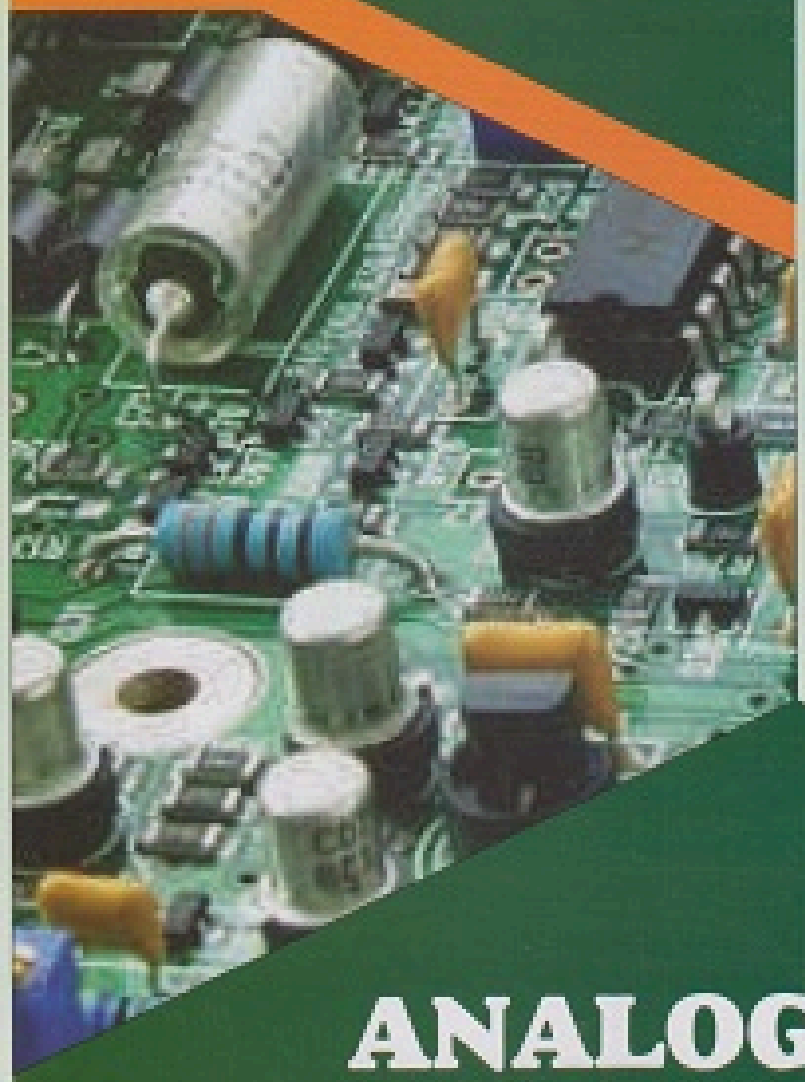
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Engineering and Technology

DIGITAL ELECTRONICS/ELECTRONICS AND TELECOMMUNICATION/
ELECTRONICS AND COMMUNICATION/ELECTRONICS/INSTRUMENTATION/
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SEMESTER-III



ANALOG ELECTRONICS

KISHOR P. AKOLE
DEEPAK A. KULKARNI

NIRALI PRAKASHAN
ABUNDANCE OF KNOWLEDGE

A Text Book Of

ANALOG ELECTRONICS

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For

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Preface ...

We take an opportunity to present this book entitled as **"Analog Electronics"** to the students of **Third Semester (Diploma in Electronics Engineering)** as per 'K' scheme. The object of this book is to present the course matter in a most **concise, compact, to the point, simple** and **lucid manner**. This book has been written strictly according to the Syllabus and industry need.

This book has been written constantly keeping in mind the requirements of all the students regarding the latest and changing trend of the Board examinations. It is also written in an **easy style**, with full details and **illustrations**. All along the approach to the subject matter, every care has been taken to arrange the matter from **simple to hard**, **known to unknown** and in a **self-style**.

Each chapter gives large number of **review questions asked in BT Examinations**. Appendices including List of Electronic Components and their Part Numbers, Important Terms and their Definitions, and Abbreviations are given at the end. Two Sample Formative Assessment Test Papers are provided for further study for the students as well as teachers, who may supplement their treatment for a given topic. In short, this book is expected to meet the carrying need of Diploma students of Electronics Engineering.

It is our proud privilege to record indebtedness to the publisher **Mr. Dinesh Furia** and **Mr.Jignesh Furia** and Staff of Nirali Prakashan especially Mr. Rahul Thorat, Mr. Kiran Kamble and Ms. Chaitali Takle for their kind interest in the entire work and publishing this book in a very short span of time.

Although every care has been taken to check mistakes and misprints, yet it is very difficult to claim perfection. Any undetected and unintentional errors, omissions, suggestions etc. from students and colleagues for improvement brought to my notice in good spirit are always most welcome.

Authors

Syllabus ...

Unit-I : Power Amplifiers **(Hrs. 08, Marks 12)**

1.1 Power Amplifier: Concept, Performance parameters like: Gain, Bandwidth, Frequency band, Efficiency and Distortion.

1.2 Classification: Class A, Class B, Class AB and Class C power amplifier and their applications.

1.3 Circuit diagram, Working, Input-output waveforms and efficiency of Single-stage Class A, Class B, Class AB and Class C power amplifiers, Push-pull amplifier, Complementary symmetry push-pull amplifier, Transformerless push-pull amplifier, Distortions in power amplifier.

1.4 Generalized Features of Audio Power Amplifier ICs, Heat sink.

Unit-II : OP-AMP and its Applications **(Hrs. 11, Marks 18)**

2.1 OP-AMP: Block diagram, Symbol, Characteristics, Open loop and closed loop amplifier, Virtual ground concept, IC-741 and its pin configuration.

2.2 OP-AMP parameters: Input offset voltage, Output offset voltage, Input offset current, Input bias current, Common Mode Rejection Ratio, Power Supply Rejection Ratio, Slew rate, Input and Output Impedance, Bandwidth and Gain-Bandwidth product, Drift parameters.

2.3 Closed loop configurations: Inverting and Non-inverting.

2.4 Basic mathematical applications such as Adder, Subtractor, Integrator and Differentiator.

2.5 Sample and Hold circuit, I-V converter, V-I converter.

2.6 Comparator: Zero Crossing Detector (Inverting and Non-inverting type), Schmitt Trigger, Window Detector and Peak Detector.

Unit-III : Waveform Generators **(Hrs. 08, Marks 14)**

3.1 Principle of Feedback Amplifier. Types of Feedback: Negative and Positive feedback, Advantages and Disadvantages of Negative feedback, Types of feedback connections (Block diagrams and features only).

3.2 Oscillator : Need of oscillator, Comparison between Oscillator and Amplifier.

3.3 Condition for Oscillations : Barkhausen's criteria, Classification of oscillators.

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Unit-IV : Active Filters **(Hrs. 08, Marks 14)**

4.1 Definition, Type of filters and difference between active and passive filter.

4.2 Merits and Demerits of Active filter over Passive filter.

4.3 Terms related to filters: Order of filter, Cut-off frequency, Pass band, Stop band, Centre frequency, Roll-off rate, Bandwidth and Q factor.

4.4 Order and Frequency response: First and Second order of Low pass and High pass filter.

Unit-V : Specialized IC Applications **(Hrs. 10, Marks 12)**

5.1 Timer IC: IC 555 Block diagram, Pin diagram and functions, Astable and Monostable multivibrators, Voltage Controlled Oscillator.

5.2 Phase Lock Loop (PLL) : IC 565 pin diagram, Block diagram and its working, Lock range and Capture range.

5.3 Applications of PLL : PLL as a Frequency multiplier, FM Demodulator.



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Chapter 1...

Power Amplifiers

Weightage of Marks = 12, Teaching Hours = 08

Curriculum Theory Content

1.1 Power Amplifier: Concept, Performance parameters like: Gain, Bandwidth, Frequency band, Efficiency and Distortion.

1.2 Classification: Class A, Class B, Class AB and Class C power amplifier and their applications.

1.3 Circuit diagram, Working, Input-output waveforms and efficiency of Single-stage Class A, Class B, Class AB and Class C power amplifiers, Push-pull amplifier, Complementary symmetry push-pull amplifier, Transformerless push-pull amplifier, Distortions in power amplifier.

1.4 Generalized features of audio power amplifier ICs, Heat sink.

Unit Outcomes

At the end of this chapter, students will be able to :

- Describe the performance of the given power amplifier parameters.
- Explain with sketches the working of given type of power amplifier.
- Compare the given type of power amplifiers on the basis of performance parameter.
- Select relevant type of power amplifier for the given applications.

INTRODUCTION

- In many electronic applications, it is required that a weak signal (i.e. voice) should be heard loudly. This becomes possible only if the power level of the weak signal is raised and supplied to the load. Therefore, it is essential in almost all electronic systems where a large amount of power is required to be supplied to the load. The power amplifier is used as a last stage in all such electronic systems. For example, a Public Address (PA) system, broadcast transmitters, TV receivers, music system, motor and relay control systems, automation systems, etc.

1.1 POWER AMPLIFIER

1.1.1 Concept

- *A power amplifier is an amplifier which is capable of providing a large amount of power to the load such as loudspeaker,* a motor etc. It raises the power level of the electrical signals that have audio frequency range. It is more commonly known as **audio amplifier**. It is also known as **large signal amplifier** because it uses a large part of the A.C. load line for operation.
- For example, a public address system consists of a microphone, a multistage (voltage) amplifier, a power amplifier and a loudspeaker. When a person speaks into a microphone, it converts sound waves into the electrical signal. This electrical signal is of very low voltage, usually a few mV. This signal, if fed directly, cannot drive the loudspeakers to give sound (audio) output. The voltage level of this signal is first raised to sufficiently high values (usually a few V_s) by passing it through a multistage voltage (or small signal) amplifier. This signal is then used to drive (or excite) the power amplifier, which is capable of delivering a large amount of power to the loudspeakers. The loudspeaker finally converts the electrical signal into sound waves. Thus, large audience can hear the speech (or music) from the orchestra, tape recorder, record player, radio receiver, television receiver or any other such gadgets.
- A block diagram of a practical public address system is shown in Fig. 1.1.

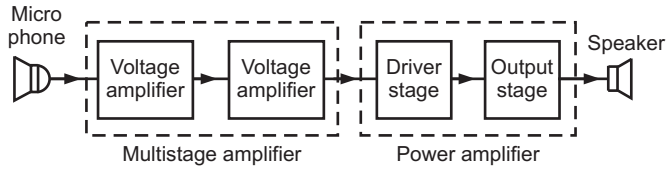


Fig. 1.1 : Public address system

- A practical power amplifier has the following stages of amplification :
  1. Multistage (voltage) amplifier,
  2. Driver stage,
  3. Output stage.

1. Multistage Amplifier :

- The multistage amplifier is basically a voltage amplifier, generally, it consists of two or more stages of voltage amplifiers. RC coupling is employed for this purpose.
- The electrical signals found, in practice, have extremely low voltage level (less than 10 mV). The voltage level of this weak signal is raised to a few volts in multistage voltage amplifier.

2. Driver Stage :

- The output from the last voltage amplifier stage of a multistage amplifier is fed to the driver stage of a power amplifier. It generally employs a Class-A transformer coupled power amplifier. This is, in fact, a power stage which increases the current level of the electrical signal. It supplies the driving power necessary for operating the output stage. This stage makes efforts to obtain *maximum power gain*.
- The stage of amplification which provides the necessary base current and voltage to the output stage is called the **driver stage**. It works as a power amplifier and drives the output stage. It also provides impedance matching.

3. Output Stage :

- The output power from the driver stage is fed to the output stage of a power amplifier. It is a final stage and feeds power directly to the loudspeaker. The output stage is normally a transformer coupled and employs Class B amplifiers in push-pull arrangement. This stage makes efforts to obtain **maximum power output**.
- Power amplifiers are different than voltage amplifiers.

Table 1.1 : Comparison between voltage amplifier and power amplifier

Sr. No.	Voltage Amplifier or Small Signal Amplifier	Power Amplifier
1.	The amplitude of input A.C. signal is small.	The amplitude of input A.C. signal is large.
2.	The transistor used has a large current gain ($\beta > 100$).	The transistor used has comparatively low current gain (β = 20 to 50).
3.	The transistor used has thin base to handle low current.	The transistor used has thick base to handle large current.
4.	The physical size of transistor used is usually small and is known as low or medium power transistor.	The physical size of transistor used is usually large and is known as power transistor.
5.	The transistor used can dissipate less heat produced during its operation.	The transistor used can dissipate more heat produced during its operation.
6.	The collector load has high resistance, usually 4 kΩ to 10 kΩ.	The collector load has low resistance, usually 5 Ω to 20 Ω.
7.	It uses usually RC coupling.	It uses invariably transformer coupling.
8.	The collector current is low about 1 mA.	The collector current is very high usually greater than 100 mA or more.
9.	The A.C. power output is low.	The A.C. power output is high.
10.	Impedance is very high usually 12 kΩ.	The output impedance is very low usually 200 Ω.

1.1.2 Performance Parameters

- The main objective for a power amplifier is to obtain maximum output A.C. power.
- There are three parameters namely
  1. Collector efficiency,
  2. Distortion,
  3. Power dissipation capability of a transistor which determines the performance of power amplifiers.

Specifications of Power Amplifier :

1. Collector Efficiency :

- The major criterion for a power amplifier is not the power gain but the maximum A.C. power output.

Hence, the amplifier converts the D.C. power supply into the A.C. power output as per input A.C. power.

- The *ability of a power amplifier to convert D.C. power supply into A.C. power supply is a measure of its effectiveness and is called its* **circuit efficiency**.
- *The circuit efficiency* may be defined as *the ratio of the maximum A.C. output power to the zero signal power,* i.e. D.C. input power supplied by the battery or D.C. power supply, of a power amplifier.

$$\text{Circuit efficiency, } \eta = \frac{\text{Maximum A.C. output power}}{\text{D.C. input power}}$$

- It ranges from 25% to 90%. It depends on class of amplifier.

2. Distortion :

- A good amplifier should produce enlarged output but faithful reproduction of the input. However, in actual practice, it is not possible to construct such an ideal amplifier, whose output is exact reproduction of the input. The output is always found to be different from the input either in its waveform or frequency content.
- *The undesired difference between the output and input of an amplifier is called* ***distortion***.
- The distortion may be defined as '*the change of output waveshape from the input waveshape of an amplifier*'.
- A transistor is essentially a **non-linear device**. Therefore, whenever a signal is applied to the transistor, the output signal is not exactly like the input signal. Thus, distortion occurs in the transistor amplifiers. It is not a problem for small signal (i.e. voltage) amplifiers, since transistor acts as a linear device for small signal variations about the operating point. However, a power amplifier handles large signals, the distortion becomes a problem in such power amplifiers. They may be ***amplitude or harmonic and crossover distortion***.

3. Power Dissipation Capability :

- As the transistor in a power amplifier handles large current, the heat is generated within the transistor due to excessive current passing through its junction during amplification. The transistor must dissipate this heat to its surroundings. Otherwise, excessive heat may damage the transistor.
- *The ability of a power transistor to dissipate heat is known as power dissipation capability.*
- If the heat generated within the transistor is greater than its power dissipation capability, then the transistor is likely to burn out.
- It may be increased by connecting a mass of metal (called *heat sink*) to the transistor case.

1.2 CLASSIFICATIONS OF POWER AMPLIFIERS (W-19)

- The classification of power amplifiers is based on transistor biasing condition (i.e. location of operating point or mode of operation) and amplitude of the input signal. It also takes into account the portion of the cycle for which the transistor conducts. On the above basis, following are the four classification of power amplifiers.

1. Class-A amplifier : The power amplifier in which the base-to-emitter bias of a transistor and the amplitude of the input signal are so chosen that the collector current flows for the complete cycle (i.e. 360°) of the input signal is known as *Class-A amplifier*.

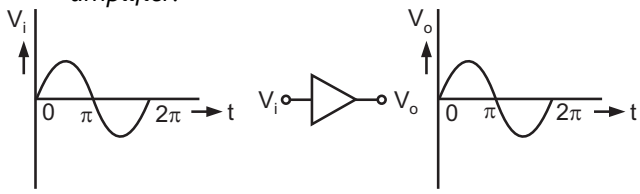


Fig. 1.2 : Class-A amplifier

2. Class-B amplifier : The power amplifier in which base-to-emitter bias of a transistor and amplitude of the input signal are so chosen that the collector current flows for only one-half cycle (i.e. 180°) of the input signal is known as *Class-B amplifier*.

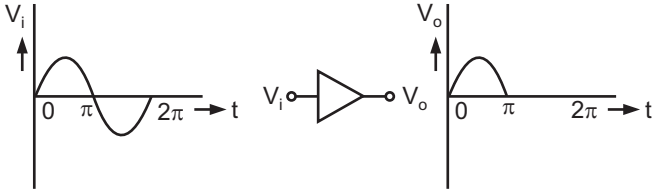


Fig. 1.3 : Class-B amplifier

3. Class-AB Amplifier : The power amplifier in which base-to-emitter bias of a transistor and amplitude of the input signal are so chosen that the collector current flows for more than one-half cycle (i.e. 180°) but less than the complete cycle (i.e. 360°) of the input cycle is known as *Class-AB amplifier*.

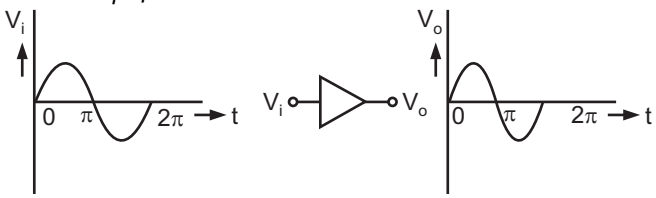


Fig. 1.4 : Class-AB amplifier

4. Class-C Amplifier: The power amplifier in which base-to-emitter bias of a transistor and amplitude of the input signal are so chosen that the collector current flows for less than one-half cycle (i.e. less than 180°) of the input signal is known as *Class-C amplifier*.

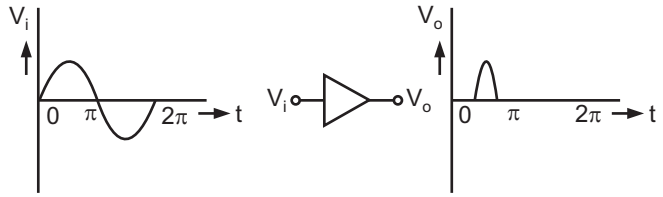


Fig. 1.5 : Class-C amplifier

- The Class-AB amplifier lies in between Class-A and Class-B amplifiers. The Class-A and Class-B amplifiers are called audio power amplifiers because they are capable of amplifying the audio signals (i.e. frequencies ranging from 20 Hz to 20 kHz).

1.3 POWER AMPLIFIER (S-22)

1.3.1 Class-A Power Amplifier (W-19)

- The Class–A amplifier is a power amplifier in which the transistor bias and amplitude of the input signal i.e. operating point is so chosen that the collector current flows for the complete cycle of the input signal.
- The Class–A amplifier is basically, a common emitter amplifier as shown in Fig. 1.6 (a). This circuit is also called direct coupled Class-A power amplifier. In this circuit, the operating point (Q) is adjusted somewhere near the centre of the A.C. load line. However, in order to obtain the maximum output signal, the Q-point is set at the centre of the load line.

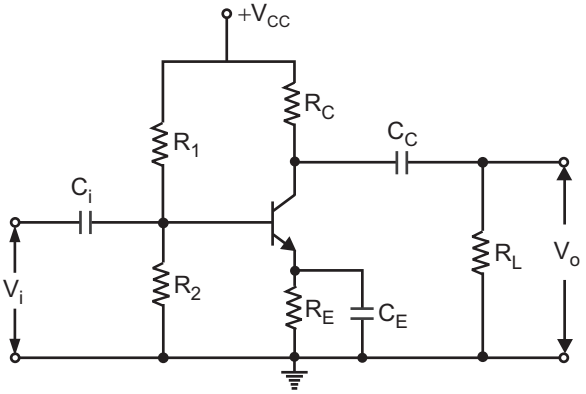


Fig. 1.6 (a) : Circuit arrangement of Class-A amplifier

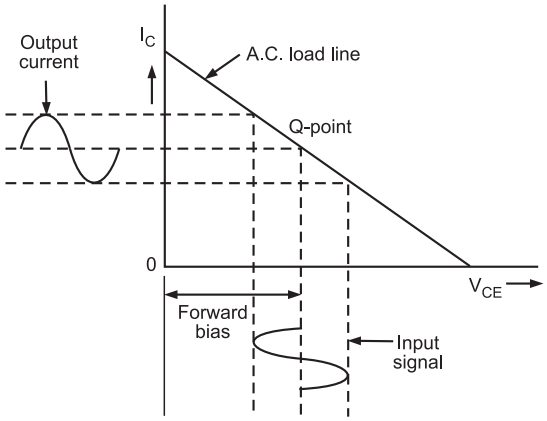


Fig. 1.6 (b) : Variation of output current

- When the input signal is applied to the circuit, the current increases or decreases alternately during each half cycle of the input signal but there is always a flow of output current through the collector load. This is shown in Fig. 1.6 (b). A Class-A amplifier, therefore, draws output current from the D.C. supply irrespective of whether the input signal is present or not. This results in poor efficiency for the circuit in converting D.C. power to signal power.

Characteristics of Class-A Amplifier :

- The important characteristics of Class-A amplifier are :
  1. The Q–point is located at or near the centre of the A.C. load line.
  2. The output current flows during the entire cycle of the input A.C. signal.
  3. The operation of the amplifier is restricted to smaller control region of the load line. The large input signals may shift the Q–point into non-linear regions near the saturation or cut-off and hence, produce amplitude distortion.
  4. Since, the transistor operates over the linear region of the load line, therefore, the output waveform is almost similar to the input waveform.
  5. As the output waveform is exactly similar to the input waveform, therefore there will be least amplitude distortion.
  6. The A.C. power output per transistor is smaller than that of Class–AB, Class–B or Class–C amplifier.
  7. The maximum possible overall efficiency is about 25%.
  8. The maximum possible collector efficiency is about 50%.

Advantages of Class-A Amplifier :

1. It has least amplitude distortion.
2. It has no hum.

Disadvantages of Class-A amplifier :

1. It has poor efficiency.
2. It provides low A.C. power output.

Applications of Class-A amplifier :

1. It is used where distortionless output is required e.g. audio power amplifier.
2. It is used as voltage amplifier for audio, radio and video frequencies.

1.3.1.1 Transformer Coupled Class-A Amplifier (S-22)

- The direct coupled class-A amplifier have poor efficiency and require large amount of D.C. power. This problem can be solved by using a suitable transformer for coupling the load to the amplifier stage as shown in Fig. 1.7.