Reform and Practice of Analog Circuits

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***Abstract*—In the new century, education has become the focus of the reform. At present, cross, penetration and integration between basic courses are the key to improve the quality of teaching and the overall quality of students. University of Electronic Science and Technology of China (UESTC) combines "circuit analysi" and "fundamentals of analog circuits" as one course "electronic circuit", the curriculum reform follows the principles of strengthening the foundation, updating the structure, penetrating the interdisciplinary and simplifying the courses. This paper discusses the principles and ideas of reforms related to the "electronic circuit": the results show that the teaching can broaden the knowledge and vision of students, as a result, the students can better adapt to the requirements of learning and challenge of the new era.**

***Index Terms*—Circuit Analysis; Fundamentals of Analog Circuits; Fundamentals of Electronic Circuit; Curriculum Reform**

I. Introduction

As well known, analog circuits is very important yet very difficult. It is can be found everywhere in modern electronic devices, and their performance is often a bottleneck for practical applications [1]–[6]. The changes of the age urge us to carry out teaching reforms [7]–[9]. The curriculum construction should reconstruct some core knowledge, the old knowledge should be upgraded, the new technology should be added to the teaching content, and the teaching design should be focused on the cultivation of learning ability and the improvement of engineering thinking. Since 2013, the University of Electronic Science and Technology of China has begun to explore the optimized conformity of the curriculum system with the core of learning ability, the development needs of the industry as the standard. Some good results have been achieved. This article will introduce detailedly the circumstances of continuous teaching reform of the "Electronic Circuit Foundation" course

II. Coherent Teaching of "analog circuit basics" and "circuit analysis"

A. Integration Plan

The integration of the two courses "circuit analysis" and "analog circuit basics" is not a simple superposition.The traditional "circuit analysis" course uses the regular higher education "Nine-Five" national level key excellent teaching material edited by Qiu Guanyuan [10], including two parts: The first part is the circuit steady state analysis, including circuit models and circuit laws, equivalent transformation of resistance circuits, general analysis of resistance circuits, circuit theorems, resistance circuit with operational amplifier, phasor method, analysis of sinusoidal steady-state circuit, Coupled inductor circuit, three-phase circuit, non-sinusoidal periodic current circuit and signal spectrum, etc. The second part is the dynamic analysis of the circuit, including first-order circuit, second-order circuit, Laplace transform, network parameters, matrix form of circuit equation, two-port network, and introduction of nonlinear circuit [11]. After the integration of the two courses "Circuit Analysis" and "Analog Circuit Foundation" [12], the content of circuit analysis has been cut in half. This is because with the rapid development of electronic circuit technology, computer-aided analysis of circuits has become a widely used scientific research method. The rapid development of electronic design automation (EDA) and various circuit simulation software greatly simplifies the complicated circuit analysis and calculation. Therefore, the "computer-aided analysis of circuits" should be strengthened during the courses, so that students can initially grasp the methods and processes of large-scale circuit computer-aided analysis, establish the concept of "scientific computing", it is not advisable to analyze the internal principle of the module too carefully and perform complicated circuit calculations. However, the classical knowledge of circuit analysis theory and the necessary knowledge for the transition to "analog circuit foundation" must be elaborated and summarized in time and accurately.

The integration plan of the two courses is shown below:

- **Introduction: Electronic Information System and Electronic Circuit**

0.1 Understand Electronic Information Systems
0.2 Understand Electronic Circuits
0.3 Understand the Basic Variables of Circuit Analysis

- **Chapter 1: Circuit Model**

1.1 Understanding Lumped Circuits
2.2 Master Kirchhoff's Law
3.3 Understand electronic components such as resistors, power supplies, capacitors, inductors, etc., understand ideal components such as resistors, independent power supplies, capacitors, inductors, etc., and master circuit models of resistors, power supplies, capacitors, inductors, etc.
4.4 Under1stand semiconductor devices such as Diodes, Zener Diodes, FETs, and transistors, understand ideal components such as controlled power supplies, and master circuit models such as diodes, Zener diodes, FETs, and transistors.

- **Chapter 2: The Method of Circuit Analysis**

2.1 Understand two types of constraints and circuit equations (resistive circuits and first-order circuits)
2.2 Master the Superposition theorem and its application
2.3 Understand the Network Equivalence, Maste Thevenin/Norton's Theorem and its Application
2.4 Understand the phasor model of sinusoidal steady-state circuits and sinusoidal steady-state circuits, and master the phasor analysis of sinusoidal steady-state circuits
2.5 Master the frequency characteristics of sinusoidal steady-state circuits

- **Chapter 3: Basic Amplification Circuit**

3.1 Understand the performance of the amplifier circuit
3.2 Master the basic performance of FET common source amplifier circuit and common drain amplifier circuit
3.3 Understand the high-frequency circuit model of FET, master the frequency characteristics of FET common-source amplifier circuit and common-drain amplifier circuit
3.4 Understand transistor common-emitter amplifier circuit, common-amplifier circuit, and understand transistor common-base amplifier circuit

- **Chapter 4: Multistage Amplifier Circuit and Integrated Operational Amplifier**

4.1 Master the basic performance of multi-stage amplifier circuits
4.2 Master the frequency characteristics of multi-stage amplifier circuits
4.3 Understand the characteristics of analog integrated circuits, understand current source circuits, active load amplifier circuits, active load differential amplifier circuits, complementary output circuits, and understand the on-chip circuits of integrated operational amplifiers.
4.4 Understand the performance of integrated operational amplifiers and master the AC small-signal circuit model of integrated operational amplifiers

- **Chapter 5: Negative Feedback Amplifier Circuit**

5.1 Understand the composition of the feedback amplifier circuit, understand the feedback equation, and master the judgment of the feedback polarity and feedback type.
5.2 Master the magnification of the deep negative feedback amplifier circuit
5.3 Understand the effect of negative feedback on other performance of the amplifier circuit

- **Chapter 6: Operation Circuit And Filter Circuit**

6.1 Master the addition and subtraction circuit
6.2 Understand the logarithmic and exponential operation circuits, master the multiplication and division operation circuit and the analog multiplier
6.3 Master the integral and differential operation circuits
6.4 Master the low-pass filter circuit and understand the high-pass, band-pass and band-stop filter circuits

- **Chapter 7: Waveform Generating Circuit and Signal Converting Circuit**

7.1 Master the RC oscillating circuit
7.2 Understand the comparison circuit, master the rectangular wave generation circuit, rectangular wave-triangle wave generation and transformation circuit, and understand the function generator
7.3 Understand the voltage-frequency conversion circuit

- **Chapter 8: AC/DC Power Supply**

8.1 Understand rectifier circuit and capacitor filter circuit
8.2 Master the regulator voltage regulator circuit
8.3 Master series regulator circuit and three-terminal regulator

B. Key points of "circuit analysis" and "analog circuit basics"

The "Circuit Analysis" course should be positioned to pave the way for "analog circuit basics". The two chapters of "Circuit and Circuit Model" and "Circuit Analysis Method" enable students to grasp the basic knowledge of electronic circuits, abstract and express complex engineering problems of circuits, and complete accurate derivation and calculation of the established models.

In the "analog circuit basics", the superposition theorem is used in the analysis of diodes, triodes and FETs, It is necessary to emphasize that the superposition theorem can only be used after the transistor is linearized with the AC small-signal model. Otherwise, the nonlinear circuit cannot be solved by the superposition theorem.

Furthermore, the feedback part is a key point and a difficult point, feedback and op amp are the essence of analog circuit. Most of the op amps are used under closed loop negative feedback conditions.Only by mastering the judgment of the feedback type can deeply understand the influence of negative feedback on the performance of the amplifier circuit.However, the judgment of the type of feedback is a knowledge point that students are not easy to grasp. The method of judgment feedback given in the textbook is not easy for students to understand. We need to help students to sort out and summarize the knowledge points that are not in the textbook or that are not easy to understand, as shown below:

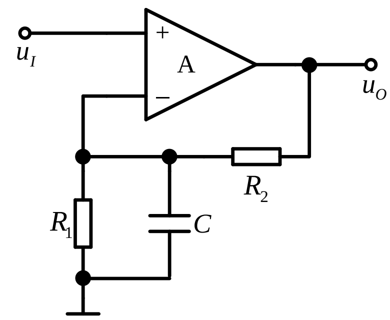

Fig. 1. DC feedback

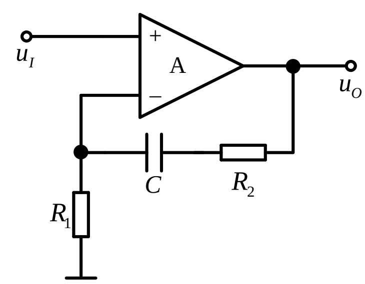

Fig. 2. AC feedback

- **AC, DC Feedback**
  Judging according to whether there are dynamic components in the feedback network:

1. If there is no dynamic component (usually a capacitor) in the feedback network, the feedback signal will be AC and DC;
2. If the feedback network has capacitors in series, it is AC feedback; (see Figure 1);
3. If the feedback network has capacitors in parallel, it is DC feedback; (see Figure 2).

- **Voltage and current Feedback**

1. The feedback network and output at the same point are voltage feedback (see Figure 3 and Figure 4 for details);
2. The feedback network and output at two different points are current feedback; (see Figure 5 for details).

- **Series and parallel Feedback**

1. Series feedback: the feedback signal and the input signal are respectively applied to the two electrodes of the input circuit of the amplifying circuit, and the feedback signal and the input signal are voltage summed;
2. Parallel feedback: the feedback signal and the input signal are respectively applied to the same electrode of the input circuit of the amplifying circuit, and the feedback signal and the input signal are current summing relationships.

- **Positive and negative Feedback**

1. Instantaneous polarity method;
2. For a single op amp, regardless of the input position, the feedback is connected to the inverting input as negative feedback, and the feedback is connected to the non-inverting input as positive feedback;
3. When the feedback signal and the input signal are applied to the same point of the input loop (parallel feedback): The instantaneous polarity is the same as positive feedback, and the instantaneous polarity is negative feedback;
4. When the feedback signal and input signal are applied to the input loop at two points (series feedback): The instantaneous polarity is the same as the negative feedback, and the instantaneous polarity is the positive feedback.

   (Note: Two points for the triode refer to the base and emitter stages, and for op amps are the non-inverting input and the inverting input)

Therefore, in the circuit shown in Fig. 1, since the feedback network formed by resistor R1 and resistor R2 has capacitors in parallel, it is DC feedback. Similarly, in the circuit shown in Fig. 2, the feedback network formed by resistor R1 and resistor R2 has capacitors in series. In the case of DC, the capacitors are open, the feedback disappears, and in the case of AC, the capacitors are short-circuited. The feedback network formed by resistor R1 and resistor R2 samples the output voltage, feedback to the input, it is AC feedback.

It is worth noting that voltage feedback and current feedback are the most difficult parts of feedback, and it is the most difficult part for students to master. Here, voltage feedback and current feedback need to be further explained. The standard definition of voltage feedback in textbooks is: Bringing some or all of the output voltage back to the input loop to affect the net input is voltage feedback. In short, it can be understood that the feedback network and the output are connected at the same point as voltage feedback. As shown in Fig. 3, the feedback network is a wire, which is the “voltage feedback” that feeds back all of the output voltage. As shown in Fig. 4, resistor R1 and resistor R2 form a resistor-divider-type feedback network that feeds a portion of the output voltage back to the input to stabilize the output voltage.

For current feedback, the standard definition of voltage feedback in textbooks is: Bringing some or all of the output current back to the input loop to affect the net input is current feedback. In short, it can be understood that the feedback

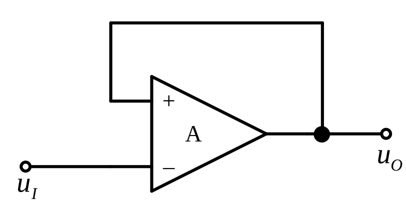

Fig. 3. “Voltage feedback” that returns all output voltages back

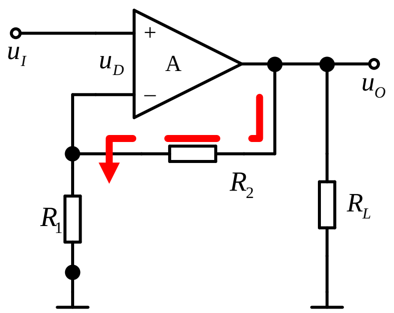

Fig. 4. "Voltage feedback" that feeds back the output voltage portion

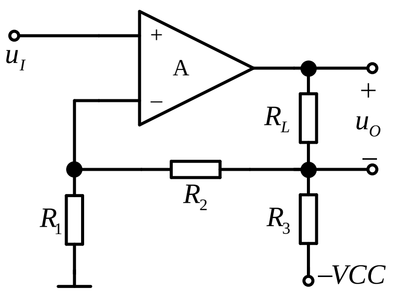

Fig. 5. "Current feedback" that feeds back the output current portion

network and the output are not connected at the same point as current feedback. As shown in Fig. 5, resistor R1 and resistor R2 form a feedback network that feeds a portion of the output current back to the input, form current feedback, stabilize output current.

Practice has proved that the "teaching of electronic circuit" can improve the ability of students to analyze circuits, and the interest in learning circuits becomes stronger, laying a solid foundation for future work in related fields

III. Conclusion

In order to deepen the reform of engineering education in colleges, the University of Electronic Science and Technology of China has launched a special education reform project: the combination of electronic circuit courses. The teaching reform is based on breaking the original segmented teaching mode, realizing the internal and smooth transition of the curriculum knowledge system, promoting the organic integration of curriculum content [13], cultivating students' innovative thinking and engineering practice ability and decision-making power to solve complex problems and decision-making power to solve complex problems and the ability of independent learning and lifelong learning.

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