

Application Of High Bandwidth Two-Stage Amplifier in Communication System

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Abstract. With the rapid development of communication technology, the application of high-bandwidth amplifiers in communication systems becomes more and more important. Currently researchers have applied high bandwidth two-stage amplifier technology in many fields such as cloud computing and data centers, video and audio transmission, virtual reality and augmented reality, Internet of Things, financial transactions, etc., and in this paper we will focus on its application in communication systems. In this paper, the basic principle and structure of two-stage amplifier are firstly described, and then the key theories of high-bandwidth technology including its concept, importance, principle and core technology of high-bandwidth design technology as well as stability analysis and design are elaborated, and the applications of high-bandwidth two-stage amplifiers in wireless communication system, fiber optic communication system, data center network, and satellite communication are enumerated. In summary, high-bandwidth two-stage amplifiers play a key role in a variety of communication systems, helping to provide stable, high-speed, long-range signal transmission. Through the research of this thesis, it is expected to provide new references and ideas for the research and development in the field of communication technology, and to promote the progress and innovation of communication system.

Keywords: High-bandwidth; Communication system; Two-stage amplifier.

1. Introduction

With the rapid development of communication technology, the application of high-bandwidth amplifier in communication system becomes more and more important. High-bandwidth amplifiers can expand the signal amplitude and transmit data, so that the communication system can process a large amount of data more effectively in the process of information transmission and improve the efficiency and reliability of communication [1]. As a common amplifier topology, two-stage amplifiers are widely used in communication systems because of their good performance at high frequencies. Researchers have already applied the high bandwidth two-stage amplifier technology in various fields such as cloud computing and data centers, video and audio transmission, virtual and augmented reality, Internet of Things, and financial transactions, etc.

The purpose of this thesis is to explore the application of high-bandwidth two-stage amplifiers in communication systems, and to study their advantages and characteristics in data transmission, signal processing and other aspects. In this paper, the basic principle and structure of the two-stage amplifier, including the first stage amplifier, the second stage amplifier, the power supply and bias circuit, and the feedback network, are firstly described. Then the key theories of high bandwidth technology including its concept, importance, principles and core technology of high bandwidth design technology and stability analysis and design are explained. Applications of high-bandwidth two-stage amplifiers in wireless communication systems, fiber-optic communication systems, data center networks, and satellite communications are listed.

By analyzing and elaborating its theoretical basis and practical applications, it aims to reveal the importance of high-bandwidth two-stage amplifiers in communication systems and the prospect of future development. Through the research of this thesis, it is expected to provide new references and ideas for the research and development in the field of communication technology, and to promote the progress and innovation of communication systems.

2. Basic principle of two-stage amplifier

The structure of two-stage amplifier is shown in figure 1. Two-stage amplifier is a common electronic component, usually by the first stage amplifier, coupling elements, the second stage amplifier, power supply and bias circuits and feedback networks.

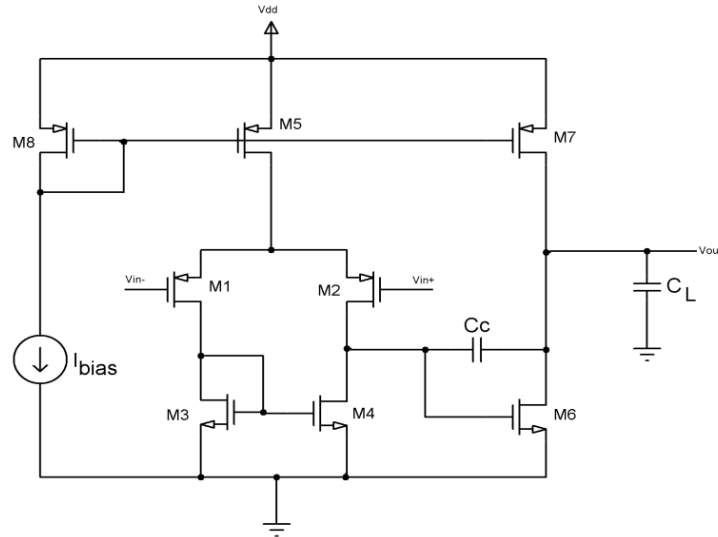


Fig. 1 Two or more references (Photo/Picture credit: Original)

2.1. First stage amplifier

The first stage amplifier is the first part of the whole amplifier circuit and plays the role of amplifying the input signal. It receives and amplifies the input signal and outputs it to the coupling element. In terms of connection, the input of the first stage amplifier is usually connected to the signal source through a coupling element, and the output is connected to the second stage amplifier through another coupling element. The purpose of this connection is to allow the input signal to be passed to the second stage amplifier, where it is gradually amplified throughout the amplifier circuit. The first stage amplifier increases the total gain of the circuit by amplifying the input signal, providing a powerful enough signal for the subsequent circuits.

2.2. Second stage amplifier

The second stage amplifier is the second level in the whole amplifier circuit, mainly responsible for further amplifying the signal processed by the first stage amplifier. Its principle of operation is similar to the first stage amplifier, receiving signals from the coupling element, and further amplification. In the second stage amplifier, the amplitude of the signal voltage generated at the output is larger than that at the input, and after this stage of amplification, the distortion and noise problems that may be encountered need to be handled carefully while ensuring that the signal is expanded properly. Through reasonable design of connection and parameter setting, the second stage amplifier can effectively improve the overall amplifier gain and performance, so that the signal can be transmitted and processed more accurately.

2.3. Power Supply and Bias Circuit

The structure of bias circuit is shown in figure 2. Power supply and bias circuits play a crucial role in the two-stage amplifier. The power supply is mainly responsible for providing stable voltage and current for the whole amplifier to ensure that the amplifier works properly. In this process, a properly designed power supply can provide the required power supply efficiency and output power and reduce the effect of power supply noise. Meanwhile, bias circuits are used to ensure that the amplifier operates at the proper operating point so that the amplifier can perform at its optimum operating

condition. By carefully designing the bias circuit, the bias current of the amplifier can be effectively controlled to optimize efficiency and improve the linearity and stability of the amplifier.

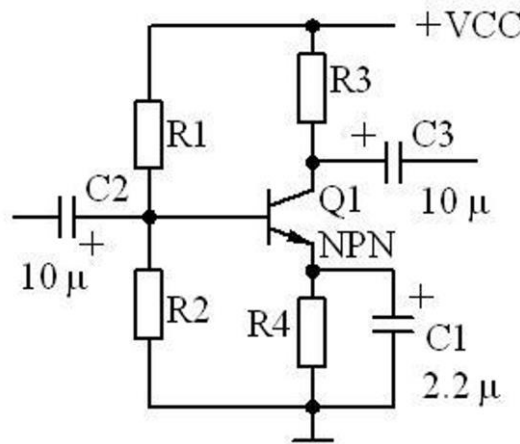


Fig. 2 Bias circuit (Photo/Picture credit: Original)

2.4. Feedback network

The feedback network plays a vital role in the electronic amplifier. It can be part of the output signal feedback to the input, to achieve the control of the amplifier gain, frequency response and stability [2]. Specifically, the feedback network can be roughly divided into two types of positive feedback and negative feedback. Positive feedback will add part of the output signal to the input, increasing the amplifier's output waveform distortion, which is not conducive to the stability of amplifier performance; while negative feedback suppresses a part of the output signal and feeds it back to the input, which helps to improve the linearity and stability of the amplifier, and reduces distortion. Common feedback networks include voltage feedback and current feedback, which are selected according to different application scenarios. Overall, feedback networks play a key role in two-stage amplifiers, and through careful design and adjustment, amplifier performance can be effectively optimized to meet different application requirements.

3. High-bandwidth design techniques

3.1. The concept of high bandwidth design technology

High-bandwidth design technology refers to a series of advanced technical means and design strategies in the field of information transmission to realize the demand for high-speed data transmission in the field of network and communication. With the arrival of the information age, people's demand for data transmission speed and efficiency is increasing, and high-bandwidth design technology becomes more and more important because it can meet this demand.

3.2. The importance of high-bandwidth design technology

The importance of high bandwidth design technology is that it can provide users with faster and more stable network connection experience. With the development of the digital era, people's demand for network speed and bandwidth is increasing, the application of high-bandwidth design technology can not only meet the diversified needs of users for high-definition video, online games, telecommuting and other diversified needs, but also for the development of the Internet of Things, 5G communications, cloud computing and other emerging fields to provide a solid technical support. Therefore, high bandwidth design technology has become one of the key factors to promote the progress and innovative development of the information society.

3.3. Principle and core technology of high-bandwidth design technology

The principle and core technology of high-bandwidth design technology cover various aspects. First of all, high bandwidth design technology needs to consider the optimization of data transmission rate, like how to effectively increase the data transmission speed to meet user needs [3]. Secondly, in terms of hardware design, including signal processing technology, high-speed wiring technology and high-frequency circuit design all play an important role. In addition, optimization of software aspects is also crucial, such as algorithm design, data compression and decompression techniques, and optimization of network protocols can enhance the overall performance of the system. Taken together, the principles and core technologies of high-bandwidth design technology are multifaceted, requiring hardware and software to cooperate with each other in order to realize the efficient operation of the system.

3.4. Stability analysis and design

High-bandwidth design technology is very important in the field of modern communications, but its stability analysis and design also face some challenges. The following are some common stability analysis and design considerations:

Signal Interference and Noise: In high bandwidth design, signal interference and noise may have an impact on signal quality. Therefore, suitable anti-interference and noise suppression measures are required, such as the use of shielding, filters, and adjustment of signal transmission parameters.[4]

Time delay and phase distortion: In high-bandwidth design, the time delay required for signal transmission as well as phase distortion may occur, which may lead to signal instability. Therefore, attention needs to be paid to time delay compensation and phase calibration during the design process to ensure stable signal transmission.

Power Management: High bandwidth designs usually require high power support, which may lead to heat buildup and excessive power consumption. Appropriate power management strategies need to be considered in the stability analysis to ensure stable operation of the device.

Data Rate: In high-bandwidth designs, the data rate is often very high, which may lead to packet loss or errors during data transmission. Therefore, techniques such as data transmission rate limiting and error correction codes need to be considered during the design process to ensure the stability of data transmission.

System Integration: In high bandwidth designs, integration between different components may lead to stability problems due to high system complexity. Therefore, adequate system testing, and verification are required to ensure compatibility and stability among the components.

4. Application of high-bandwidth two-stage amplifier in the communication system

High-bandwidth two-stage amplifiers are widely used in the direction of communication. The following are some of the common application scenarios:

4.1. Wireless communication system

High-bandwidth two-stage amplifiers can be used to enhance the signal strength in wireless communication systems, thereby expanding the signal coverage and increasing the data transmission rate. For example, they can be used in mobile communication base stations or wireless local area network (WLAN) devices.

Xin Zhou of Hangzhou University of Electronic Science and Technology (HUST) used a hybrid design strategy to simplify the design of broadband high-efficiency power amplifiers [5]. The strategy combines the theoretical impedances of hybrid continuous-mode power amplifiers with a new circuit that realizes these theoretical impedances. The new circuit can be realized only by a single-stage coupler with improved termination and impedance-frequency modulation characteristics. This hybrid design strategy can effectively reduce the complexity and footprint of mixed-continuous-mode class

designs. Test results show that the realized power amplifier has a saturated output power of 40.2-42.7 dBm in the frequency range of 0.4-3.0 GHz, a drain efficiency of 60.4-74.5%, and an area of $48.3 \times 24.6 \text{ mm}^2$.

The L-band RF amplifier module designed by Sujie Cheng is based on transverse double-diffused metal-oxide-semiconductor (LDMOS) transistor as the core device, and the DC parameters and impedance points of the power tubes are obtained by using load pulling system, probe table and other equipment's, and the matching circuit adopts the broadband matching technology, and the frequency characteristics of microstrip transmission line and capacitive components are used to realize the broadband performance [6]. RF amplifier module using three-stage cascade amplification signal, by analyzing the advantages and disadvantages of various types of broadband RF amplifier basic circuit structure, the final stage of the RF amplifier selected balanced broadband circuit structure, the circuit structure has a broadband impedance matching, as well as high power output and other characteristics. A four-port directional coupler is used at the end of the RF amplifier module to realize power detection. Using AD software to complete the RF amplifier module schematic, layout drawing, and finally complete the physical assembly, debugging and testing. Test data show that the RF amplifier module can be well used in radar or wireless communication transmitter link, which has good engineering application value.

4.2. Fiber-optic communication system

In fiber-optic communication networks, high-bandwidth two-stage amplifiers are widely used to amplify and regenerate fiber-optic signals. They can convert optical signals into electrical signals and increase the signal strength and quality by electronic amplification.

Wu Junyu propose the use of high-bandwidth erbium-doped fiber amplifiers to replace the forward-distributed Raman pump amplifiers in the unrepeated communication system of the unrepeated communication system architecture, and through the simulation platform modeling and analysis of the comparative method, it is concluded that the use of high-power pumping to increase the signal optical power into the fiber to achieve the traditional unrepeated communication system of the forward Raman pump amplification gain, and more suitable with wave division to increase the signal strength and quality. effect and is more suitable to cooperate with WDM technology to realize higher speed relay less communication transmission [7]. Through experiments, it has been confirmed that the unrepeated communication system using only the EDFA pump amplification structure can achieve a single channel unrepeated communication transmission at a 10G rate over a distance of 500km, and in combination with the WDM system, it can achieve a communication transmission at a rate of $4 \times 10\text{G}$ over a span of 500km fiber optic links.

4.3. Data center network

With the development of cloud computing and big data applications, data centers need to handle large amounts of data traffic. The use of high-bandwidth two-stage amplifiers can achieve high-speed data transmission and processing to ensure stable data transmission in the data center network.

The limiting amplifier designed by Chen Yande consists of a limiting amplifier main path, a DC misalignment cancellation circuit, a signal loss detection circuit, a fully differential structure, a sense of peaks, equalization technology, a DC misalignment cancellation circuit, and a signal loss detection circuit with a programmable threshold, which suppresses the common-mode noise of the circuit in a limited fashion, improves the bandwidth of the limiting amplifier and the integrity of the signal, and reduces the effect of the mismatch of the devices on the performance of the circuit, and improves the versatility of the circuit [8]. It improves the versatility of the circuit and realizes a high-speed limiting amplifier suitable for 25Gbps information transmission rate.

4.4. Satellite communication

Satellite communication systems usually require low signal loss and good signal quality over long transmission distances. High-bandwidth two-stage amplifiers can be used as relay stations in satellite communications to provide powerful signal amplification to ensure reliable signal transmission.

Xingsheng Chen have solved four key technical difficulties in power synthesis, thermal design, pre-distortion technology, gain flatness design, and solved four key technical difficulties in power synthesis, thermal design, pre-distortion technology, and gain flatness design. Key technical difficulties, solved the high-density circuit board temperature gradient sintering control and small-size components sintering easy to monument and other key process technologies, and ultimately realize the high-frequency, high-power, miniaturization of the Weitong amplifier, while meeting the high linearity, high harmonic clutter suppression, a wide range of operating temperatures, the realization of the solid-state power amplifier RF input signal amplified by the RF gain unit and the RF driver unit to promote the final entry into the final stage [9]. High-power combined power amplifier for its power amplification, output power of up to 150W or more, power supply unit for the solid-state amplifier to provide energy, monitoring circuit unit for the solid-state amplifier to provide secondary power supply and monitoring (such as over-voltage, over-current, over-excitation, over-reflection, over-temperature and other alarm protection) function.

Zhang Xuechao adopts millimeter-wave GaN power chip gain characteristics of high-reliability linearization technology, small-scale high-density and high-efficiency AC/DC power supply technology and lightweight and high-efficiency heat dissipation technology, small-scale and high-efficiency power amplifier module and micro-assembly process and other core technologies and processes, to meet the demand of 5G communications on power amplifiers for higher frequency and higher power, replacing foreign traveling wave tube and gallium arsenide power amplifier products, solving the problem of short life and embargo, providing high-quality satellite communications, 5G communications, civil and commercial aerospace low-cost base stations, etc [10]. It can meet the demand for higher frequency and higher power of power amplifier for 5G communication, replace foreign traveling wave tube and GaAs power amplifier products, solve the problems of short life and embargo, and provide high-quality domestic core solid-state power amplifier equipment for satellite communication, 5G communication, and civilian commercial aerospace low-cost base station.

5. Conclusion

The stability analysis and design of high-bandwidth design techniques need to comprehensively consider multiple factors such as signal interference, time delay, power management, data transmission rate and system integration, and ensure the stability and reliability of high-bandwidth systems through reasonable technical means and strategies. In summary, high-bandwidth two-stage amplifiers play a key role in a variety of communication systems, helping to provide stable, high-speed, long-range signal transmission.

However, in practical application, high-bandwidth design technology faces many challenges. Firstly, with the increasing amount of data, the transmission speed requirement is getting higher and higher, which puts forward higher requirements for communication equipment and network architecture; secondly, the high-bandwidth design technology needs to solve the problems such as delays and packet loss that may occur in data transmission, to ensure the stable transmission of data; in addition, with the rapid development of the Internet of Things, cloud computing and other emerging fields, more flexible and scalable high-bandwidth design technology is needed.

In response to these challenges, engineers are constantly exploring innovations. They are researching and developing new high-speed communication protocols and technologies to enhance data transmission speed and stability; they are also optimizing transmission routes and network topologies to reduce latency and increase data throughput; and they are also researching how to combine high-bandwidth design techniques with new technologies, such as artificial intelligence and edge computing, to achieve more intelligent and efficient network transmission. Through continuous

efforts and innovations, it is believed that high-bandwidth design technology will usher in a brighter future.

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