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The Development and Application of Hierarchical Experimenting Platform for Embedded System Course

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Abstract

There are many disadvantages existing in the current experimenting platforms for embedded system course. Therefore, this paper has devised a hierarchical experimenting platform based on the CDIO education mode to improve both the teaching and learning experience. The experimenting platform devised in this paper is composed of a motherboard and several microprocessor plug-in boards. The motherboard can meet with various experimenting requirements by changing different plug-in boards. The demonstration source code is plug-in board independent, so the source code can be shared by different plug-in boards. The teaching practical shows that, this hierarchical experimenting platform can significantly improve the teaching and learning experience.

Keywords: *Experimenting Platform; Modularize; Embedded System Course*

1. Introduction

Nowadays, embedded systems can be found anywhere, such as smart phone, iPod, automobile, flash disk, and even the space aircraft. So more and more universities and colleges have set up the embedded system course to meet the great demand for embedded system technicians [1]. However, the teaching and learning experience of the embedded system course are not as desirable as expected. The reason deeply rooted in such a shortcoming is the inflexibility of experimenting platforms. Usually, the hardware and function of the experimenting platform is fixed forever when it is manufactured. As a consequence, it becomes impossible to perform re-development on the experimenting platform. In other words, the existing experimenting platform is demonstrative but not creative. Even the students who have learned about single-chip microcomputers will still feel tough to learn about embedded systems.

Fortunately, the CDIO engineering education mode (known as Conceive, Design, Implement and Operate) [2-5] makes the frustrating situation a big change. By introducing the CDIO education mode into the hierarchical experimenting platform, students can design their own experiment from original conception to final implementation. During designing process, students can learn about many details about embedded system, instead of running demonstration code and seeing what happened, thus, both the learning and teaching experience will be dramatically enhanced. What's more the hierarchical experimenting platform can help students grasp the knowledge of embedded system as soon as possible, based on their knowledge of single-chip microcomputer.

2. The Hardware Design

The hierarchical teaching platform is composed of a motherboard and several microprocessor plug-in boards (it will be called as plug-in board in later chapters).

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The platform hardware adopts multiple core board fit common functions to expand the double-layer structure design idea of floor of the upper as the core board motherboard and the several microprocessor plug-in board. The motherboard supplies some basic hardware resources such as keyboard, LCD, LEDs, speaker and so on. The plug-in boards are equipped with different microprocessors, such as MSC51 series microprocessors, and LPC2103 embedded processor. In use process, the bottom plate (means motherboard) are fixed by simply pull out plug to change different upper core board makes its respectively as entry-level microcontroller embedded courses platform or a high level of using embedded learning platform, forming hierarchical open structure as a whole. The completely beginners without any knowledge about single-chip microcomputers and embedded system can start with the single-chip microcomputers plug-in board (such as MSC51, STM32) to learn some basic knowledge of microprocessors, and then, continue with the embedded microprocessor plug-in boards (such as LPC2103). The novices of embedded system can directly start with the embedded microprocessor to explore in the world of embedded system. And this is where the "hierarchical" lies in.

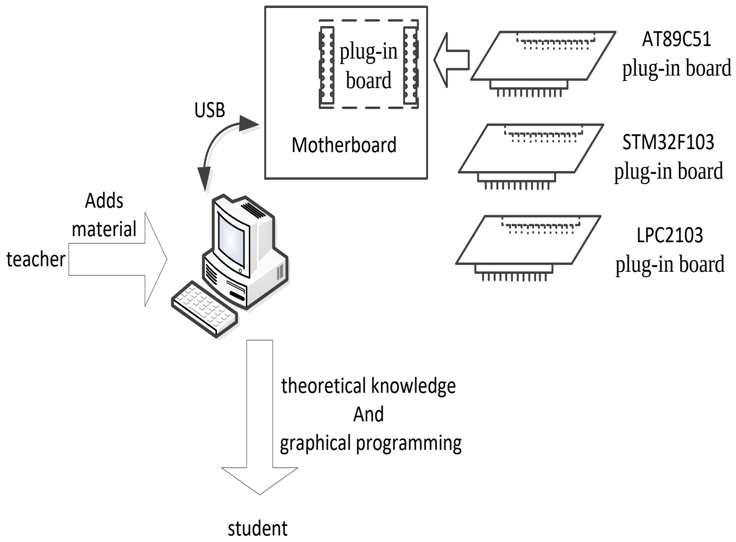

Figure 1. Hierarchical Learning Platform for Embedded Curriculum Model Diagram

The motherboard together with the plug-in board (also called "target board"). The target board is connected to standard PC through an USB cable to download, run or debug programs. And all the PCs are connected to a server that stores applicable documentations, slideshows, source code packages and software toolkits for the target board. Teachers can manage all the files on the server , while students can only download files from the server. The Figure 1, shows the principal of the hierarchical experimenting platform.

2.1. The Plug-in Board Design

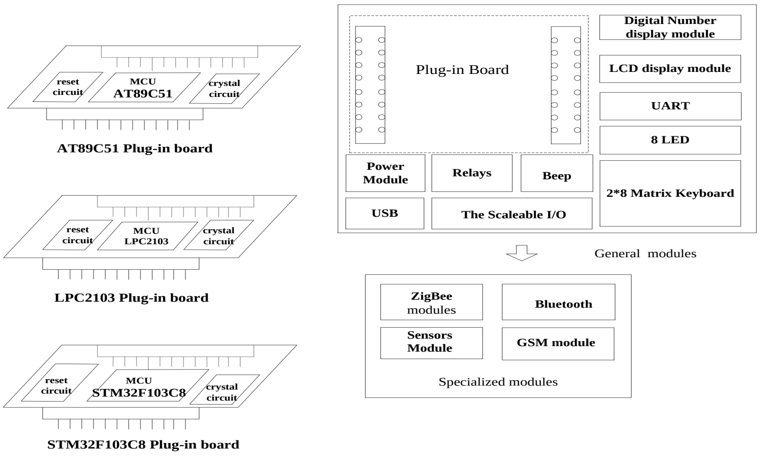

Figure 2. Hardware Platform Diagram

Table 1. Microcontroller and Embedded Chip Contrast Table

51 kernel SCM	ARM7 Microprocessor
8-bit code instruction	32-bit code instruction
8-bit Data bus	32-bit Data bus
16-bit address bus	32-bit address bus
6 interrupt sources	7 interrupt sources
Working register（R0 ~ R7）	37 Working registers
Program counter	Program counter
Status register	Status register
Accumulator A and B	37 accumulators
Addressing a 16-bit address range width	Addressing a 32-bit address range width
1 Work pattern	7 Work patterns
Does no support coprocessor	Support Coprocessor
Does no support JTAG coprocessor	Support JTAG debug

The plug-in board is actually a minimum system with a microprocessor, crystal oscillator and a circuit to reset the minimum system [6-8]. Ranked by complexity, there are respectively three plug-in boards in this experimenting platform: the STC89C51, STM32F103C8 and LPC2103 plug-in board. As is shown in Figure 2， all the I/O pins of the three aforementioned microprocessors are lead out and can be connected to the jack on the motherboard. As in table 1, the three microprocessors are ISP-capable, cheap and featured with Timer /Counter, programmable I/O ports, programmable full-duplex serial port and various interrupt sources. Therefore, it is convenient to perform re-development on them and sufficient to the teaching requirements.

2.2. The Motherboard Design

The motherboard is mainly designed to learn about the application of peripheral interface. The motherboard can be divided into general modules and specialized modules. The general modules include I/O ports, serial ports, and keyboards, Analogue-Digital Converter, LEDs and LCD. Furthermore, students can design their own modules and connect to the motherboard via the on-board extensible I/O ports to personalize their motherboard. The specialized modules include ZigBee, Bluetooth, traducers, GSM. All the general and specialized modules are optional according to different majors and teaching requirements.

3. The Software Design

All the source codes for this experimenting platform are also modularized and stored on the server. The forte of such modularization is the enhancement of source code structure, readability and simplicity. The experimenting board adopts the KeilμVision4 as the software Integrated Development Environment (IDE).

3.1. The Design of Modularized Source Codes

The process of source code modularization is shown in Figure 3. The students configure the IDE and target board, teachers create the modularized source code with the header files and source code files provided in the source code library. The modularized source codes are encapsulated within separated files. Different source code modular can be called and inserted interactively. The source code modular can also be optionally compiled by conditional compilation. The IDE will read the chip configuration files to determine which source code files should be compiled and which source code files shouldn't. These source codes modular can be shared by both the single-chip microcomputer and embedded microprocessors. Therefore, students can compare and find many detailed differences between the single-chip microcomputer and embedded microprocessors, and such comparison can effectively help the students to understand embedded microprocessor.

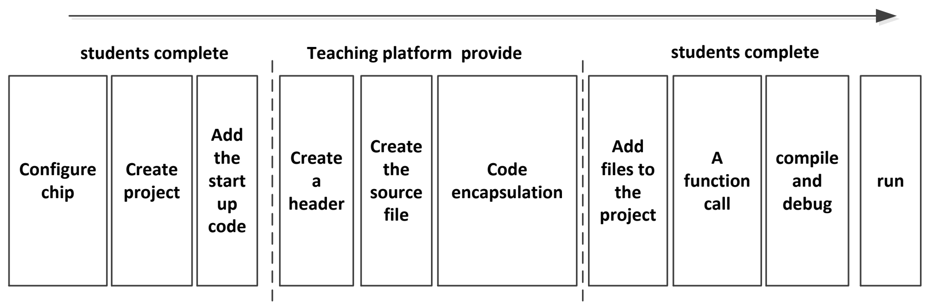

Figure 3. Program Modular Encapsulation Process

3.2. A Demo for Source Code Modularization

Take the keyboard controlled segment displays as an example. This experiment involves both hardware modular and software modular. The hardware module include keyboard, segment displays and 74HC595 chip. The software module include 74HC595 driver, segment displays driver, keyboard scan routine and key value fetching routine.

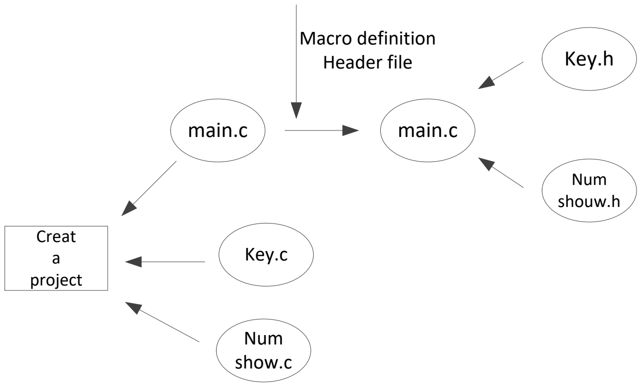

Figure 4. Modular Program Structure

74HC595 driver routine is responsible for sending data to the 74HC595 chip. The Key.c file contains the keyboard scanning and key value fetching routine. The Num_Show.c file contains the routine to display digits on the segment displays. This file is available on the server. The IDE will compile this source code file while reading the chipset configuration file, the configuration file contain find describes the type of chipset and the make a hex file and download to the microprocessor.

The students should firstly create a project with Keil and then write a main source file in which will call these modularized routines. The diagram of source code modular call back is shown in Figure 4.

Students should write the main function in the main.c file according to this diagram.

4. Analysis on Application of CDIO Experimenting Platform

4.1. The Application of CDIO Experimenting Platform

Embedded hierarchical teaching experiment platform is based on CDIO idea, it stress that integrates now embedded course teaching and practice. At the same time to "experiment" throughout the whole process of teaching, cultivate students gradually from 51 series of classic microcontroller based transition to a fully functional integrated single-chip microcomputer. Finally learning contains mu C/OS - II ARM7 system of the operating system, and the learning curve step by step from simple to complex.

The first stage of this experimenting platform is based on LPC2103、STM32F103C8. The STC89C51 is served as a comparison. Students should download the source file to the microprocessor and observe what happened on the experimenting board. The unified software and hardware structure will promise the learning efficiency.

The second stage is design. The experimenting platform provides sufficient documentation support, students can design experiments of their own by referencing to these support documentation. Teachers and students can also reference to the provided experiments (such as UART, USB, LCD, keyboards and so forth) and transform into their own. During the process of designing experiments, students can be familiar with the basic operation on ARM 7 microprocessors and lay the foundation of advanced development [9].

During the stage of implementation, students start with the basic experiments such as D/A、A/D touchscreen and LCD experiments and grasp the knowledge about the MSC 51 single-chip microcomputer and ARM7 microprocessor [10]. After the basic learning stage, students can try to learn about the implementation of

Bootloader and transplantation ofμC /OS-II embedded operating system and the Windows CE embedded operating system.

4.2. Arrangement of Experiments under the CDIO Education Mode

The CDIO education mode is beneficial for teaching reformation; it transforms the conventional theory-based teaching into a theory-and-practice oriented teaching mode.

The experimenting system designs all the experiments based on AT89S51、STM32F103C8 and LPC2103. The experiments include LCD display control, 2*8 matrix keyboard, external interruption, and serial port communication, A/D and D /A covert [11].

The experiments based on simple operating system include the transplantation ofμC /OS-II embedded operating system, creating, pending resuming , synchronizing and removing operating system tasks. The software of experimenting platform is modularized, so students can select whatever they want to learn about. This experimenting platform will give a full play to the subjective initiative of students. They can design various innovative experiments such smart agricultural information system.

5. Conclusions

The experimenting platform has realized the feature of multiple plug-in boards. Each modular work well. The teaching practice shows that, this experimenting platform provides with sufficient interface resources and can perform re-development on the experiment platform. It can well meet the requirements of different teaching schedules and help students to grasp the knowledge of embedded system as soon as possible. This experimenting perform is applicable with different majors. It also has a strong pertinence, the teaching efficacy is obvious, and what is more, this experimenting platform can enhance the thinking and innovative ability of university students and lay the foundation for the future development of students.

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