

The Application of EDA Technology in the Teaching of Communication Circuits

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Abstract

With the design and simulation of single and double-tuned amplifiers as an example, this paper discusses the application of NI Multisim, the advanced software, in the communication circuit teaching. Using the NI Multisim simulation platform, the parameters of various components in the circuit can be set freely. The relationship between the specific circuit parameters and the circuit performance can be investigated directly and in depth by referring to the simulation results. The proper combination of NI Multisim simulation software and the NI ELVIS platform can provide an effective training platform for improving the students' comprehensive abilities in circuit design.

Keywords

EDA; Communication Circuits; Tuned Amplifier; NI ELVIS

Introduction

Electronic communication circuit is an engineering subject, for which practical training is very important for students to raise their abilities in system design and solve problems in practical engineering. In a laboratory, the software and hardware conditions are restricted, and therefore the experiments are mainly verification experiments; i.e., the students simply connect the wires on the developed circuit modules, measure the experimental data, conduct data analyses and finally submit experimental reports. By performing these experiments, the students can be trained to use the basic experimental instruments very skillfully. However, since the circuit modules have already been developed, the parameters of the components cannot be changed and the induced variations in circuit performance cannot be observed and measured. Correspondingly, the students are uncertain of the key components that can impose significant effects on circuit performance, and therefore their systematical design abilities cannot be refined by these experimental processes in which the data have been passively measured and recorded.

The NI software Multisim has been introduced in the experimental teaching of electronic communication circuits with the aim of solving the above-described problems (HOU Haipeng, 2006). Using this simulation platform, the parameters of circuit components can be flexibly adjusted and the effects of component parameters on the circuit performance can be directly investigated. For example, in a small-signal tuned amplifier, by changing the load resistance, which is connected into the tuned network in parallel, the way that the load affects the Q-value of the loop can be investigated, and further effects can be imposed on the frequency-selecting characteristics of the amplifier (Sayre C., 2008). With regarding to a double-tuned amplifier, by means of the simulation software Multisim, the parameters of coupling capacitance in the double-tuned circuit can be scanned and then the variation process, from a single -peak to the twin-peak distribution of the frequency-selecting characteristic, can be investigated. In experiments related to electronic communication circuits, through simulation and analysis using Multisim software and the construction of hardware circuits using ELVIS software, the physical properties of a circuit can be measured using the built-in virtual instrument in the platform, and can then be compared with the simulation results. The procedure can greatly improve the efficiency and flexibility of experiments. As a consequence, the concept of design is integrated into the teaching process, and the objectives of ability-training in innovation and engineering design are then effectively achieved.

Communication Circuits Simulation

A Single-Tuned Amplifier

A tuned amplifier is an amplifier loaded with the resonance circuit, which consists of a capacitor and inductor, whose gain varies with frequency. By using a

tuned amplifier, the high-frequency signals within a certain frequency range can be magnified selectively. The resonance often tuned to the center frequencies of target signals. Due to the fact that the parallel resonance impedance of the tuned loop is quite large around the resonant frequency, a comparatively large voltage gain can be acquired in the amplifier (Gilmore R. and Besser L., 2006). When the circuit is at a frequency far away from the resonance point, the impedance of the loop decreases dramatically and the gain of the amplifier decreases accordingly. Conclusively, a tuned amplifier is a type of narrow-band amplifier with high gains and favorable frequency selections.

In this study, the focus was on the circuit of an intermediate-frequency amplifier (IF-AMP) in a frequency modulated receiver, as displayed in Fig. 2.1. By making use of the powerful circuit analysis ability of Multisim, the effects of emitter resistance on the gain of an amplifier, as well as the effects of the load resistor in an LC frequency-selective network on the frequency-selecting characteristics, were studied in this paper.

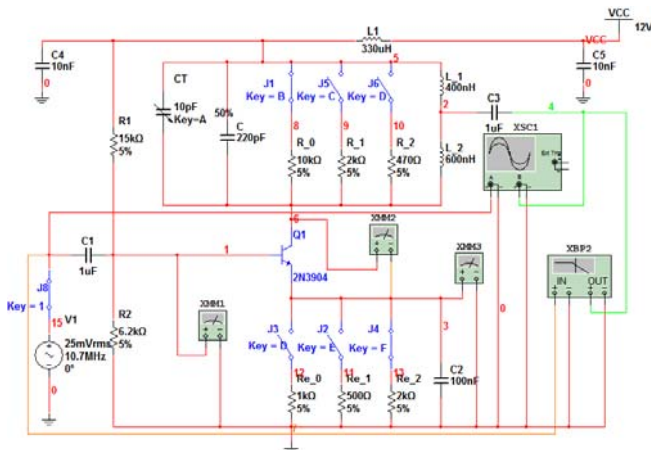


FIG. 2.1 AN INTERMEDIATE FREQUENCY SINGLE TUNED AMPLIFIER

1) The Influence of an Emitter Resistor on the Gain of a Tuned Amplifier

The frequency and amplitude of the input signals of Fig. 2.1, the simulated circuit constructed in Multisim, were set as 10.7 MHz and 25 mv, respectively. The CT of variable capacity was adjusted so that the amplifier was tuned at 10.7 MHz. The collector resistance was set as 10 KΩ, i.e., $R=R_0=10k\Omega$, while R_e was assigned to be 500, 1000, and 2000 Ω. The oscilloscope, as showed in Fig. 2.1, was used for observing the input and output waveforms, with the simulation results showed in Fig. 2.2-2.4.

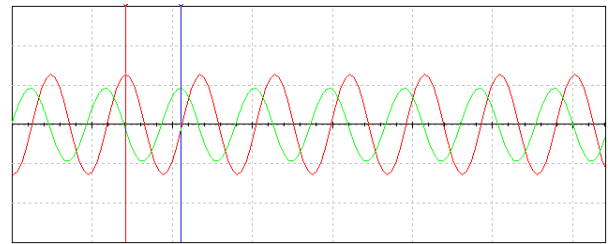


FIG. 2.2 THE $R_e=500\Omega$ INPUT AND OUTPUT WAVEFORM

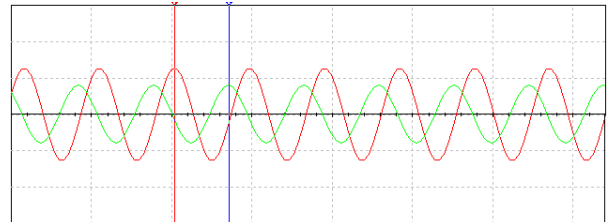


FIG. 2.3 THE $R_e=1k\Omega$ INPUT AND OUTPUT WAVEFORM

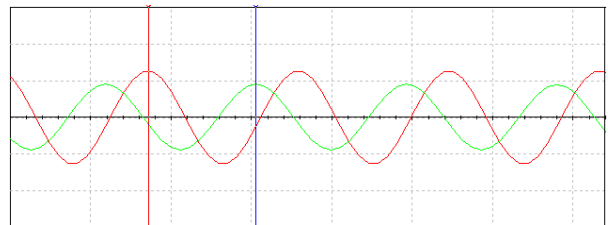


FIG. 2.4 THE $R_e=2k\Omega$ INPUT AND OUTPUT WAVEFORM

The cursor was shifted to the peak values of the input and output signals, and then the gain of amplifier (A) when R_e was set as 500, 1000 and 2000Ω were calculated according to the simulation results in Fig. 2.2-2.4. The calculation results of the gain are listed as follows:

$$A = 1.831 \text{ V} / 25.351 \text{ mV} = 72.226 \text{ dB} \text{ (} R_e = 500 \Omega \text{)}$$

$$A = 1.580 \text{ V} / 24.987 \text{ mV} = 63.232 \text{ dB} \text{ (} R_e = 1000 \Omega \text{)}$$

$$A = 899.399 \text{ V} / 24.970 \text{ mV} = 36.024 \text{ dB} \text{ (} R_e = 2000 \Omega \text{)}$$

As indicated in the simulation results, the voltage gain are reduced with the increase of R_e , with the same input signals V_i . Theoretically, R_e , which can provide negative current feedback, plays an important role in stabling the quiescent operating point of an amplifier. On the other hand, R_e sacrifices the gain of an amplifier. The following problem was assigned to students as the after-school training: as the bypass capacitance of emitter resistance in Fig. 2.1 is increased from 100 to 1000 nf, please perform simulations on the gain characteristics when R_e is 500, 1000 and 2000 Ω, compare, and give reasonable explanations for the obtained simulation results.

2) The Effect of Load Resistance on the Frequency-Selecting Characteristic of the Tuned Amplifier

The frequency-selecting characteristic of an amplifier is

referred as to its band-pass properties. The signals within a bandwidth of 3dB can be amplified effectively by an amplifier, while the signals outside of the band present a rapidly-decreasing gain.

Set $R_e=1\text{ K}\Omega$, $R=470$, 2000 and 10000Ω , respectively, the amplitude-frequency characteristic of the amplifier, was observed using the Bode Plotter, as shown in Fig. 2. The simulation results are displayed in Fig. 2.5-2.7.



FIG. 2.5 THE AMPLITUDE VERSUS FREQUENCY CHARACTERISTIC WHEN $R=470\Omega$



FIG. 2.6 THE AMPLITUDE VERSUS FREQUENCY CHARACTERISTIC WHEN $R=2\text{ K}\Omega$



FIG. 2.7 THE AMPLITUDE VERSUS FREQUENCY CHARACTERISTIC WHEN $R=10\text{K}\Omega$

Based on the simulated results as shown in Figures 2.5-2.7, the cursor was shifted to the upper and lower side frequencies, which were 3dB below the peak values, and then the 3dB bandwidth (BW) of the amplifier when the load resistance (R) was 470, 2000 and 10000Ω was calculated. Specifically:

$$BW = (11.47 - 9.933) \text{ MHz} = 1.539 \text{ MHz} (R = 470 \Omega)$$

$$BW = (10.894 - 10.442) \text{ MHz} = 0.452 \text{ MHz} (R = 2000 \Omega)$$

$$BW = (10.592 - 10.447) \text{ MHz} = 0.145 \text{ MHz} (R = 10000 \Omega)$$

The simulation results suggest that the amplitude-frequency characteristic of an amplifier is significantly affected by the load resistance R in the LC frequency-selective network. The larger the R, the narrower the pass band of the amplifier, i.e., the more preferable the frequency-selecting characteristic. As displayed in Figure 2.5, when the load resistance R is small, the frequency-selecting characteristic and gain of the amplifier can be affected. Accordingly, when designing a tuned amplifier, if the given load resistance is small, an impedance transformation should be used by partly inserting the transformer coils in order to increase the load resistance in the tuned circuit.

B Double Tuned Amplifier

The load in a double tuned amplifier is comprised of two tuned circuits coupled by an inductor or capacitor. The double tuned amplifier is commonly used in the intermediate frequency amplifier (IF-AMP) in a super-heterodyne receiver (Rowan Gilmore, Les Besser, Yang Fang and Weng Muyun, 2006). Generally, the signal tuned amplifier has a simple circuit but several defects in its properties, such as a poor frequency-selecting characteristic, uneven in-band and slow out-band attenuation. Moreover, there is a conflict between the selectivity and pass band in a single tuned circuit, which can be effectively solved by the double tuned amplifier (Gruenbacher D, Natarajan B and Kuhn W, 2006). In a double tuned amplifier, the rectangle coefficient is greatly improved. Fig. 2.8 displays the circuit of a double tuned amplifier, in which C_4 is the coupling capacitor in two tuned circuits. When C_4 was set as 5, 12, and 30pf, the amplitude-frequency characteristic of the amplifier was observed using the Bode Plotter, and the simulation results are displayed in Fig. 2.9-2.11.

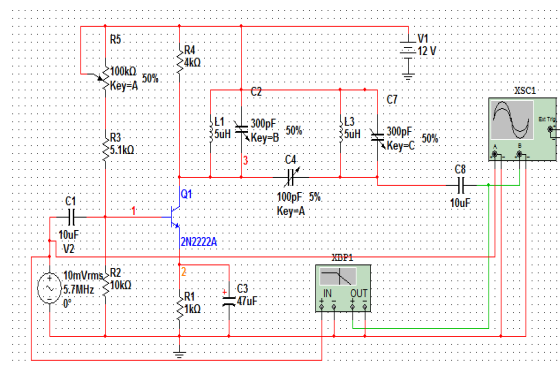


FIG. 2.8 A DOUBLE TUNED AMPLIFIER

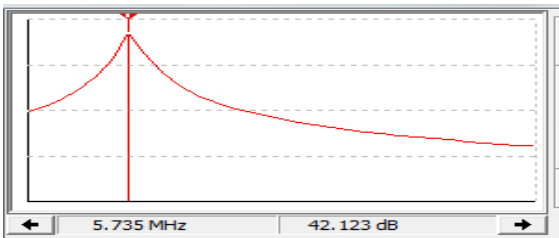


FIG. 2.9 THE AMPLITUDE VERSUS FREQUENCY CHARACTERISTIC WHEN C₄=5PF

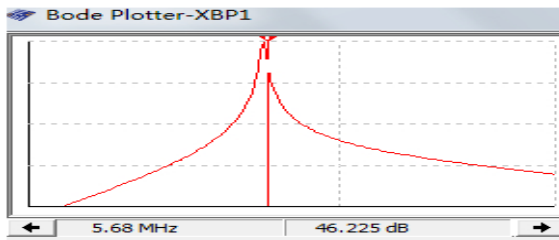


FIG. 2.10 THE AMPLITUDE VERSUS FREQUENCY CHARACTERISTIC WHEN C₄=12PF

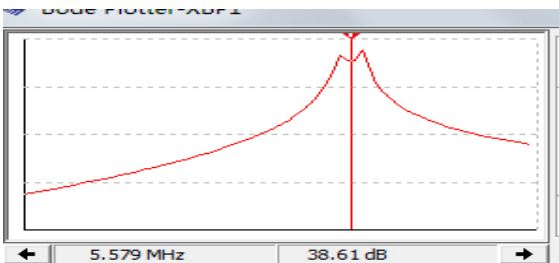


FIG. 2.11 THE AMPLITUDE VERSUS FREQUENCY CHARACTERISTIC WHEN C₄=30PF

Similarly, according to the simulated amplitude-frequency characteristics in Figures 2.9-2.11, by shifting the cursor to the upper and lower side frequencies, which were 3dB below the peak values, the 3dB bandwidth (BW) of the amplifier when C₄ was 5, 12, 30 pf can be calculated; specifically:

$$BW = (5.982 - 5.534) \text{ MHz} = 0.448 \text{ MHz} \quad (C_4 = 5 \text{ pf});$$

$$BW = (6.101 - 5.097) \text{ MHz} = 1.004 \text{ MHz} \quad (C_4 = 12 \text{ pf})$$

$$BW = (6.652 - 4.789) \text{ MHz} = 1.863 \text{ MHz} \quad (C_4 = 30 \text{ pf})$$

As can be observed from the simulation results, the coupling state of the circuit is closely related to the coupling capacitance C₄. When C₄ is small, the circuit is weakly coupled, with a narrow pass band and small gain. This state should be avoided in the design of an amplifier. As the coupling capacitance C₄ gradually increases, the circuit firstly changes to a critical coupling state while the amplitude-frequency characteristic curve is single -peaked; however, the pass band and the gain of the amplifier are more perfect compared to the situation of weakly coupled. When C₄ is further increased, the circuit becomes strongly coupled. As can be observed by the Bode

Plotter, the amplitude-frequency characteristic curve is twin-peak distribution, and the pass band becomes broader, showing a concave between two peaks. As C₄ continually increases, the concave between the two peaks becomes wider and deeper. Through simulation analyses, the coupling capacitance can be reasonably selected in accordance with the frequency-selecting characteristic of the circuit, and therefore the design objective can be achieved quickly and accurately; i.e., the design efficiency can be greatly enhanced.

The Circuit Implementation Based On NI ELVIS

The schematic circuit diagram, which had been simulated in Multisim, was constructed in the virtual ELVIS II+ platform, and thus the circuit components were connected in a virtual environment. Accordingly, it was possible to verify whether the electrical connection of the components was correct. Having been examined to be satisfactory, the hardware circuit was implemented on the physical ELVIS II+ platform, and the circuit performance was tested using the 12 kinds of ELVIS II+ built-in virtual instruments. Moreover, the test results obtained by the virtual instruments could be compared with the simulation results from Multisim. Fig. 3.1 displays the constructed hardware circuit based on the platform of ELVIS II+, in which the left part displays the circuit constructed on the built-in bread board of a prototyping board. If the circuit passed the test, i.e., the test results fitted well with the requirements, the PCB circuit as shown in the right part of Fig. 3.1 was then produced so that the stability of circuit performance could be ensured.

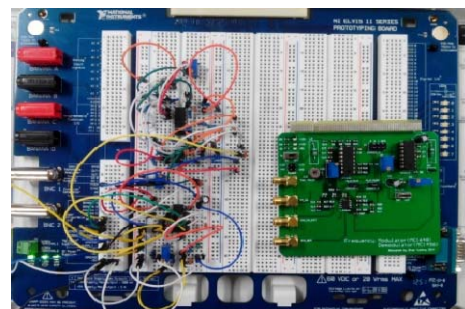


FIG. 3.1 THE IMPLEMENTATION OF A HARDWARE CIRCUIT BASED ON NI ELVISII+

The power supply and various input signals required by the circuit are provided by NI ELVIS II+. The 12 kinds of virtual instruments in ELVIS II+, with a USB interface, can be connected with the computer so that the circuit performance tests can be easily conducted and directly compared with the simulation results. Combined with fast and simple measurements and

displays, the design efficiency of communication circuits can be significantly improved (Mitchell J., Canavan B. and Smith J, 2010). The designer, whether a beginner or a veteran, can be trained on this hardware platform and complete the designs.

Conclusions

Compared with conventional cut-and-try designing methods, using Multisim to simulate circuit performance has a great advantage. Owing to the powerful simulation function of Multisim, circuit designers can change the component parameters as needed, and Multisim will provide an intuitive simulation result, which helps in knowing whether the design is suitable. If it is not, the component parameters can be optimized until the circuit performance is satisfactory. Finally, the hardware circuit is implemented on the NIELVIS II+, which integrates 12 common-used virtual instruments within the platform, and makes the circuit performance testing very easy, without any of the limitations of laboratory equipment. The most important thing is that by means of Multisim simulation, the designer gets to know the key component parameters, which best suit the circuit performance. This paper discusses the influence of the load resistor's values on the amplitude versus the frequency characteristic of a single-tuned amplifier, and the coupled capacitor's values on the amplitude versus the frequency characteristic of the double-tuned amplifier. The analyses are taken as examples to show the methods of changing the component parameters and the resulting influences on the circuit performance with the use of Multisim.

With the help of advanced EDA software, the efficiency and the possibility of successful circuit

design are greatly enhanced. Incorporating performance simulation and a physical test platform make it possible to introduce comprehensive experiments into the teaching of Communication Circuits, which will help foster students' ability as regard to both engineering problem solving and innovation.

ACKNOWLEDGMENT

The work of this paper is part of the project "High-quality engineering courses construction", funded by Shanghai Education Committee.

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