output characters such as 0~F, displayed on the LED digital LED, so as to master the method of controlling LED digital LED display.

(3) Timer capture / comparison design. This experiment focuses on making students understand the comparison and capture function of timer. By connecting a virtual waveform generator, square wave signals with a variety of duty cycle are provided to the system. The time or frequency of the input square wave signal is measured by the capture function of the timer. In addition, the design connects a separate key and achieves the comparison function of the timer by counting the keys.

(4) Pulse width modulation (PWM) waveform control and drive design. The pulse width modulation (PWM) function of the microcontroller is used to design the output of the one PWM signal, and the port P0.7 is connected with a LED drive circuit. In addition, there is one separate key circuit connected to the key KEY1. During the experiment, the duty cycle of the PWM driving signal was adjusted by the buttons UP and DOWM. Different duty cycles will cause significant difference in LED's brightness. It is helpful for students to understand the function and function of PWM signal.

(5) A/D converter data acquisition. LPC2138's ADC has 4 data acquisition channels. The SPI interface is used to transmit the sampled data for display and the result is sent to the host computer through UART.

(6) Real time clock RTC design. The experiment uses the RTC clock of LPC2138 to realize the display of the calendar. The interrupt key is used to control the display state. It displays 5 states of the year, the date, the time, the second and the week in the array composed of 4 seven segments of digital LED. Use the key KEY1 to control the switch display status.

(7) Watchdog timer design. This experiment takes advantage of 4 pre-frequency divider and 32 bit counter in LPC2138. The clock enters the timer through the preset frequency division, and the timer uses the decrement counting to realize feeding the dog. The clock signal enters the timer through the preset frequency division, and the timer uses the decrement counting to realize feeding the watchdog.

(8) LCD display character design. This experiment mainly focuses on the use of LPC2138 to control dot-matrix LCD screen. This experiment, of which the content is the P0 port to the LCD screen output characters, enable students to master the LCD screen initialization, display text, check the bus busy state and other programming methods.

2.3 Design of software platform

The software development adopts IAR Embedded Workbench for ARM version and Proteus 7.8, which has fast compilation speed and high efficiency. The user interface is friendly, easy to use and debug, with strong simulation functions. Proteus 7.8 is used to design the hardware circuit. Proteus can simulate and analyze various analog circuits and integrated circuits. It has rich component resources and circuit test signal sources, and has the function of collaborative simulation of single chip microcomputer. IAR is used as a software programming tool, because its source code editor is very powerful, and can be written, compiled and connected to support the source code of the advanced C language. The above two software Proteus and IAR can be set up to achieve joint debugging, which will greatly improve the efficiency of software and hardware debugging of the virtual experiment platform.

3. Summary

In conclusion, by using the Proteus and IAR development tools, a virtual experiment platform of embedded system based on ARM7 kernel is designed through virtual simulation technology. The platform is divided into 2 levels: basic experimental module and comprehensive experimental module. Thanks to the VEPES, the knowledge point coverage is comprehensive, installation is convenient and fast, time and space are not limited, it can be well applied to the teaching of embedded system. In addition, the teaching effect of the experimental platform is analyzed by fuzzy comprehensive evaluation theory. Practice shows that the platform can help students understand the knowledge of ARM embedded system and improve students' practical ability and learning enthusiasm when it is applied to teaching. The students' overall evaluation of the platform is excellent, and the evaluation results verify the practicability of the platform. In this paper, the research and construction of the virtual experiment platform of embedded system can also provide some reference for the construction of other virtual laboratory of electronic courses.

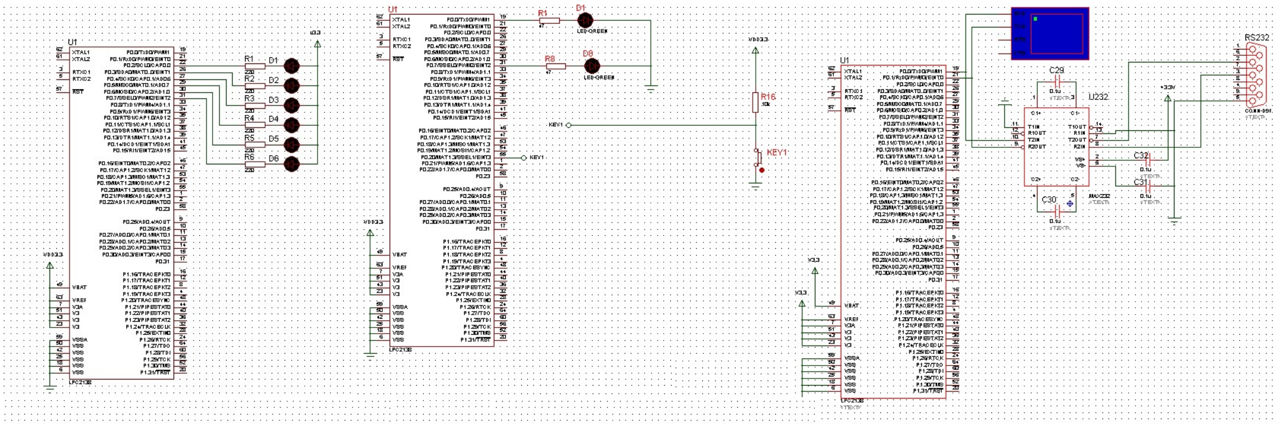

Fig. 1. Simulation circuit of VEPES: GPIO, Interrupt control, UART (From left to Right)

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