A Project Based Approach to Teaching Microelectronics Circuit Analysis and Design

Wenjie Chen and Feng Zhang

***Abstract*—Microelectronics circuit analysis and design is one of the most important courses for all undergraduate majors in the School of Electrical Engineering. However, traditional lecture teaching method suffers from the disadvantage of low efficiency, large amount of time consuming and passive learning habits. This paper discusses the use of project based approach to improve the quality of teaching/learning for analog circuit design. The proposed methodology has been applied in several electrical engineering courses. The method allows students to better understand some complex circuit and physical-level phenomena, by describing them at a higher abstraction level. In addition to enhance their understanding of design problems and skills, students become more motivated and satisfied. As an application, a case study is considered in this work: a square wave and triangular wave generator.**

***Index Terms*—Microelectronics circuit, project based approach, teaching strategies.**

I. Introduction

Microelectronics circuit and system today is more essential than ever before. With the growth of digital systems, wireless communications, complex industrial and automotive systems, designers are challenged to develop sophisticated analog solutions. Their potential, however, is not limited to such application. Indeed, their intrinsic non-linear dynamics, coupled with signal processing capabilities, makes them ideal candidates for a wide range of tasks. Therefore, Microelectronics circuit analysis and design has become one of the most important courses for every electrical engineering college student.

To have a good understanding of this knowledge, undergraduate students have to spend a lot of time to study the textbook chapter by chapter. However, traditional teaching method suffers from lower students' learning activity, poor education efficiency and misunderstanding of the circuit principle.

To cope with this problem, different alternative education techniques [1]-[6] have been developed which improve the teaching efficiency at the price of increasing the cost in their courses. Among others, one of the best trade-offs is achieved by the so-called project based approach. This paper presents the implemented Project Based Approach (PBA) replacing the traditional textbook teaching and learning method applied to the analog electronic circuits' course.

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From an educational perspective, the benefits of using project based approach in teaching are twofold. On the one hand, students learn practical skills, which are essential for their professional career. On the other hand, they get a better insight about design problems in complex circuits and systems. The main goals, therefore, are to heighten students' interest to Microelectronics circuit, show Microelectronics circuit's role in modem engineering and give the students sufficient theoretical and practical fundamentals enabling them to take subsequent microelectronics circuit courses with greater confidence. The paper shows that the implementation of this new approach has motivated the students and has given them increased autonomy and efficiency at the end of the project.

The paper is organized as follows: Section II describes the context of the course, the traditional education approach and the related problems. The operational principle of project based approach is discussed in Section III. Section IV presents a case study of square wave and triangular wave generator. Section V reports the main conclusions and lays out future work.

II. Traditional Approach of Teaching

The Microelectronics circuit analysis and system is opened for second-year undergraduates in School of Electrical Engineering from Xi'an Jiaotong University after they have finished the two preamble courses — Circuit Theory and Electromagnetic. The course will discuss the most important theoretical and practical problems in microelectronics and low-voltage circuits on an advanced level. Among others, the course will cover semiconductor materials and diodes, bipolar junction transistors and amplifier, field effect transistors and amplifier, integrated circuit, ideal operational amplifiers and op-amp circuits, feedback circuits, Schmidt trigger, oscillation circuits, power amplifiers and so on.

Traditional courses emphasize analysis techniques at the expense of instilling an intuitive understanding of the problem and the underlying engineering principles. What the students need to do is to listen to the teacher and to read the textbook chapter by chapter. Then some exercises and lab experiments are followed by the knowledge study. The procedure of the traditional teaching method is depicted in Fig. 1. Some significant problems were encountered, including the following:

- Feedback received by students from their exercises were not consistent and enough. In most cases, the exercises could be just copied with ease. There is a lack of mechanisms that trigger students' auto-evaluation or self-learning motivation.

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- Due to the fast changes in microelectronic circuit, students have little chance to acquire the most frontier technology by traditional textbook teaching method. They are satisfied with just having a high score at the end of the course test.
- Since much of practical circuit design is not linear and cannot be reduced to linear circuit analysis problems, the interrelationships of current, voltage, power, diodes, transistors, op-amps, resistors and capacitances are difficult to be understood both mathematically and intuitively.

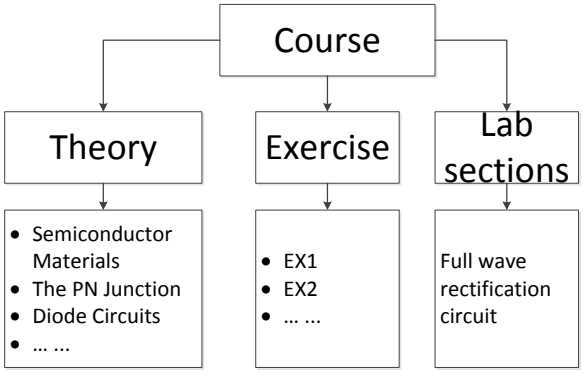

Fig. 1. Block diagram of the traditional teaching method.

On considering the these disadvantages, the motivation of this paper is try to find an alternative teaching method that both balances the practical and intuitive aspects of microelectronics circuit analysis, and could give undergraduate students deep insight into the theoretical fundamental of the course.

III. Project Based Approach

Project-based teaching is an authentic instructional strategy in which students plan, implement, and evaluate projects that have real-world applications beyond classrooms. Moreover, students find projects fun, motivating, and challenging because they play an active role in choosing the project and in the entire planning process. The use of Project Based Teaching method is one of the most important methodological issues for acquisition of engineering skills by the students of electrical engineering branch.

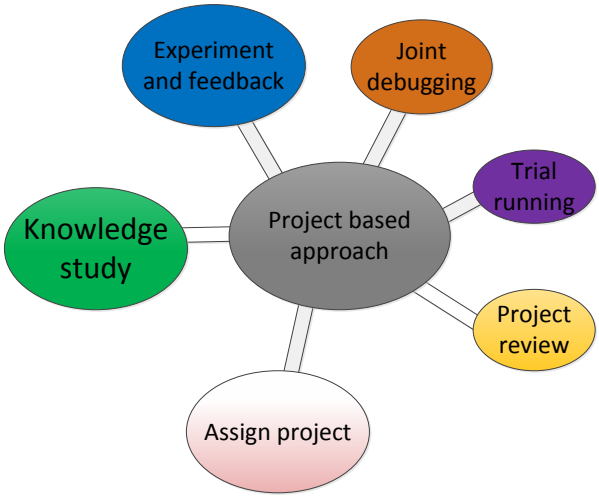

Fig. 2. Diagram of project based approach.

Fig. 2 shows the diagram of project based approach. With this approach the students did an intensive solution search with higher degree of liberty, and the learning level was increased and enriched. Moreover, the instructor has a less central role, and students take more responsibility for their own learning, which results in higher student involvement and real problem-solving ability.

In the course of Microelectronics circuit analysis and design, the course was divided into three main sections: 1) First, a typical teaching consists of introduction to design theory and mechanical theory is given. 2) Then, projects with certain objective are assigned to students. In order to solve the problem, students may spend their spare time to read up the literature, to discuss with other students, or to do some simulations through such software as PSPICE, SABER, MATLAB and so on. 3) Laboratory experiments are carried out to reinforce technical and theoretical ideas from designers through hands-on exercises and to introduce the students to the skills and thought process necessary for the design project. Five projects are assigned to undergraduate students in our school. The topics of these five projects are:

- Full wave rectification circuit design. AC to ± 12 Volts DC supply. Theory of diodes applications and regulator circuit.
- Multi-stage bipolar junction transistor (BJT) amplifier circuit design, including negative feedback network. Theory of BJT circuit DC and AC analysis, frequency response and stabilization analysis.
- Operational amplifier circuit design. Theory of inverting amplifier, summing amplifier, non-inverting amplifier and so on.
- Sinusoidal and non-sinusoidal oscillator design. Theory of Wein bridge oscillator, Schmitt trigger oscillator, square-wave oscillator and triangular wave oscillator.
- Power amplifier design. Theory of audio signal processing, filtering circuit, integrated op-amp and power amplifier.

These projects were given to students at the beginning of the semester. During the ten-weeks-long teaching procedure, several discussions about each project are carried out in the class. Students are encouraged to put forward their design scheme in front of the classmate. To fulfill the mission, the students should have enough knowledge study beforehand.

A breadboard as well as a set of electronic components (such as op-amp, bipolar junction transistor, diodes and all available components) was distributed to every student. Then, design, simulation and experiment procedure were carried out step by step. In order to ensure each project is done in the right way, final paper work is provided after the experiment is finished, which in turn, provides a good understanding of the electronic circuit knowledge.

IV. A Case Study

In the course of analog circuit design, there are many basic circuit structures for undergraduates to learn. In this paper, the design of a square wave and triangular wave generator is discussed. The project has several objectives within the course:

- Bring the students to become aware of his responsibility, also develop his capability to be creative.
- Improve the theoretical knowledge and circuit design skills of the students.

- Provide a hardware joint debugging and trial running experience to the students.

The project has four phases. The first phase consists in the theoretical analysis of the operational amplifier, the Schmitt trigger circuit and the integral circuit. The students are required to derive the nonlinear transfer characteristic of the oscillator. The second phase consists in the design of the circuit. Using the expressions and transfer characteristic derived in the first phase the students should design the oscillator in order to achieve the desired performance goals. The design is confirmed through PSPICE simulations of the circuit. The third phase consists in building the circuit using a breadboard and testing the circuit in order to verify if it was correctly designed. The final phase consists in complete a four pages report which include the design, simulation and experimental results of the project.

There are only three design goals set for the oscillator:

- The oscillator should be capable of generate a square-wave and a triangular wave with identical frequency.
- The amplitude of the square-wave should be 12Vand the amplitude of the triangular-wave should be 6V.
- These two signals could be moved vertically and respectively.

The circuit of the proposed oscillator is depicted in Fig. 3. It consists of two parts. Op-amp A_1~A_3 is used to generate the square-wave and triangular wave. The circuit of Op-amp A_4 and are Op-amp A_4 identical. So they can be built with the same components. This part is used to generate a reference DC signal that is finally adding with the square-wave or the triangular wave.

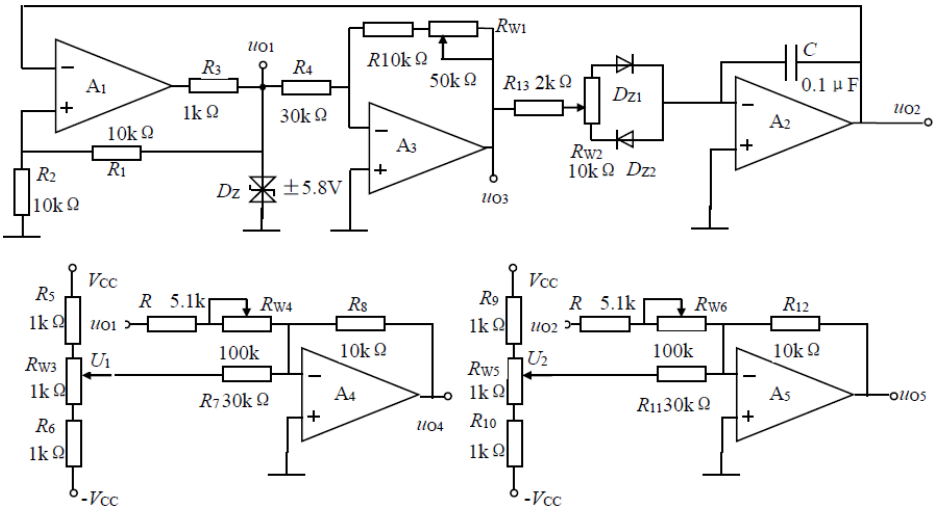

Fig. 3. Schematic of the proposed oscillator.

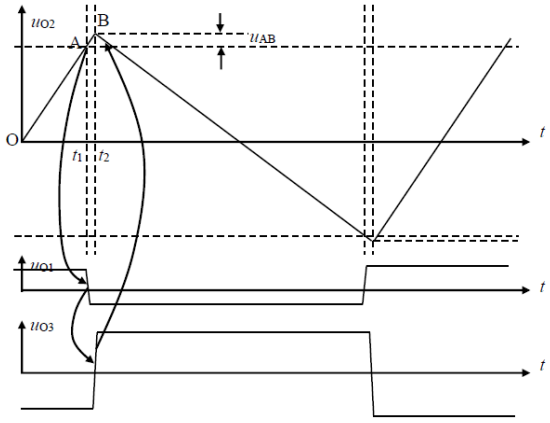

Fig. 4. Waveform of the triangular wave.

Fig. 4 shows the debugging procedure of the oscillator. When students are making theoretical analysis, they often neglect the output time delay of op-amp. However, with the increasing of operation frequency, the charging (or discharging) time constant will become very small, which in turn, resulting a fast change of triangular wave slope. It can be seen in Fig. 4, from t_1 to t_2. This overshoot voltage u_{AB} is in proportion to the triangular wave slope. Thus, the overshoot voltage will increase with the increasing of oscillation frequency. If the duty cycle is very large (higher than 90%) or very small (lower than 10%), it is easy to observe this phenomenon. And that can only be found during the project debugging and trial running. Fig. 5 shows the one of the student's hardware placed on a breadboard.

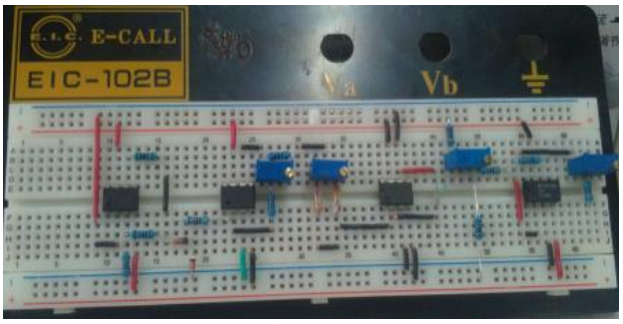

Fig. 5. Photo of the oscillator hardware.

V. Summary

Project based approach provides a successful mechanism to help students achieve high-level learning goals and deal with real problem-solving activities. In project-based learning, the instructor has a less central role, and students take more responsibility for their own learning, which results in higher student involvement and better understanding of the circuit. In this paper, project based approach is utilized in teaching Microelectronics circuit analysis and design for undergraduate students in School of Electrical Engineering. It shows that the implementation of this new approach has motivated the students and has given them increased autonomy and efficiency at the end of the project.

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