Comparative Study of the Different Types of Signal Amplifiers and their Applications

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Abstract: Comparative studies have been carried out for the different types of signal amplifiers to find their performance characteristics with respect to circuit topologies, gain calculations, and merits and demerits of them. Studies have also been done to find their suitable applications in various fields. With respect to circuit topologies, the circuit diagrams are shown with single BJT to multiple BJTs; differential mode to push-pull mode and BJT to MOSFET with PMOS and NMOS and CMOS. Then, the use of an operational amplifier (OPAM) circuit to an operational trans-conductance amplifier (OTA) circuit. The biasing of the amplifier is considered as voltage bias or current bias with resistors or diodes. The gain of the amplifier is generally expressed as the ratio of the amplitudes of the output and input signals. It can be given as voltage gain, current gain or power gain (in dB) or in terms of trans-conductance. On the basis of the advantages and dis-advantages, each signal amplifier has its own application in the different fields based on its suitable performance with respect to low power consumption, optimum gain, good bandwidth, optimum weight and space ratio and good frequency response. The discussion has been made and conclusion has been drawn for this investigation.

Keywords: Signal amplifiers; gain of the amplifier; power consumption; Merits and demerits of the amplifiers; applications of the amplifiers; Operational trans-conductance amplifier.

1. Introduction: Amplifiers have wide applications in different fields to magnify the magnitude of voltage, current and power signals. Signal amplifiers are used to amplify the input signals into output voltage signals. There are a series of modifications and developments in circuit design of the signal amplifiers due to improve their performances. This is due to the applications of the latest technology and methods as the results of continuous research in this field [1]. The solid state devices with integrated circuits have important roles with respect to reduction of space used and power consumption[2]. The gain of the amplifier is the ratio of the amplitudes of output and input signals. But, it depends on the many parameters of the amplifier. One of the examples is that the nature of the input and output signals may not be the same, but it can get distorted.

The solid state voltage amplifier was designed with a circuit of Class- A amplifier using a single Bi-polar Junction Transistor and then its modification with Class- B to overcome the initial disadvantages of the Class-A amplifier [3]. The circuit of the Class- B amplifier was redesigned as a Push-pull Class- B amplifier using two transistors, one PNP and another NPN. Further improvement was done by designing the circuit of AB - amplifiers consisting of Class-A and Class-B amplifiers together to rectify the problems of the both amplifiers. The performance of AB - amplifier was studied by employing different biasing methods, such as- Voltage bias, Resistor bias and Diode bias. The Operational amplifier as an IC, with embedded transistor and resistor, was also used as voltage gain amplifier with both inverting and non-inverting modes, having many advantages compared to ordinary transistor-amplifier[4,5]. The field effect transistor amplifier is the amplifier that makes use of one or more units. The most common type of FET voltage amplifier is MOSFET amplifier[6,7]. CMOS amplifiers are an important category of amplifier which has wide applications in many fields [8,9].

The latest version of the voltage amplifier is the Operational trans-conductance amplifier (OTA [10]). It consists of many stages of CMOS with diodes and current biasing[11].

In this investigation, an attempt has been made to make comparative study of the different types of voltage amplifiers with respect to their circuit diagrams, gain calculation and indicating advantages and dis-advantages, and mention their applications.

2. Circuit Topologies and calculation of gain: The following circuit topologies of different types of voltage amplifiers have been considered to make comparative study of their characteristics.

2.1 Class-A amplifier:

The Fig.1 shows the basic diagram of a typical class-A amplifier using single transistor.

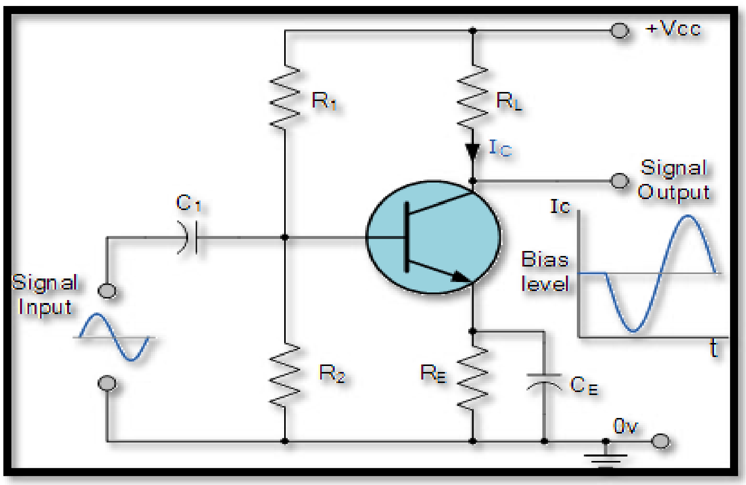


Fig.1: Basic circuit diagram of a Class-A amplifier.

Gain: Voltage gain, A_v $=V_{out}$ / V_{in}.
Current gain, $A_i = I_{out}$ / I_{in}.
Power gain in dB = 10 $\log_{10}$ (P_{out} / P_{in}).

2.2. Class-B amplifier:

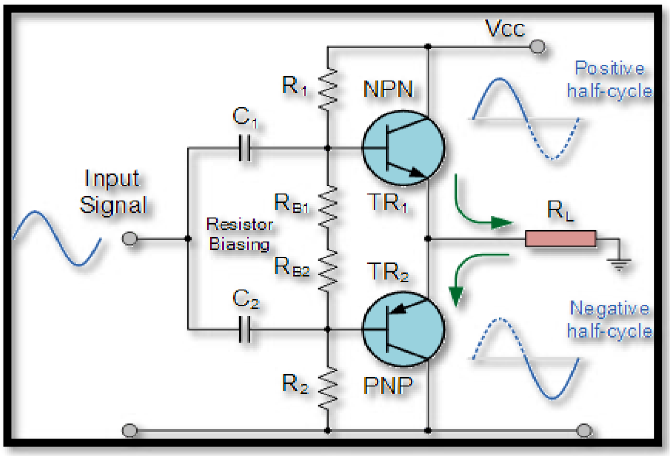


Fig.2: Basic circuit diagram of Class-B amplifier

Gain:
Voltage
gain, A_v $=V_{out}$ / V_{in}.
Current gain, $A_i = I_{out}$ / I_{in}.
Power gain in dB = 10 $\log_{10}$ (P_{out} / P_{in}).

2.3 Class A-B amplifier:

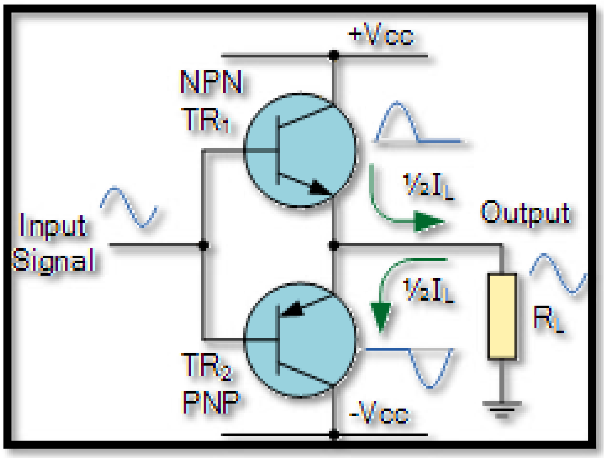
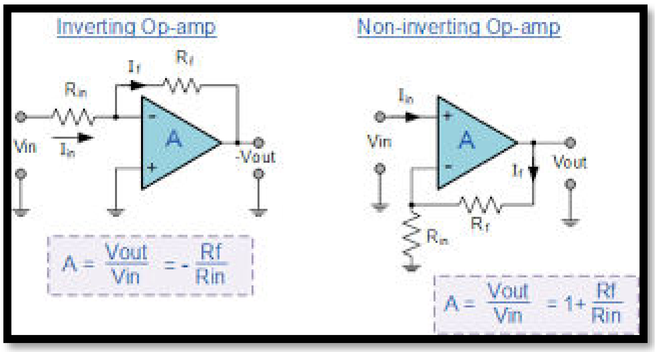


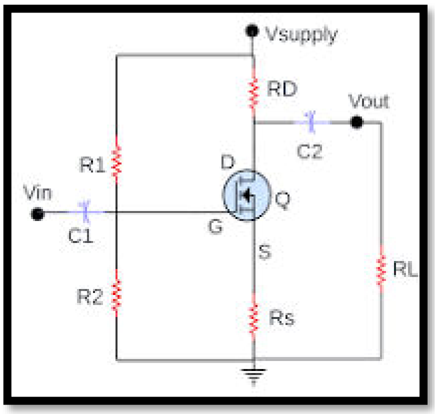
Fig. 3: Schematic circuit diagram of Class A-B amplifier.

Gain:
Voltage gain, A_v $=V_{out}$ / V_{in}.
Current gain, $A_i = I_{out}$ /$\mathbf{I_{in}}$.
Power gain in dB = 10 $\log_{10}$ (P_{out} / P_{in}).

2.4 Operational amplifier:



2.5 MOSFET amplifier:



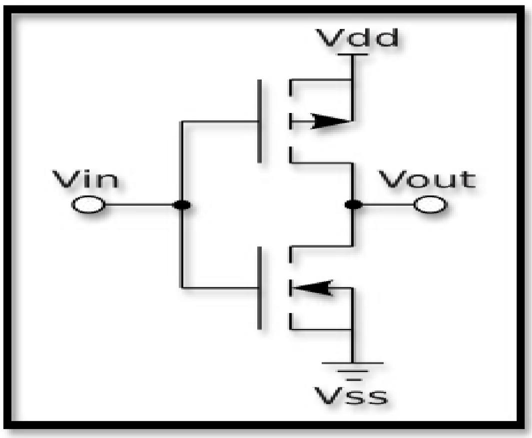
Gain:

Voltage gain, $A_v = V_{out} / V_{in}$.

Current gain, $A_i = I_{out} / I_{in}$.

Power gain in dB = $10 \log_{10} (P_{out} / P_{in})$.

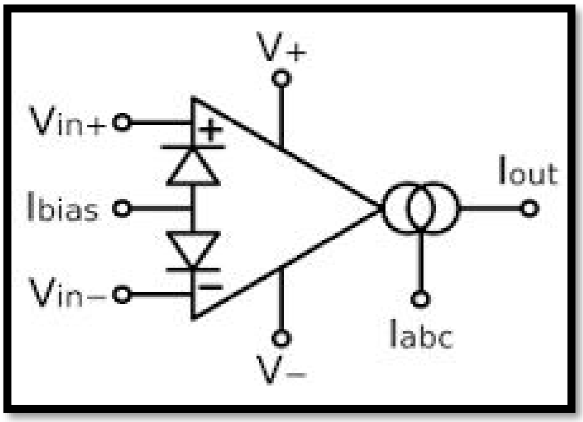
2.6. CMOS amplifier:



Gain: Voltage gain, $A_v = dV_{out} / dV_{in}$

Intrinsic gain, $A_{vin} = g_m . r_o$

2.7. Operational trans-conductance amplifier:



Gain: The gain of the trans-conductance amplifier can be expressed as -

$A = I_{out} / V_{in} = I_{out} / (V_{in+} - V_{in-}) = G_m$

3. Merits and Demerits of Different Types of Signal Amplifiers:

3.1 Merits and de-merits of Class-A amplifier: **Merits:**i) Simple in design ii) High gain iii) It uses one transistor iv) Low distortion.

Demerits: i) Very low efficiency ii) Wastage of much power in resistive load iii) It needs a larger heat sink. iv) Needs high supply voltage.

3.2 Merits and de-merits of Class-B amplifier:

Merits i)Simple in structure ii) More efficient than Class-A amplifiers.

Demerits:i)It conducts half of the time period ii) Not used in high frequency applications.

3.3 Merits and demerits of Class A-B amplifier:

Merits: i) It is more efficient than Class-A and Class-B amplifiers. ii) No DC bias current is required. So, power consumption is greatly reduced. iii) Output stage power consumption is reduced since only signal current flows through the transistor.

Demerits: i) When the base DC voltage is zero, both the transistors remain cut off. ii) There is crossover distortion for a period of time when neither transistor is on.

3.4 Merits and demerits of Operational amplifier:

Merits: i) High gain can be achieved. ii) Cost-effectiveness iii) Compact in size, iv) High precision and reliability v) Easy to handle.

Demerits: i) Limited high frequency response ii) Complexity at high voltage application iii) Requires two same values of power supplies with +ve and -ve polarities.

3.5 Merits and demerits of MOSFET amplifier :

Merits: i) High speed of operation ii) Easy to fabricate iii) Easy to manufacture iv) Low power consumption v) High input impedance vi) Low output impedance.

Demerits: i) Short life period ii) Susceptible to overload.

3.6 Merits and demerits of CMOS amplifier:

Merits: i) Useful for digital circuit design ii) Channel length can be reduced.

Demerits: i) Intrinsic gain reduction ii) Stability problem in closed loop application iii) Needs high supply voltage.

3.7 Merits and demerits of Operational trans-conductance amplifier (OTA):

Merits: i) Low power consumption ii) No distortion in the output signal iii) Scaling and hence Gain can be adjusted using more devices.

Demerit i) If output resistance is taken into account, then the current gain will be lower.

4. Applications of Different Types of Amplifiers:

4.1 Class-A amplifier:

Applications: i)Premium audio systems ii) Professional audio equipment iii) AM and FM broadcasting systems.

4.2 Class-B amplifier:

Applications: i) Inverters and voltage regulators ii) Radio transmitter iii) Phased array antennas iv) Motor drivers v) Power control systems vi) Hand held communication systems.

4.3 Class -AB amplifier:

Applications: i) EMC systems ii) Instrumentation and measurements iii) Broadcasting iv) Car audio v) CD players vi) TV receiver vii) Radio receiver viii) Public address systems.

4.4 Operational amplifier:

Applications: Used as -i) Voltage follower ii) Active filters iii) High pass filters iv) Voltage to current converter v) comparators vi) Integrator.

4.5 MOSFET amplifier:

Applications: i) Digital circuits ii) CMOS Logic circuits iii) Brushless DC motors iv) Inverter v) Electronic DC relays vi) Switched mode power supplies vii) Medical appliances.

4.6 CMOS amplifier:

Applications: i) Computers ii) Smart phones. iii) Audio systems iv) Telecommunication systems v) Biomedical systems.

4.7 Operational trans-conductance amplifier:

Applications: i) Oscillators ii) Filters iii) Mixers iv) LED driven circuits v) Analog to Digital converters vi) Digital to Analog converters vii) Medical devices.

5. Discussions and Conclusion:

It can be seen from the circuit topologies, merits and demerits, and applications of different types of signal amplifiers that the application of Class-A amplifier is limited to some specific systems due to its low efficiency and wastage of power in resistive loads though it has some advantages like- high gain,low distortion and making use of simple circuit consisting of single transistor. To overcome some of the disadvantages of Class-A amplifiers, Class-B amplifiers have been developed. But, it also has some disadvantages, though its performance is better than the previous one and does not fully satisfy the required characteristics. Due to gradual development of Science and Technology, Class-AB amplifier circuit has been designed to further improve the performance of signal amplifiers. Then, considering optimum weight and space, the signal amplifiers designed are operational amplifiers, FET amplifiers, MOSFET amplifiers, CMOS amplifiers. Each of these are developed as IC in a single chip to minimize cost with improved performance, low power consumption and applications in various fields. Nowadays, the new class AB operational trans-conductance amplifier is a special class of amplifier with adjustable gain, lower power consumption, less distortion, good bandwidth and optimized frequency response, which plays an important role for its applications in various immersing fields of telecommunications and medical technology.

From the above discussion, it is seen that with rapid development of microelectronics technology, the scope of integrated circuits is gradually extending, and the integration of chips is getting larger and larger. Among the various types of signal amplifiers, CMOS amplifiers, at present, are found to be wide applications due their low power consumption and adjustable voltage and current gains. Further improvement can be made by optimizing their structures, frequency response and good band width.

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