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Application and Practice of Comprehensive Case Teaching Model in the Teaching of Analog Electronic Technology Theory

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Abstract. In order to cultivate students' ability of analog electronic circuit design and solve the problem of fragmentation of teaching content in analog electronic technology theory, the comprehensive case teaching model is introduced into the teaching of the analog electronic technology theory course. By taking the specific comprehensive design case as an example, that is a sound and light alarm circuit based on temperature control, the positive role of the teaching model in improving students' ability of analog electronic circuit design is expounds in this paper.

Introduction

Analog electronic technology course is a compulsory basic course for electrical majors, such as automation, electrical engineering, communication engineering, electronic information, Electronic Science and so on. It is the basis for students to learn follow-up professional courses and occupies a very important position in the whole curriculum system. The course of analog electronics technology takes semiconductor diodes, semiconductor triodes and field effect transistors as its core electronic devices. It covers the voltage amplification circuit, power amplification circuit, operational amplification circuit, feedback amplification circuit, signal operation, and processing circuit, signal generation circuit, DC regulated power supply and so on.

At present, there is a general problem of fragmentation in the teaching content of analog electronic technology theory. For example, when teaching the application of operational amplifier circuit, the proportional operation circuit, addition and subtraction operation circuit, integral and differential operation circuit, voltage comparison circuit, waveform generation circuit and so on are introduced. However, students are often confused about how these circuits constitute a complete application circuit. This kind of teaching content is complicated and fragmented, which is not conducive to the construction of students' overall analog electronic circuit design ideas. In order to solve this problem, on the basis of rearranging and combing the teaching contents of analog electronic technology theory, a comprehensive case teaching model is proposed.

Application of Comprehensive Case Teaching Model

A comprehensive case of analog electronic circuits is a complete circuit with certain functions and contains at least 2-3 basic circuits. In this paper, a comprehensive design case, that is an sound and light alarm circuit based on temperature control, is taken as an example to illustrate the application of the comprehensive case teaching model in the teaching of analog electronic technology theory. The case simulation circuit is shown in Figure 1. The corresponding teaching contents are voltage comparator and RC oscillator circuit.

The sound and light alarm circuit based on temperature control alarms by sound and light when the ambient temperature exceeds 60°C. The circuit consists of four modules: temperature acquisition circuit, voltage comparator, RC oscillator circuit, and sound and light display circuit. The temperature acquisition circuit consists of a bridge composed of thermistors and linear resistors. MF52 10K/3470 with negative temperature coefficient is optional for thermistors. The thermistor has a resistance value of 10KΩ at 25°C and a resistance value of 2.825KΩ at 60°C. In the simulation circuit, potentiometer can be used to replace thermistor, as shown in Module 1 of Figure 1. The resistance R3 is set to the resistance value of thermistor at alarm temperature. The potential UR is 6V because R1 equals to R2. The potential UT varies with the ambient temperature. When the temperature is higher than 60°C, the resistance of thermistor begins to be less than 2.825 KΩ, and UT begins to be greater than 6V. The two voltage signals UR and UT output by the temperature acquisition circuit are used as inputs of the voltage comparator, as shown in Module 2 of Figure 1. A simple voltage comparator can be composed of an operational amplifier. According to the voltage transmission characteristics of operational amplifier, when UT is greater than UR, the output Uo of operational amplifier is equal to +UOM. When UT is less than UR, the output Uo of operational amplifier is equal to about 0. The simulation result of temperature acquisition and voltage comparator is shown in Figure 2.

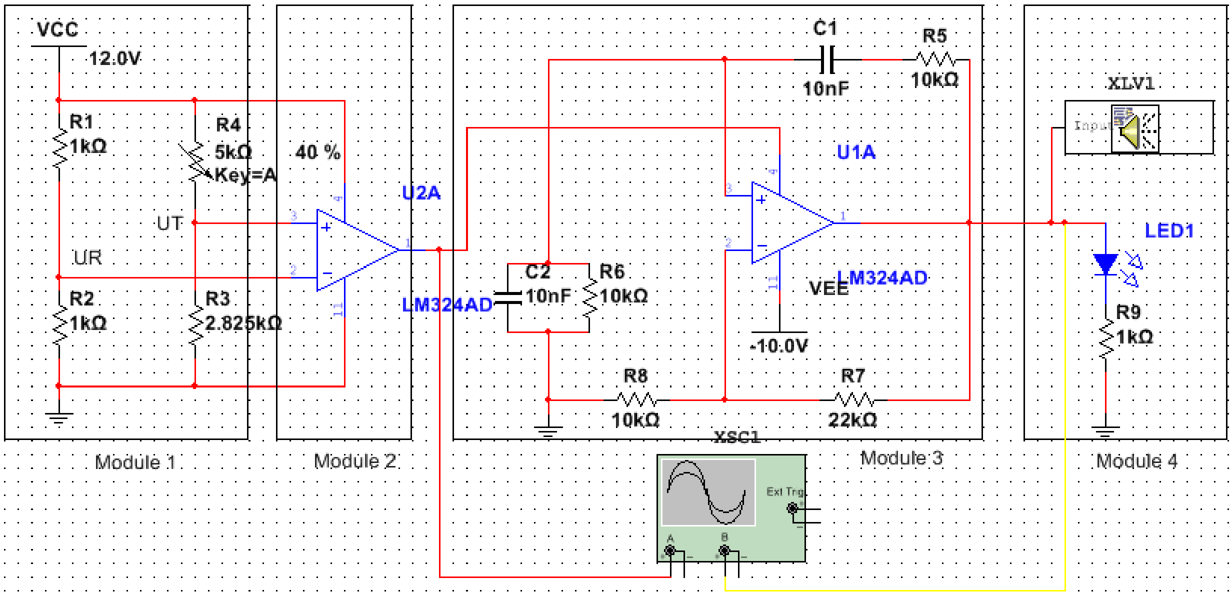


Figure 1. Sound and light alarm simulation circuit based on temperature control

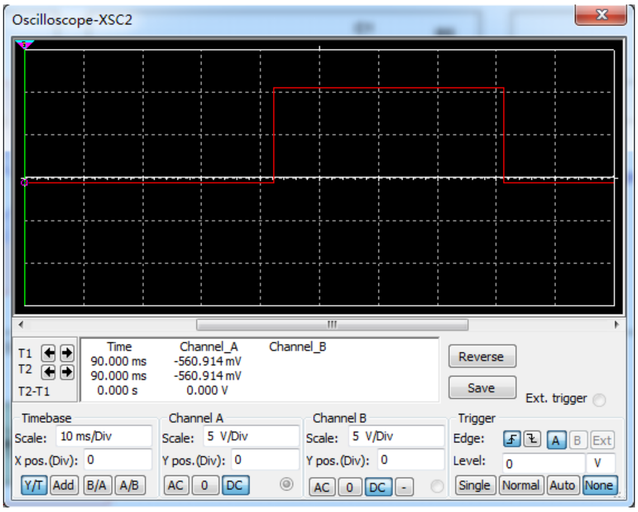


Figure 2. Simulation result of temperature acquisition and voltage comparator

When the ambient temperature exceeds 60°C, the output of the voltage comparator jumps to a high level of about 10V; when the ambient temperature is below 60°C, the output of the voltage comparator jumps again to a low level of about 0V. After module 1 and module 2, the change of temperature is transformed into the change of level of voltage. The sound alarm component used in this circuit is loudspeaker, which needs AC signal driving in 20-20KHz frequency band to make sound, so the output level of voltage comparator can not drive loudspeaker directly.

The output of the voltage comparator is connected to the positive power supply of the operational amplifier of the RC oscillator circuit to control whether the operational amplifier works or not, as shown in Module 3 of Figure 1. The oscillator circuit is composed of RC series-parallel frequency-selective network and comparable amplifier circuit. Feedback coefficient of RC series-parallel network is shown in Equation (1).

$$\dot{F}=\frac{\dot{U}_f}{\dot{U}_o}=\frac{R//\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}+R//\frac{1}{j\omega C}}=\frac{1}{3+j(\omega RC-\frac{1}{\omega RC})} \tag{1}$$

Set $f_0=\frac{1}{2\pi RC}$, and the feedback coefficient is expressed as Equation (2).

$$\dot{F}=\frac{1}{3+j(\frac{f}{f_0}-\frac{f_0}{f})} \tag{2}$$

It is written in terms of amplitude-frequency characteristic and phase-frequency characteristic, shown in Equation (3) and (4).

$$\left|\dot{F}\right|=\frac{1}{\sqrt{9+(\frac{f}{f_0}-\frac{f_0}{f})^2}} \tag{3}$$

$$\varphi_F=\arg\dot{F}=-\arctan\frac{\frac{f}{f_0}-\frac{f_0}{f}}{3} \tag{4}$$

According to the phase-frequency characteristic, only when $f=f_0$, phase-frequency characteristic $\varphi_F=\pm 2n\pi \quad n=0,1,2\cdots$. That is to say, the phase of $\dot{U}_f$ is the same as that of $\dot{U}_o$. Because the output and input of the same-phase amplifier circuit are in phase, the signal with frequency $f=f_0$ satisfies the phase balance condition of the oscillator circuit. Thus it may be known, the amplitude-frequency characteristic $\left|\dot{F}\right|$ equals to $\frac{1}{3}$.

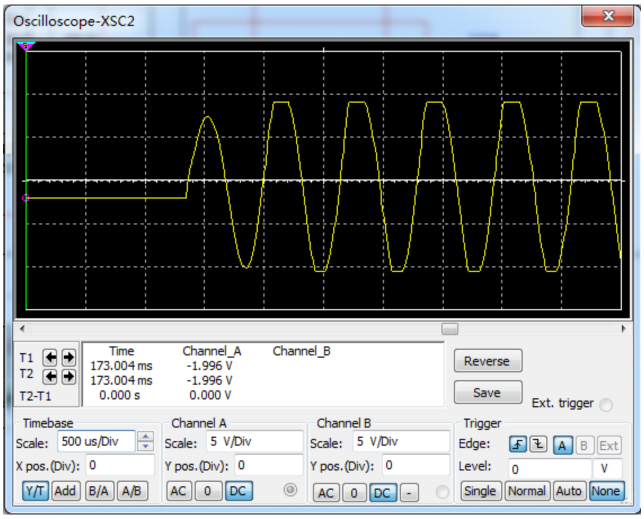
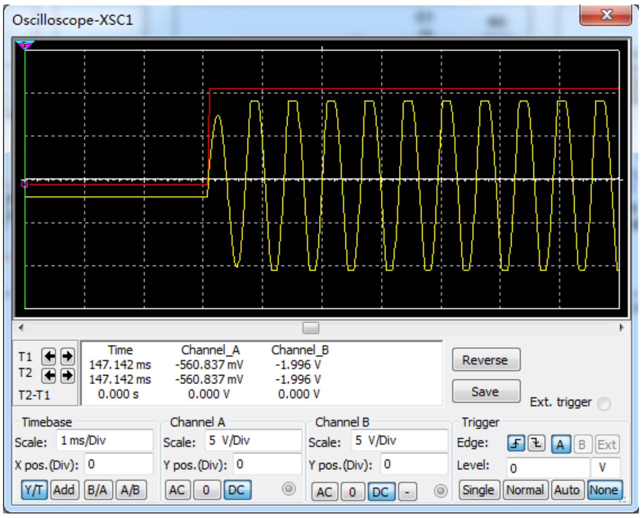


Figure 3. Simulation result of RC oscillator circuit

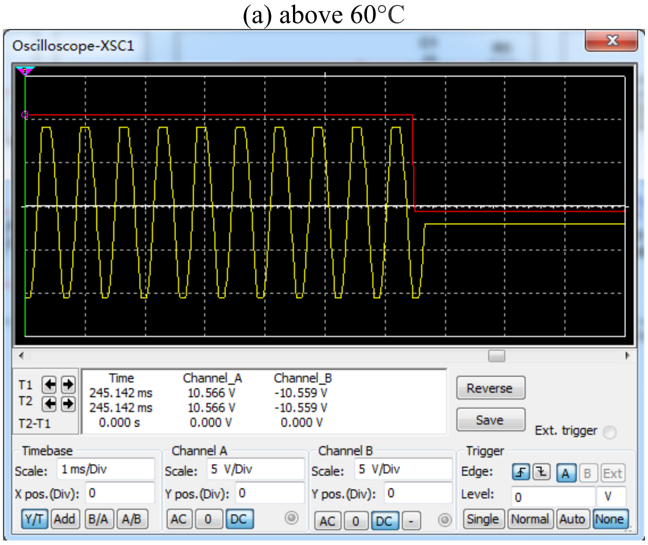
In order to satisfy the condition of amplitude balance of oscillator circuit $\left|\dot{A}\dot{F}\right|=1$, the amplification factor of the same-phase amplifier circuit should be set as $\left|\dot{A}\right|=1+\frac{R_7}{R_8}=3$, that is

$\frac{R_7}{R_8} = 2$. To ensure the reliable starting of the circuit, it can be set to slightly greater than 2. The simulation result of RC oscillator circuit is shown in Figure 3.

As shown in Figure 3, when the potentiometer is adjusted to make the comparator output high level, the oscillator circuit starts to output sine wave, but the waveform is distorted quickly. This distortion is caused by $\frac{R_7}{R_8} > 2$. To maintain a good waveform, non-linear components such as thermistor and voltage regulator can be used to stabilize the amplitude. But in this circuit, the output of RC oscillator circuit is only used to drive the flicker of light emitting diode and the sound of loudspeaker in this teaching module. Therefore the waveform requirement is not strict, so the amplitude stabilization part can be avoided. The result of circuit operation is shown in Figure 4. The red waveform in Figure 4 is the output of the voltage comparator and the yellow waveform is the output of the RC oscillator circuit. When the ambient temperature starts to be higher than 60°C, the voltage comparator outputs high level, the oscillator circuit outputs sine wave, the light emitting diode flickers, and the loudspeaker makes sound. When the ambient temperature starts to be below 60°C, the voltage comparator outputs low level, the oscillator circuit stops working, the light emitting diode does not emit light, and the loudspeaker does not make sound.



(a) above 60°C



(b) below 60°C

Figure 4. The result of circuit operation

Summary

The application of comprehensive case teaching model in the teaching of analog electronic technology theory shows that this teaching model can effectively solve the problem of fragmentation of teaching content, and is beneficial to establishment of basic design idea of analog circuit, that is "signal acquisition, signal processing, and signal output". At the same time, through abundant comprehensive case teaching, students' interest in learning and the ability to design circuits independently are greatly enhanced.

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