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Design and Implementation of Amplifier Circuit Based on EWB Environment

Hengyue Pan[1]

[1] School of Waterford, Nanjing University of Information Science and Technology, Nanjing, China
*Corresponding author: 202283920022@nuist.edu.cn

Abstract:

This study details the creation and execution of a common-emitter amplifier circuit utilizing the 2N2222 NPN transistor. The study explores the fundamental principles of amplifier circuits and highlights key parameters such as voltage gain, current gain, and input/output impedance. Through simulations conducted on the EWB platform, the designed amplifier circuit demonstrated significant voltage gain and phase inversion, confirming the expected characteristics of the common-emitter configuration. The results indicate that the amplifier operates effectively within a wide frequency range, showing good bandwidth and stability. This design approach can serve as a foundation for further exploration and optimization in amplifier circuit design, particularly in modern electronic devices.

Keywords: Common-emitter amplifier, 2N2222 NPN transistor, voltage gain, EWB simulation, circuit design

1. Introduction

In modern electronic technology, amplifier circuits are one of the core components of various electronic devices and systems, widely used in communication, audio processing, signal transmission, and other fields. As a fundamental analog circuit, the design and optimization of amplifier circuits are crucial for improving the performance of electronic devices[1]. The common-emitter amplifier circuit is one of the most common amplifier circuits due to its high voltage gain, large input impedance, and good frequency response characteristics. It is widely used in low- and mid-frequency amplification scenarios such as audio amplification and sensor signal amplification[2].

However, the design and analysis process of traditional amplifier circuits is complex and time-consuming, especially requiring precise simulation and optimization of performance before the actual circuit implementation[3]. In recent years, with the development of electronic design automation (EDA) tools, circuit design software has become a powerful tool for engineers to design, analyze, and optimize circuits[4]. EWB (Electronics Workbench), as one of the circuit simulation software, provides an intuitive circuit design interface and efficient simulation capabilities, greatly improving the efficiency of circuit design and analysis[5]. Using such simulation software helps deepen the understanding of the basic principles and design methods of amplifier circuits.

This paper, based on the EWB environment, designs and implements a common-emitter amplifier circuit. The amplification effect and performance indicators of the circuit were verified through EWB's simulation functions. In this paper, the design process and simulation results of the common-emitter amplifier circuit are analyzed in detail, summarizing how to design an amplifier circuit in EWB.

The first chapter of the paper is the introduction, which introduces the research background, significance, and content of the paper. Chapter 2 delves into the design and implementation of the common-emitter amplifier circuit, discussing its fundamental principles, key parameters, and the process of design, analysis, and simulation. The third chapter is the conclusion and outlook, summarizing the whole paper and detailing the aspects that future research can optimize and expand.

2. Design and Implementation of Common-Emitter Amplifier Circuit

2.1 Basic Principles of Common-Emitter Amplifier Circuit

The primary function of an amplifier circuit is to amplify the weak input signal, outputting a stronger signal while maintaining the frequency and relative waveform of the signal unchanged. Therefore, amplifier circuits are widely used in various electronic devices, such as audio amplifiers and RF amplifiers. Common amplifier circuits include common-emitter amplifiers and common-source amplifiers. This paper focuses on the common-emitter amplifier circuit.

A common-emitter amplifier is a basic amplifier circuit based on bipolar junction transistors (BJT). In this amplifier, the input signal is directed to the transistor's base, the output is drawn from the collector, and the emitter is typically connected to the ground.The common-emitter amplifier is known for producing an output signal that is 180° out of phase with the input signal and offering a significant voltage gain. This type of amplifier is highly effective in low- to mid-frequency amplification applications, making it a popular choice in audio amplification circuits[6].

2.2 Key Parameters of Amplifier Circuits

When designing and analyzing amplifier circuits, several key parameters need special attention:

Gain :

- Voltage Gain (A_v): Represents the ratio of output voltage to input voltage and is a direct indicator of the amplifier circuit's amplification capability. Voltage gain can be calculated through the impedance in the circuit and the gain characteristics of active devices.
- Current Gain (A_i): Represents the ratio of output current to input current, typically expressed as the transistor's current gain (β) in a common-emitter amplifier.
- Power Gain (A_p):This measures the ratio of output power to input power, highlighting the circuit's efficiency in converting the input signal into a more powerful output signal.

Impedance :

- Input Impedance($\mathbf{R}_{in}$): This parameter indicates the impedance encountered by the signal source. Higher input impedance suggests that the circuit places less load on the signal source, thus minimizing its impact on the signal's characteristics. In a common-emitter amplifier, input impedance is generally lower, while in a common-source amplifier, it tends to be higher.
- Current Gain ($\mathbf{R}_{out}$): This describes how well the amplifier is matched with the load. A lower output impedance is typically preferable for driving low-impedance loads, as it reduces power loss and enhances efficiency. Output impedance is often optimized through the use of negative feedback.

2.3 Implementation and Simulation of the Common-Emitter Amplifier Circuit

Figure 1 shows a common-emitter amplifier circuit designed using the 2N2222 NPN transistor in EWB simulation software. The goal is to amplify the input signal. The design process begins with selecting appropriate circuit components, considering key factors such as voltage gain, input and output impedance, and frequency response[7]. The specific design is shown in Figure 1:

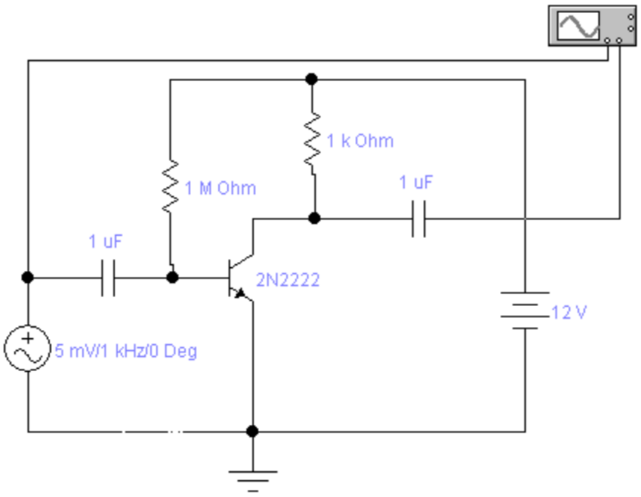


Fig. 1 Design of the common-emitter amplifier circuit using 2N2222 NPN transistor

The 2N2222 transistor was chosen as the core amplification element due to its high current gain and moderate operating voltage, as well as its good amplification characteristics in low- and mid-frequency ranges. The circuit is powered by a $12\,V$ DC power supply, which is a suitable power supply voltage for common amplifier circuits, providing sufficient voltage margin for the transistor while maintaining circuit stability. A $1\,k\Omega$ resistor R_B is used to provide bias current to the transistor's base, ensuring the transistor operates in the amplification region. This bias current ensures that the transistor can quickly enter the proper working state when receiving the signal. A 1kΩ resistor R_c is placed between the collector and the power supply to primarily establish the voltage gain[8]. A larger load resistor can provide higher gain but will also affect the circuit's frequency response. Two $1\,\mu F$ coupling capacitors are used for signal coupling at the input and output, serving to block the DC component while allowing the AC signal to pass, thus preventing DC current from affecting signal transmission[9]. The input signal is a 1kHz sine wave with a $5\,mV$ amplitude, representing a low-level audio signal to evaluate the amplifier circuit's performance. Figure 2 presents the voltage and current data obtained during the static operating point simulation of the circuit shown in Figure 1.

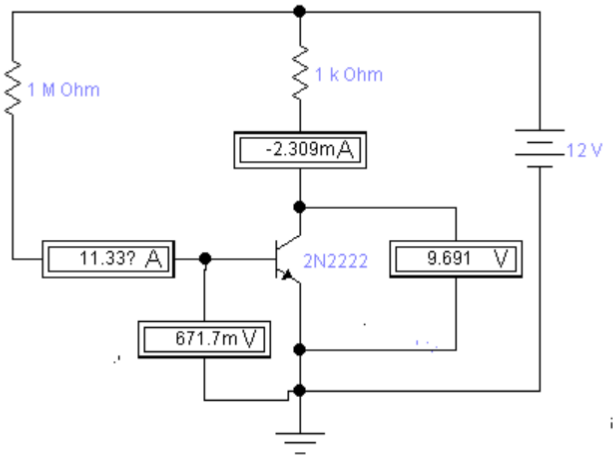


Fig. 2 Static operating point of the common-emitter amplifier circuit designed using the 2N2222 NPN transistor

The static operating point is the state of the transistor when no signal is input. It is determined by the base current I_{BQ}, collector current I_{CQ}, and collector-emitter voltage U_{CEQ}. The simulation data in Figure 2 can be listed in Table 1:

Table 1.Voltage and current data measured at the static operating point during simulation

Basic Current I_{BQ}	Collector Current I_{CQ}	Base-Emitter Voltage U_{BEQ}	Collector-Emitter Voltage U_{CEQ}
11.33 μA	-2.309 mA	671.7 mV	9.691 V

I_{BQ} = 11.33 μA, indicating that the current through the base is relatively small.

I_{CQ} = -2.309 mA, the negative sign signifies that the direction is contrary to the established convention (i.e., the direction from the collector to the inside of the transistor).

U_{CEQ} = 9.691 V, this voltage represents the voltage measured between the collector and ground.

Usually, the U_{BEQ} of a silicon transistor is greater than 0.6-0.7 V, which will turn on. Here, U_{BEQ} = 671.6 mV, which has reached the conduction voltage range, indicating that the transistor is in conduction and has entered the amplification state.

The emitter voltage UE is usually grounded, so U_E is 0 V .

The transistor's current gain can be determined using the data provided above:

$$\beta = \frac{I_{CQ}}{I_{BQ}} = \frac{2.309\text{mA}}{11.33\mu A} \approx 203.8 \tag{1}$$

Usually, the U_{BEQ} of a silicon transistor is greater than 0.6-0.7 V, which will turn on. Here, U_{BEQ} = 671.6 mV , which has reached the conduction voltage range, indicating that the transistor is in conduction and has entered the amplification state. In this common-emitter amplifier circuit, the voltage gain is determined by the following formula:

$$A_v = -\beta \times \frac{R_C}{r_{be}} \tag{2}$$

Where $r_{be} = \beta \times r_e$, and the voltage gain expression can be simplified as

$$A_v = -\frac{R_C}{r_e} \tag{3}$$

where R_C is the collector resistor, R_E is the emitter resistor; r_{be} represents the dynamic input resistance between the base and emitter, also known as input impedance, reflecting the relationship between base current and voltage changes in the voltage amplifier; r_e is the dynamic part of the emitter resistor, which can be approximated as

$$r_e = \frac{26mV}{I_E} \tag{4}$$

where I_E is the emitter current, which is approximately equal to the collector current I_C [10]. This leads to the following calculations:

$$R_C = 1\ \text{k}\Omega \tag{5}$$

$$I_E \approx I_C = 2.309\text{mA} \tag{6}$$

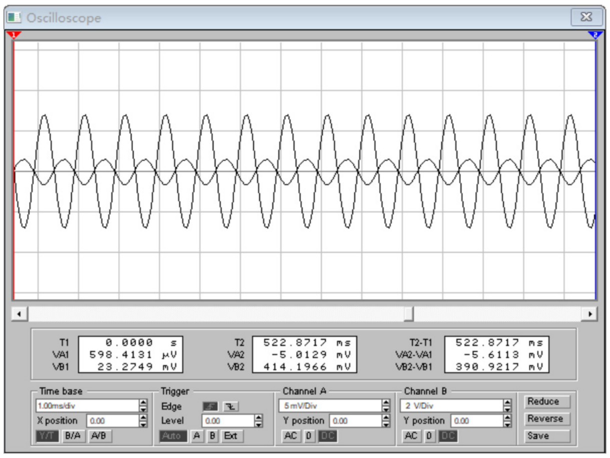
$$r_e = \frac{26mV}{I_E} = \frac{26mV}{2.309\text{mA}} \approx 11.26\Omega \tag{7}$$

This can be substituted into the voltage gain formula:

$$A_v = -\frac{R_C}{r_e} = \text{-}88.8 \tag{8}$$

Thus, the voltage gain of this common-emitter amplifier circuit is −88.8.

Figure 3 shows the simulated waveform diagram of the circuit in Figure 1 after it is powered on.



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T1     0.0000   s     T2   522.8717 ms    T2-T1     522.8717 ms
VA1  598.4131  µV     VA2   -5.0129 mV    VA2-VA1    -5.6113 mV
VB1   23.2749  mV     VB2  414.1966 mV    VB2-VB1   390.9217 mV
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Time base: 1.00ms/div
X position: 0.00
Y/T B/A A/B

Trigger: Edge
Level: 0.00
Auto A B Ext

Channel A: 5 mV/Div
Y position: 0.00
AC 0 DC

Channel B: 2 V/Div
Y position: 0.00
AC 0 DC

Fig. 3 Simulated waveform diagram of the common-emitter amplifier circuit designed using the 2N2222 NPN transistor

According to the simulated waveform diagram, there is a 180° phase inversion between the output signal and the input signal, and the output signal is indeed amplified while maintaining the relative sinusoidal waveform. This shows that the circuit successfully amplifies the signal and can operate over a wide frequency range. Based on the simulation results, the circuit's gain, bandwidth, and stability can be further optimized to meet specific application needs.

3. Conclusion

This paper explores the basic principles and key parameters of amplifier circuits through the design and simulation of a common-emitter amplifier circuit. Supported by the EWB simulation platform, the amplification effect of the common-emitter amplifier circuit designed using the 2N2222 NPN transistor was successfully verified. The output signal not only achieved the expected voltage gain but also exhibited a 180° phase inversion relative to the input signal, in line with the characteristics of the common-emitter amplifier.

Future research and applications can be expanded and optimized in the following areas.In practical applications, the component parameters in the circuit can be further optimized to achieve higher amplification effects and lower noise levels. At the same time, exploring more advanced simulation software and tools to improve design efficiency and simulation accuracy. Besides the 2N2222 NPN transistor, other types of transistors, such as MOSFET or JFET, can be used for design to meet performance requirements in different application scenarios .Also ,Combine the amplifier circuit with other circuit modules and apply it to more complex systems, such as signal processing, communication equipment, and audio amplification, to further verify its performance and reliability. In addition, Deepen the study of the impact of external factors such as temperature and frequency response on circuit performance, ensuring the stability and reliability of amplifier circuits in different working environments.

Through in-depth exploration of these research directions, the design of amplifier circuits will become more mature, providing stronger support for the development of modern electronic technology.

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