1.6 Amplifiers:

Classification of Output Stages

Amplifiers are classified into various output stages based on their operating conditions, efficiency, and distortion characteristics:
Class A amplifiers are known for their linearity and low signal distortion because the active device conducts for the entire 360° of the input cycle. However, their inefficiency arises from continuous power dissipation in the output device, even during idle operation. These amplifiers are commonly used in low-power audio amplification where signal fidelity is critical.
Class B amplifiers improve efficiency by using two transistors, each conducting for half the cycle (180°). The push-pull configuration reduces power wastage but introduces crossover distortion at the zero-crossing point of the waveform. This distortion makes Class B amplifiers unsuitable for high-quality audio applications without additional circuitry.
Class AB amplifiers bridge the gap between Classes A and B by slightly biasing both transistors to conduct for a little over 180°. This design minimizes crossover distortion while achieving better efficiency than Class A. Due to this balance, Class AB amplifiers are extensively used in audio power amplification.
Class C amplifiers, in contrast, conduct for less than 180° of the input cycle. This mode significantly enhances efficiency but generates high levels of distortion. As a result, Class C amplifiers are limited to RF and high-frequency applications where signal fidelity is less critical, and the focus is on power efficiency.

Class A Output Stage

The Class A output stage operates with the active device (usually a transistor) biased in such a way that it remains in the active region throughout the entire input signal cycle. This ensures continuous conduction and minimizes distortion. However, this continuous operation results in high power loss as heat, leading to poor efficiency. Heat sinks are often employed to manage thermal dissipation. Despite its inefficiency, the Class A output stage is valued for its high fidelity and is commonly used in audio amplifiers and small-signal applications requiring minimal distortion.

Class B Output Stage

The Class B output stage addresses the inefficiency of Class A by utilizing two complementary transistors in a push-pull configuration. Each transistor handles one-half of the input waveform, effectively halving the power dissipation compared to Class A. However, the abrupt switching between the transistors at the zero-crossing introduces crossover distortion. To mitigate this issue, Class AB amplifiers, which maintain slight conduction overlap, are preferred in audio applications.

Class AB Output Stage

Class AB amplifiers operate with transistors biased slightly above cutoff, ensuring that both transistors conduct during the zero-crossing of the waveform. This overlap eliminates the crossover distortion inherent in Class B designs while retaining much of the efficiency advantage. The design involves careful biasing, often using diodes or temperature-compensating circuits, to maintain stability and minimize thermal drift. Class AB amplifiers are ubiquitous in audio power amplification, offering an excellent compromise between fidelity and efficiency.

Biasing the Class AB Stage

The Class AB stage requires precise biasing to achieve optimal performance. The bias voltage ensures that the transistors remain slightly conductive during the zero-crossing of the input signal, preventing distortion. This bias voltage is typically set using a combination of diodes, resistors, and thermistors to maintain temperature stability. Improper biasing can lead to thermal runaway, distortion, or inefficiency, underscoring the importance of careful design and implementation.

Power BJTs

Power bipolar junction transistors are designed to handle high currents and voltages, making them essential for power amplifiers and switching applications. They feature a robust construction with large junction areas to manage heat dissipation effectively. Power BJTs operate in the active region for amplification and the saturation or cutoff regions for switching. Their performance is characterized by parameters like current gain, thermal resistance, and switching speed. Applications include motor drives, inverters, and power supplies.

Transformer-Coupled Push-Pull Stages

In transformer-coupled push-pull amplifiers, the output stage uses a transformer to combine the outputs of two transistors operating in push-pull mode. The transformer provides impedance matching between the amplifier and the load, improving power transfer efficiency. This configuration reduces even-order harmonics, enhancing the fidelity of the amplified signal. Although widely used in early audio amplifiers, transformer coupling has been largely replaced by modern designs due to its bulk and potential bandwidth limitations.

Tuned Amplifiers

Tuned amplifiers are specialized circuits designed to amplify signals at a specific frequency or within a narrow frequency band. These amplifiers incorporate resonant LC circuits in their design to achieve high selectivity and gain at the desired frequency. Tuned amplifiers are extensively used in communication systems, such as radio and TV receivers, to filter and amplify specific signals while rejecting noise and interference. Their performance depends on factors like quality factor (Q), bandwidth, and stability.

Op-Amps

Operational amplifiers are highly versatile electronic components used in a myriad of analog applications. They feature high open-loop gain, high input impedance, and low output impedance, making them ideal for signal amplification and processing. Op-amps can be configured in various ways, such as inverting and non-inverting amplifiers, integrators, differentiators, and voltage followers. They are integral to analog computing, active filters, oscillators, and instrumentation. Modern op-amps are implemented as integrated circuits, offering excellent performance and reliability in compact packages.