Circuits and Embedded Systems Design Teaching for Postgraduate Student Focusing on Engineering Applications

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Abstract. Engineering education for postgraduate student is becoming more and more important at university. This paper discusses the training objectives and methodological principles for circuits and embedded systems course focusing on engineering applications. By utilizing an example of IF signal sampling system, we present the detailed course preparation and teaching methods. Finally, the paper gives some suggestions on engineering education.

Introduction

The innovation of engineering technology promotes the development and progress of human civilization. Thus the education of engineering is of great significance in the civil development [1-2]. Circuits and embedded systems (CES) is one of the most important elective courses for master students in electronic engineering (EE). The pre-requisite courses for circuits and embedded systems include circuits analysis, digital circuits, analog circuits, MCU system design, and high-frequency electronic circuits. Thus the theoretical basis of the CES course is the electronic circuits series of courses for undergraduate students. According to the training objectives and employment requirements, especially for the national defense mission of National University of Defense Technology, it is of great significance to increase the proportion of the education of engineering applications in university. Consequently, it is becoming an important issue to integrate the engineering education concept into general university courses. And this can make the knowledge on the textbook better adapt to the requirements of engineering talents in the development of the times.

The authors of this paper have been engaged in undergraduate and postgraduate courses in electronic circuit series for many years. Meanwhile the authors participate in a number of research projects. Therefore, this paper presents some thoughts and experience for the training objectives and methodological principles for circuits and embedded systems course focusing on engineering applications. Furthermore, we present the course preparation and teaching methods by taking the signal sampling and recording system as example. Finally, the paper gives some suggestions on engineering education.

Principles and Objectives

Engineering is the application and destination of science and technology, and the solution for the problems of the real world by using new ideas. The main development form of engineering is synthesized integration. The main mean is design, manufacture, application, and service. The achievement is products, works, engineering realization and industry.

Based on the above theory, we take circuits and embedded systems course as an example to analyze the ability and quality of an excellent engineer.
Determine and Solve Real Project Problem

Theoretical teaching is the foundation of engineering practice. The traditional teaching system in China emphasizes the theoretical characteristics of circuits and the analytical methods, and focuses on the system and the integrity of the course content. Take the CES for instance, the students should have the basic technology knowledge of the pre-courses like circuits analysis, digital circuits, analog circuits, MCU system design, and high-frequency electronic circuits. During the course, the students are also taught in the order of components, discrete circuits, and systems integration. In foreign countries, the teaching emphasizes the engineering applicability and experiment besides the theoretical knowledge. Furthermore, they spend more time to explain the relevance between different courses and knowledge. This is the trend for development of electronic engineering, since more and more complex systems have mixed with analog circuit and digital circuits, even with radio frequency circuits. Especially, the postgraduate students have to be able to solve some project problems, at least part of project. This raises the requirement for the postgraduate to possess the ability from modelling, designing and implementation, and verification. Consequently, we should make some teaching reform from the objective to the methodology for the current electronic courses, and the first important thing is to teach the students solve real project problems.

Cultivate and Build Cooperation Spirit and Teamwork Ability

Teamwork ability is the essential quality for a student to become an excellent engineer. To realize an embedded systems, teamwork is the necessity from the initial design, feasibility judgment and simulation to the hardware implementation and verification. The teaching methods usually include cooperative learning and teamwork. It means that the organizer of the course should assign the students into several groups according to a specific project or experiment to let the students work together to complete the project. During the project, the students have the chance to not only learn the relative knowledge, but also solve the uncertain factors together. Circuits and embedded systems is the professional elective course in electronic engineering, it combines lots of different knowledge system and engineering technology, which makes it very suitable to organize the course as a group or team of students for a real project.

Build Design and Implement Capabilities

Due to the lack of effective school-enterprise, academic-research cooperation, designing and developing valuable systems is relatively new to students. The Massachusetts Institute of Technology (MIT) has adopted a method of using students' extracurricular and holidays to strengthen students' engineering capabilities. They cooperate with companies to organize the students to participate in a design or engineering project. This allows students to face engineering problems and innovative design at the beginning of university. Although there are multidisciplinary intersections in engineering teaching, each subject can still use the curriculum design method to encourage students to learn the relevant knowledge of the subject from a systematic perspective. For circuits and embedded systems, it could be one good start point to design a digitally controlled analog front end (AFE) for IF acquisition system, and this is more helpful for students to understand the practical considerations when developing a practical system.

Competent for Interdisciplinary Tasks

Modern engineering technology covers various fields related to national economy and people's livelihood, such as machinery, electrical and electronics, civil engineering, chemical engineering, computer engineering, and industrial manufacturing. These engineering fields are also constantly breaking the boundaries of the traditional discipline, thus splitting and merging more branches of science and technology. Faced with the rapid technology development, many foreign colleges and institutions have actively promoted the disciplinary cross-plan in various ways according to their own conditions and actual social requirements. Circuits and embedded systems is the professional elective course in electronic engineering, but for other professions, such as industrial automation, electrical
automation, communication engineering, and computer engineering, the focus of the application is different. It is necessary to let the student have the thought that their knowledge should not be limited to one course or one certain subject. One excellent engineer is capable to complete the design in different disciplines.

**Possess Learning Abilities and Habits**

Learning ability is the necessity for an excellent engineer, who are required to learn by themselves, especially for students to enter the workplace. The development and application of electronic circuits in related fields, such as computer, image processing, and chemical biology, is a major feature. It is broader than modern teaching technology and closer to modern technology. However, most students only learn theoretical knowledge from the course through homework and test. Few students have self-learning skills in electronic circuit applications, such as could not understand the actual circuit diagrams. At the same time, students did not develop good self-learning habits throughout the university, including the habit of self-reviewing information to solve problems.

**Teaching Example**

In this section, we will present a teaching example of our course circuits and embedded systems, in which we put more efforts to show the real application requirements for the students. And we try to make the students learn some useful technical skills. This part of course is about designing an IF data sampling and analyzing system and is organized into four steps, which are given as follows.

**Step 1:** explain the background and the requirements for the sampling and analyzing systems. The task of the sampling system is to capture the IF signal transmitted from the satellite. This is very important to the communication function between the satellite and the ground station. The specifications and requirements of the sampling system include

- Center frequency: 70 MHz
- Signal bandwidth: 20 MHz
- Amplitude range: -60 dBm to 0 dBm
- Spurious-free dynamic range: > 60 dBc
- Analyze the signal spectrum power on board

Then we have to offer enough time for the students to think themselves. And this could be helpful for them to build the self-learning capabilities. Once they encounter problems, they have the chance to inquire from the teacher group. The teacher group includes several guides, who have different professions and can give provide comprehensive guidance.

**Step 2:** After the first step, the students should understand the requirements of the application. Further, the teacher is going to review the relative theoretical knowledge, such as amplifying circuit, Nyquist sampling theory, Fourier transform, and the dynamic performance of analog-to-digital converter. However this is not enough for the students to complete the entire project. Therefore one has to introduce some new knowledge for the students.

First of all, the theory and advantages of bandpass sampling should be explained [3], where the basic sampling rate equations are given as

$$\frac{2f_H}{k} \leq F_s \leq \frac{2(f_H - B)}{k - 1} \text{ and } k \leq \frac{f_H}{B}$$

(1)

Where $f_H$ and $B$ are the upper band and the bandwidth of the input signal, respectively. $F_s$ is the sampling rate, and $k$ should be integer. Secondly, upper limit of the clock jitter should be calculated according to the SNR requirement [4], which is given as

$$SNR = -20\log\left(\frac{2\pi f_H \delta_j}{k}\right)$$

(2)
Where the $\delta_j$ is the entire jitter of the sampling clock path. Finally, the definitions of the dynamic performance of analog-to-digital converter (ADC), such as signal to noise and distortion ratio (SINAD), spurious-free dynamic range (SFDR), and effective number of bits (ENOB), are introduced and analyzed, meanwhile the teacher will also emphasize the issues about how to improve these specifications [5].

**Step 3:** This part is essential of the whole course. The teacher will explain and analyze the requirements of the project, and then provide a reference system design of the project. The project is designed by top-down strategy, in which part of the important components are listed for reference. The students are encouraged to complete their design either by using the list or by choosing new design and unit according to their own understanding. Once the system design is done, the students will be parted into three groups. The structure and the tasks of the three groups are given as in Fig. 1. One project group generally consists of 3 to 5 members, who are responsible for hardware, software, and algorithm, respectively, based on interests and expertise. For hardware tasks, the group members are required to design the schematic diagram, the printed circuit board, and the debug work after the hardware has been fabricated. The prerequisite skills include PADS Logic, Layout, and Router, and operation capability of some basic instruments, such as multimeter, oscilloscope, signal generator, and spectrum analyzer, etc. The software members are in charge of the FPGA programming through VHDL (or Verilog) language. The Vivado and Modelsim is recommended for FPGA programming and debugging, respectively. The algorithm members for this project are responsible for realizing the FFT algorithm and calculating the dynamic specifications, like SINAD, SFDR, and ENOB. The software is recommended as Matlab and System Generator.

**Step 4:** The final step of the course is to verify the designed system. For such a data acquisition system, the main evaluation standard is the dynamic performance, such as SINAD, SFDR, and ENOB. The evaluation standard is very simple, however for such a complex project, there are always some of the groups that cannot finish the whole system. For this circumstances, we also prepare some evaluation boards for the students that cannot complete the hardware. In such condition, the hardware tasks are examined through the schematic diagram and PCB, and the simulation results for the analog front end circuits. The software tasks, i.e., FPGA programming can be implemented on the evaluation board. The algorithm can also be checked by simulation results, if hardware implementation cannot complete. It is worth noting that, this step is also essential for the whole project, that is helpful for the students to carry out the complete procedure of one project. However, considering the conditions and
limitations, the teacher should prepare for the unwanted conditions and consider how to evaluate the work of the students.

**Summary**

In this paper, we discuss the training objectives and methodological principles for circuits and embedded systems course focusing on engineering applications. By utilizing an example of IF signal sampling system, we present the detailed course preparation and teaching methods. Finally, the paper gives some suggestions on engineering education.

**References**


