Combining Theory with Practice in Circuits and Systems Education

[1,2,3*]HUA FAN, [1]MINGYU LIANG
[1]School of Integrated Circuit Science and Engineering(Exemplary School of Microelectronics), University of Electronic Science and Technology of China, Chengdu, CHINA
[2]Chongqing Institute of Microelectronics Industry Technology, University of Electronic Science and Technology of China, Chongqing, CHINA
[3]Institute of Electronic and Information Engineering of UESTC in Guangdong, Dongguan, CHINA

Abstract: In electronic information and related majors, “Circuit Analysis and Electronic Circuits” is a compulsory course, and its importance is self-evident. The teaching method that combines theory and practice has now become a more common method for circuit courses, but the inherent characteristics of circuit courses: a wide range of knowledge, complex basic theories and basic concepts, and many important and difficult points. Which results in the relatively simple setting of practical content corresponding to theoretical knowledge, Furthermore, students will find the course content boring and boring. Starting from this point, this article carries out innovative reforms to the teaching content in both the theoretical content and the practical content, so that the theory and the practical content are fully integrated. At the same time, abandoning the traditional teacher-centered classroom, the teacher only acts as a “guide”, giving students the identity of the “master” of the classroom, allowing students to explore and seek knowledge independently, and achieve “low input and high output”. In turn, a good sense of self-learning and exploration and innovation ability can be formed, which can train students into comprehensively developed learning, research and application talents.

Keywords: electronic circuit foundation, teaching method, course reform.

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1. Introduction

Due to the remarkable progress made in integrated circuit technology in recent years, integrated circuits have been improved in terms of high speed, high performance and high integration [1]. In order to keep up with the pace of the times, colleges and universities need to reform and innovate in related courses. Electronic circuit courses are the basic content of integrated circuit technology and one of the main technical theory courses for electronic science and technology majors. The content is more, boring and complicated, with strong logic, and the course hours are relatively small. According to the characteristics of the course, it is necessary to simplify the teaching content and absorb the essence of the past teaching content, On this basis, further optimize innovative teaching content. To reform the teaching, we know that the characteristics of the curriculum are far from insufficient, and we need to fully understand the contemporary college students in order to better teach students in accordance with their aptitude. From the perspective of cognitive ability, they are talents of the information age in the new century and have good image thinking ability. Analyzed from the psychological characteristics, they are full of interest and curiosity in new things, full of exploration spirit, but not interested in pure theoretical learning content. In order to train students into applied talents who can solve practical problems, it is not only necessary to add engineering content to the curriculum to strengthen students’ awareness of engineering practice, On the other hand, in order to increase students’ interest in learning, it is recommended to use various non-traditional methods to teach courses, such as project-based learning [2], collaborative learning [3] or integrating experiments into the classroom [4]. Obviously, the traditional teaching model cannot meet the needs of students. Therefore, it is imperative to change the traditional model, establish a new analog circuit teaching system, and optimize and innovate teaching content.

2. Analysis of Problems in Teaching

In order to better implement the curriculum reform, it is first necessary to analyze the problems that existed in the previous teaching process of the basics of electronic circuits.

Although the importance of experiment and practice to the curriculum has been emphasized, it is undoubtedly difficult to combine theory and practice in teaching in a limited time. At the same time, for most students, their grades make them pay more attention to theoretical knowledge and take a perfunctory attitude towards practice and experimental content, believing that these content are optional. On the other hand, the school adopts the separate teaching method of theory and experiment when setting up courses, so that students basically rely on the experimental instruction book instead of the knowledge learned in the classroom in the experimental class, which greatly reduces the effect of the experimental class. So it is difficult to achieve the desired result.

3. Teaching and Curriculum Content Reform

In view of the problems in the teaching and course content proposed in this article, proceed from these two aspects. Uphold the teaching concept of “inquiry-based teaching, project-driven approach” in the classroom, Take the case of street lamp automatic controller as the introduction, review the voltage transmission characteristics of the integrated operational amplifier, and analyze it layer by layer.Guided by clear circuit design cases, students are trained to solve practical problems through problem exploration, teacher analysis, and student discussion. Using the specific circuit application of the street lamp automatic controller, the circuit parameters of the voltage comparator are calculated and analyzed, and the final implementation scheme is obtained, which reveals the law of the voltage transmission characteristics of the voltage comparator. Starting from the voltage transmission characteristics of the integrated operational amplifier working in the linear region, the two forms of operational amplifier working in the saturation region are analyzed, and students are gradually guided to complete the learning of the single-threshold voltage comparator and the double-threshold voltage comparator. The teaching process combines the actual application case of the voltage comparator with the circuit model, Deepen the understanding of circuit theory concepts, and analyze the corresponding voltage transmission characteristics through animation demonstration.

In order to complete the teaching of the above content in a limited time and give students a rich and colorful class, it is necessary to carefully prepare the course design of the content to be taught before class. In the course design, the teaching content is divided into knowledge review (2 minutes), teaching introduction (3 minutes), teaching content (35 minutes), teaching summary (3 minutes), outreach training (1 minute) and homework (1 minutes) . A total of 45 minutes for the six stages. This is only an estimated time arrangement. The specific implementation process is determined by the actual situation in the classroom. The teaching arrangement is flexible and the time can be slightly adjusted.

3.1 Optimize and Innovative Textbook Knowledge

Curriculum construction should rebuild some core knowledge, recombine knowledge, optimize and upgrade old knowledge, add new technologies to teaching content, and teaching design focuses on the cultivation of learning ability and the improvement of engineering thinking. When teaching, pay attention to the connection between the front and rear knowledge points. The knowledge review at the beginning of the class is an important part of the learning process. This process can not only systematize the knowledge that has been learned, but also strengthen the understanding, consolidation and improvement of knowledge, and can also make up for the defects of knowledge. In this way, students can review their knowledge while creating a good classroom atmosphere. At the same time, they can be guided into the learning of the content of this section through questions, so that students can truly enter the classroom and become the “master” of the classroom. For example, before learning the voltage comparator, briefly review the knowledge points about the op amp and directly give the intuitive transmission characteristics. As shown in Fig. 1, At the same time, cooperate with teachers to explain to strengthen students’ mastery of integrated operational amplifiers and help students establish a more complete knowledge framework of voltage comparator circuits. Teaching introduction, it is the beginning of a class, and it is also a key link of a class. Appropriate teaching introduction can play a pivotal role in

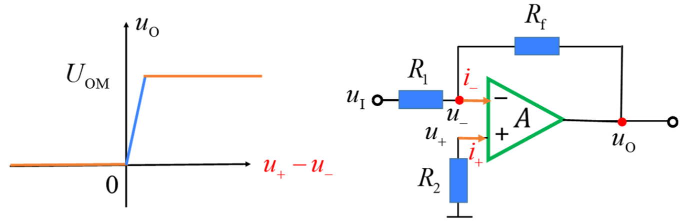

Fig. 1. The voltage transfer characteristics of the operational amplifier working in the linear region.

the entire class, making students full of curiosity and interest in knowledge, and fully mobilizing their enthusiasm. For example, give an example: automatic street lamp controller, as shown in Fig. 2. Taking the common street lamp control in life as an example, on the one hand, it raises questions to stimulate students’ interest in learning, and on the other hand, it brings out the classroom theme of voltage comparator just right. Combine the curriculum theory with life examples, from the shallower to the deeper, and visualize the abstract theory. As far as the voltage comparator course is concerned, the

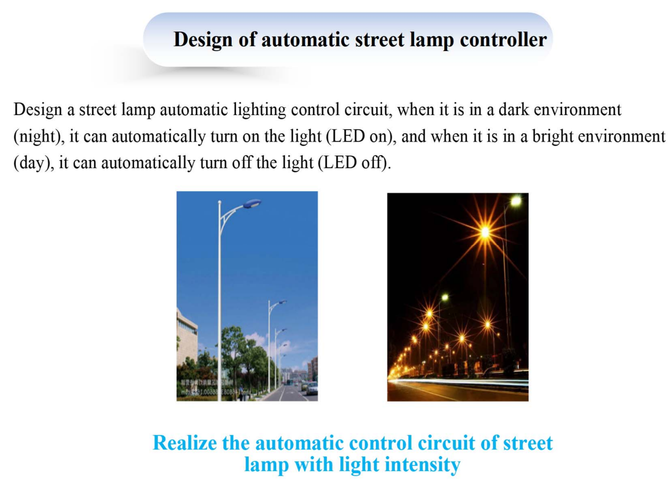

Fig. 2. Design of street lamp automatic controller.

basic content starts from the design of street lamp automatic controller. The teacher reminds the students by asking “to realize the design of an automatic street lamp controller, which can control the opening and closing of the street lamp according to the intensity of the light”. According to the prompts, combined with what they have learned, let students think from practical problems, and under the guidance of teachers, lead to the first teaching theme-Single threshold voltage comparator. Analyze layer by layer and introduce how to use a single threshold voltage comparator to realize the design of street lamp automatic controller. Teachers’ teaching is based on the inquiry-based teaching method, supplemented by other methods, to fully tap the students’ learning potential and allow students to rely on the knowledge they have already mastered. Guided by the teacher, take the initiative to explore, think, and discuss step by step to refine the three key points of analyzing the voltage comparator. The first step is to analyze the design points of the street lamp automatic controller. The light-sensitive resistor is used as the sensing unit to realize the link of converting the intensity of light into voltage input changes. As shown in Fig. 3. Utilizing the circuit principle of the photoresistor and the fixed resistor in series with the voltage divider and the characteristic of increasing the illuminance that the photoresistor decreases, the characteristic that the input voltage also increases linearly as the illuminance increases. Through the high and low level of the output voltage to control the on or off of the transistor to control whether the LED light is turned on. We hope that when the light is strong enough, the street light controller can automatically turn off the lights. So, here we need to design a single-threshold voltage comparator to achieve voltage comparison and control the output level. This concludes the first key point of the voltage comparator: To achieve voltage comparison, first ensure that the integrated operational amplifier works in the saturation region. Then consider, since the turn-on and turn-off of the street lamp is determined by the output voltage, how does the threshold voltage affect the voltage transfer curve of the comparator? When the input voltage is at the inverting input of the op amp, when the input voltage is less than the threshold voltage, the output voltage is high, and when the input voltage is greater than the threshold voltage, the output voltage is low. Therefore, the second key point is summarized here: When the input voltage is equal to the threshold voltage, it is an important basis for judging the state jump of the comparator. Finally, analyze the jump direction of the output voltage. When the input voltage is at the non-inverting input terminal of the op amp, the input voltage gradually increases. When the threshold voltage is passed, the output voltage produces a positive jump and the output is high; when the input voltage is at the inverting input terminal of the op amp, the input voltage gradually increases , When the threshold voltage is passed, the output voltage produces a negative jump, and the output is low. Therefore, the third key point is summarized here: when the voltage at the non-inverting input terminal of the op amp is greater than the voltage at the inverting input terminal, the output of the comparator is high, and vice versa, the output of the comparator is low. Therefore, the key is to analyze whether the input voltage is located at the non-inverting input terminal or the inverting input terminal of the op amp, and also to pay attention to the relationship between the input voltage and the threshold voltage. So get the design method of street lamp control, as shown in Fig. 4.

Advanced content is to ask questions and find solutions on top of the basic content. The single-threshold voltage comparator proposed above has only one threshold voltage. When the input voltage is equal to the threshold voltage, it will cause the output state to jump. This shows that its sensitivity is high, but high sensitivity also brings its biggest disadvantage, poor anti-interference ability. Fig. 5 shows the voltage transmission curve of single-threshold street lamp control. In real life, the illuminance fluctuates due to various factors. As a result, the operating state of the street lamp control realized by the single-threshold voltage comparator is not stable.

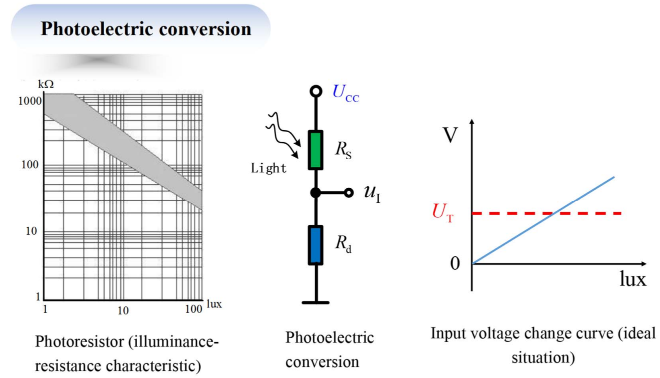

Fig. 3. Photoelectric conversion process.

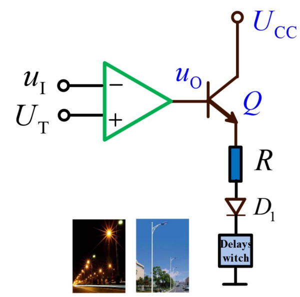

Fig. 4. Single threshold to achieve street lamp control.

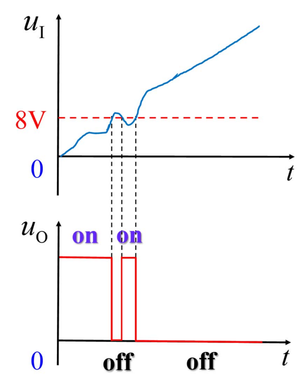

Fig. 5. Voltage transmission curve of single threshold street lamp control.

Then a feasible solution needs to be found for the problem raised, and a dual-threshold voltage comparator is drawn, as shown in Fig. 6. First of all, we need to know the working principle of the dual-threshold voltage comparator. The voltage transmission characteristics are determined by the threshold voltage, the change trend of the output voltage and its amplitude. In the first step, according to the “virtual short” and “virtual break” properties of the op amp, and Kirchhoff’s voltage law (KVL), the following can be obtained:

$$u_+ = \frac{R_1}{R_1 + R_2} u_O + \frac{R_2}{R_1 + R_2} U_T \quad (1)$$

Since when u_I ¿ U_T, u_O=U_{OM},the corresponding upper threshold voltage can be obtained, and when u_I ¡ U_T, u_O=0, the corresponding lower threshold voltage can be obtained. Substituting these two conditions into the above formula, the upper threshold voltage and the lower threshold voltage are respectively:

$$U_{TH} = \frac{R_1}{R_1 + R_2} U_{OM} + \frac{R_2}{R_1 + R_2} U_T \quad (2)$$

$$U_{TL} = \frac{R_2}{R_1 + R_2} U_T \quad (3)$$

Define the difference between the upper and lower threshold voltages of the dual-threshold voltage comparator as the hysteresis voltage, and its expression is:

$$\Delta U_T = U_{TH} - U_{TL} = \frac{R_1}{R_1 + R_2} U_{OM} \quad (4)$$

It can be seen from the voltage transmission characteristic curve that when the input signal disturbance is relatively large, it will cause the output of the double-threshold voltage comparator to undergo an error jump. However, the interference less than the hysteresis will not cause the comparator output to jump. Feedback accelerates the jump. To further

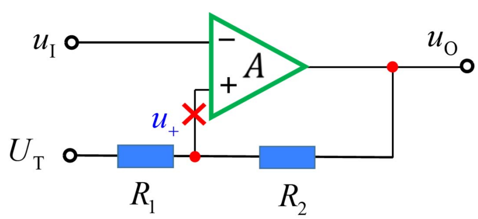

Fig. 6. Dual-threshold voltage comparator circuit.

enable students to change passive learning into active learning. Group the students for team training, train them to study together to achieve the course goals proposed by examples [5]. Analyze the application design of the dual-threshold voltage comparator in the street lamp automatic controller, and discuss the circuit parameters that meet the requirements. According to the performance requirements of the street lamp automatic controller, it can be known that the upper threshold voltage is 8V, the lower threshold voltage is 6V, and the resistance $R_1 = 10k\Omega$. Combining the upper threshold voltage formula and lower threshold voltage formula obtained above and the known conditions, the threshold voltage can be calculated $U_T = 7.2V$, Feedback resistance $R_2 = 50k\Omega$. The voltage transmission characteristics of the dual-threshold voltage comparator can be further analyzed by means of animation demonstration. The input voltage of the comparator is introduced from the inverting end of the operational amplifier. When the input voltage is equal to the threshold voltage, the output of the comparator jumps. As shown in Fig. **??**, When the input voltage is relatively low, the voltage at the inverting terminal of the op amp is less than the voltage at the non-inverting terminal, and the comparator output is a high level 12V. When the input voltage gradually increases and reaches the upper threshold voltage (8V), the comparator output is in a state, the transition from high level 12V to low level 0V. Next, analyze the reverse process. When the input voltage is high, the voltage at the inverting terminal of the op amp is greater than the voltage at the non-inverting terminal, and the comparator output is low level 0V. As the input voltage continues to decrease, when the input voltage is equal to the lower threshold voltage (6V) When the output state jumps, from low level 0V to high level 12V. After the

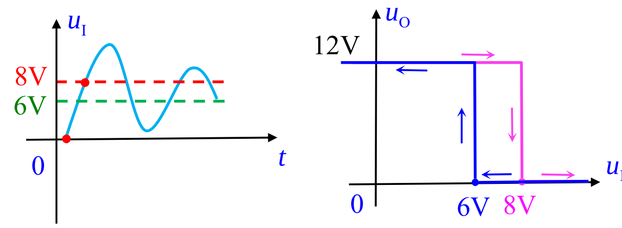

Fig. 7. Voltage transmission characteristics of double-threshold voltage comparator.

above analysis, students have been gradually guided to design a dual-threshold voltage comparator whose circuit parameters meet the requirements, as shown in Fig. 8. Applying this dual-threshold voltage comparator to a street lamp control circuit can analyze its voltage transmission characteristics. As shown in Fig. 9, When the input signal amplitude is relatively low, the comparator outputs a high level, the transistor is turned on, and the LED light is on. When it increases to the upper threshold voltage (8V), the comparator output changes from high to high. Ping jumps to low level, the transistor is cut off, and the LED light goes out. We can see that when there is noise interference, the input voltage produces multiple up and down disturbances near the upper threshold voltage (8V), and the output voltage does not jump wrongly, which can realize the stable control of street lights.Through the above analysis, we can get such a conclusion, the double-threshold voltage comparator has strong anti-interference ability.

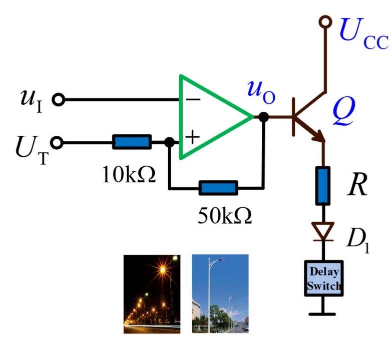

Fig. 8. Voltage transmission characteristics of double-threshold voltage comparator.

3.2 Combination of Theory and Practice

Practical content, that is, outreach training must only focus on theoretical knowledge. In the teaching process, based on the modern simulation software Multisim, practical content is reasonably inserted into the explanation of theoretical knowledge. The practical content is based on theoretical knowledge, comprehensive and open. Specifically, teachers will group students into groups, and the division of groups should take into account the combination and collocation of students

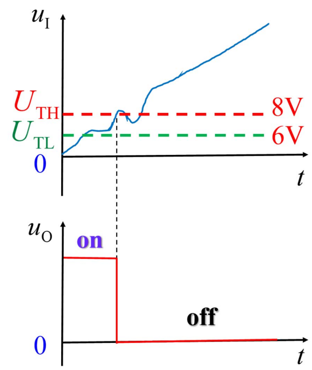

Fig. 9. Voltage transmission characteristics of dual thresholds to achieve street lamp control.

at all levels. Students will discuss and analyze, calculate appropriate capacitance and resistance values, use Multisim circuit simulation software for simulation and team up to complete hardware production. The teacher guides students to divide the curriculum knowledge into pieces, combine the knowledge they have learned to solve practical problems, and cultivate their ability to independently analyze circuit principles. An example of the circuit is shown in Fig. 10. The introduction of engineering examples is conducive to further improving students' ability to master and learn new knowledge. In the process of circuit simulation and hardware design, students can obtain intuitive perceptual cognition and reduce the difficulty of abstract thinking. Implementing hierarchical education, teaching students in accordance with their aptitude, and expanding training content can allow students with strong learning abilities to master more knowledge and improve their abilities. At the same time, the model of teamwork also provides a very good learning platform for students with poor foundations. This active learning environment can improve students' self-confidence and desire for performance [6]–[10], which greatly improves the efficiency of learning. The importance of teaching summary is self-evident. You can

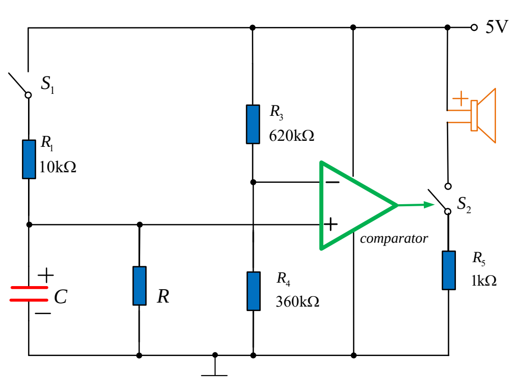

Fig. 10. Timing alarm circuit.

summarize and sort out the previous content, review important knowledge, deepen students' understanding of knowledge, and have a positive effect on students' full circuit design methods. In this case, the classroom becomes a place to solve problems, propose concepts and participate in collaborative learning.

4. Conclusion

By taking the teaching stage of voltage comparator as an example, this article analyzes some problems in the theory, practice and content of the electronic circuit course, and puts forward effective methods for the problems. When teaching, the teacher starts from the actual situation of the students, runs through the classroom with an inquiry-based teaching method, optimizes and innovates the content, and combines theory and practice reasonably. The ultimate goal is to improve students' ability to analyze and apply circuits, and train them to adapt to the times.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.