SMALL-SIGNAL AND LARGE-SIGNAL AMPLIFIERS

The input signal to a multistage amplifier is generally small (a few mV from a cassette or CD or a few µV from an antenna). Therefore, the first few stages of a multistage amplifier handle small signals and have the function of only voltage amplification. However, the last stage handles a large signal and its job is to produce a large amount of power in order to operate the output device (e.g. speaker).

(i) Small-signal amplifiers

Those amplifiers which handle small input a.c. signals (a few µV or a few mV) are called small-signal amplifiers. Voltage amplifiers generally fall in this class. The small-signal amplifiers are designed to operate over the linear portion of the output characteristics. Therefore, the transistor parameters such as current gain, input impedance, output impedance etc. do not change as the amplitude of the signal changes. Such amplifiers amplify the signal with little or no distortion.

(ii) Large-signal amplifiers

Those amplifiers which handle large input a.c. signals (a few volts) are called large-signal amplifiers. Power amplifiers fall in this class. The large-signal amplifiers are designed to provide a large amount of a.c. power output so that they can operate the output device e.g. a speaker. The main features of a large-signal amplifier or power amplifier are the circuit’s power efficiency, the maximum amount of power that the circuit is capable of handling and the impedance matching to the output device. It may be noted that all large-signal amplifiers are not necessarily power amplifiers but it is safe to say that most are. In general, where amount of power involved is 1W or more, the amplifier is termed as power amplifier.
Difference between Voltage and Power Amplifiers

A voltage amplifier is designed to achieve maximum voltage amplification. It is, however, not important to raise the power level. On the other hand, a power amplifier is designed to obtain maximum output power.

1. Voltage amplifier

The voltage gain of an amplifier is given by:

\[ A_v = \beta \times \frac{R_C}{R_{in}} \]

In order to achieve high voltage amplification, the following features are incorporated in such amplifiers:

(i) The transistor with high \( \beta \) (>100) is used in the circuit. In other words, those transistors are employed which have thin base.

(ii) The input resistance \( R_{in} \) of the transistor should be quite low as compared to the collector load \( R_C \).

(iii) A relatively high load \( R_C \) is used in the collector. To permit this condition, voltage amplifiers are always operated at low collector currents (approx. 1 mA). If the collector current is small, we can use large \( R_C \) in the collector circuit.

2. Power amplifier

A power amplifier is required to deliver a large amount of power and as such it has to handle large current. In order to achieve high power amplification, the following features are incorporated in such amplifiers:

(i) The size of power transistor is made considerably larger in order to dissipate the heat produced in the transistor during operation.
(ii) The base is made thicker to handle large currents. In other words, transistors with comparatively smaller $\beta$ are used.

(iii) Transformer coupling is used for impedance matching.

The comparison between voltage and power amplifiers is given below in the tabular form:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Particular</th>
<th>Voltage amplifier</th>
<th>Power amplifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>$\beta$</td>
<td>High ($&gt; 100$)</td>
<td>low (5 to 20)</td>
</tr>
<tr>
<td>2.</td>
<td>$R_C$</td>
<td>High (4 – 10 kΩ)</td>
<td>low (5 to 20 Ω)</td>
</tr>
<tr>
<td>3.</td>
<td>Coupling</td>
<td>usually $R - C$ coupling</td>
<td>Invariably transformer coupling</td>
</tr>
<tr>
<td>4.</td>
<td>Input voltage</td>
<td>low (a few mV)</td>
<td>High (2 – 4 V)</td>
</tr>
<tr>
<td>5.</td>
<td>Collector current</td>
<td>low (≈ 1 mA)</td>
<td>High (&gt; 100 mA)</td>
</tr>
<tr>
<td>6.</td>
<td>Power output</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>7.</td>
<td>Output impedance</td>
<td>High (≈ 12 kΩ)</td>
<td>low (200 Ω)</td>
</tr>
</tbody>
</table>

Performance Quantities of Power Amplifiers

(i) Collector efficiency

The main criterion for a power amplifier is not the power gain rather it is the maximum a.c. power output. Now, an amplifier converts d.c. power from supply into a.c. power output. Therefore, the ability of a power amplifier to convert d.c. power from supply into a.c. output power is a measure of its effectiveness. This is known as collector efficiency and may be defined as under:

The ratio of a.c. output power to the zero signal power (i.e. d.c. power) supplied by the battery of a power amplifier is known as collector efficiency.

Collector efficiency means as to how well an amplifier converts d.c. power from the battery into a.c. output power. For instance, if the d.c. power supplied by the battery is 10W and a.c. output power is 2W, then collector efficiency is 20%. The greater
the collector efficiency, the larger is the a.c. power output. It is obvious that for power amplifiers, maximum collector efficiency is the desired goal.

(ii) Distortion
The change of output wave shape from the input wave shape of an amplifier is known as distortion. A transistor like other electronic devices, is essentially a non-linear device. Therefore, whenever a signal is applied to the input of the transistor, the output signal is not exactly like the input signal *i.e.* distortion occurs. Distortion is not a problem for small signals (*i.e.* voltage amplifiers) since transistor is a linear device for small variations about the operating point. However, a power amplifier handles large signals and, therefore, the problem of distortion immediately arises.

(iii) Power dissipation capability
*The ability of a power transistor to dissipate heat is known as* power dissipation capability. A power transistor handles large currents and heats up during operation. As any temperature change influences the operation of transistor, therefore, the transistor must dissipate this heat to its surroundings. To achieve this, generally a *heat sink* (a metal case) is attached to a power transistor case. The increased surface area allows heat to escape easily and keeps the case temperature of the transistor within permissible limits.

Expression for Collector Efficiency
For comparing power amplifiers, collector efficiency is the main criterion. The greater the collector efficiency, the better is the power amplifier.
Now, Collector efficiency, $\eta = \frac{\text{a.c. power output}}{\text{d.c. power input}} = \frac{P_o}{P_{dc}}$

where

$\star P_{dc} = V_{cc}I_c$

$P_o = V_{ce}I_c$

where, $V_{ce}$ is the r.m.s. value of signal output voltage and $I_c$ is the r.m.s. value of output signal current. In terms of peak-to-peak values (which are often convenient values in load-line work), the a.c. power output can be expressed as:

$\star P_o = [(0.5 \times 0.707) v_{ce}(p-p)][(0.5 \times 0.707)i_c(p-p)]$

$= \frac{v_{ce}(p-p) \times i_c(p-p)}{8}$

Collector $\eta = \frac{\frac{v_{ce}(p-p) \times i_c(p-p)}{8 V_{cc} I_c}}{2}$

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**Maximum Collector Efficiency of Series-Fed Class A Amplifier**

A series – fed class A amplifier is shown in figure 12.6(i). This circuit is seldom used for power amplification due to its poor collector efficiency. Nevertheless, it helps to understand the class A operation. The d.c. load line of the circuit is shown in Fig. 12.6 (ii). When an ac signal is applied to the amplifier, the output current and voltage will vary about the operating point $Q$. In order to achieve the maximum symmetrical swing of current and voltage (to achieve maximum output power), the $Q$ point should be located at the centre of the dc load line. In that case, operating point is

$I_c = V_{cc}/2R_c$ and $V_{CE} = V_{cc}/2$. 

Thus, the maximum collector efficiency of a class A series-fed amplifier is 25%. In actual practice, the collector efficiency is far less than this value.