Transformer Coupled Class A Audio Power Amplifier

In large signal Class A amplifier, the load resistor is directly connected in the output circuit. Hence, the quiescent current passes through this resistor resulting in considerable waste of power as it does not contribute to the ac signal at the output, thereby decreasing the efficiency of the amplifier. Further, it is not advisable to pass the dc component of current through the output device. For example, the voice coil of a loud speaker. This problem can be solved by using a suitable trans-former for coupling the load to the amplier as shown in Figure 1. Since the load is not directly connected to the collector terminal, the dc collector current does not pass through it. In an ideal transformer, the resistance of the primary winding is zero. Hence, dc power loss in the load is zero.

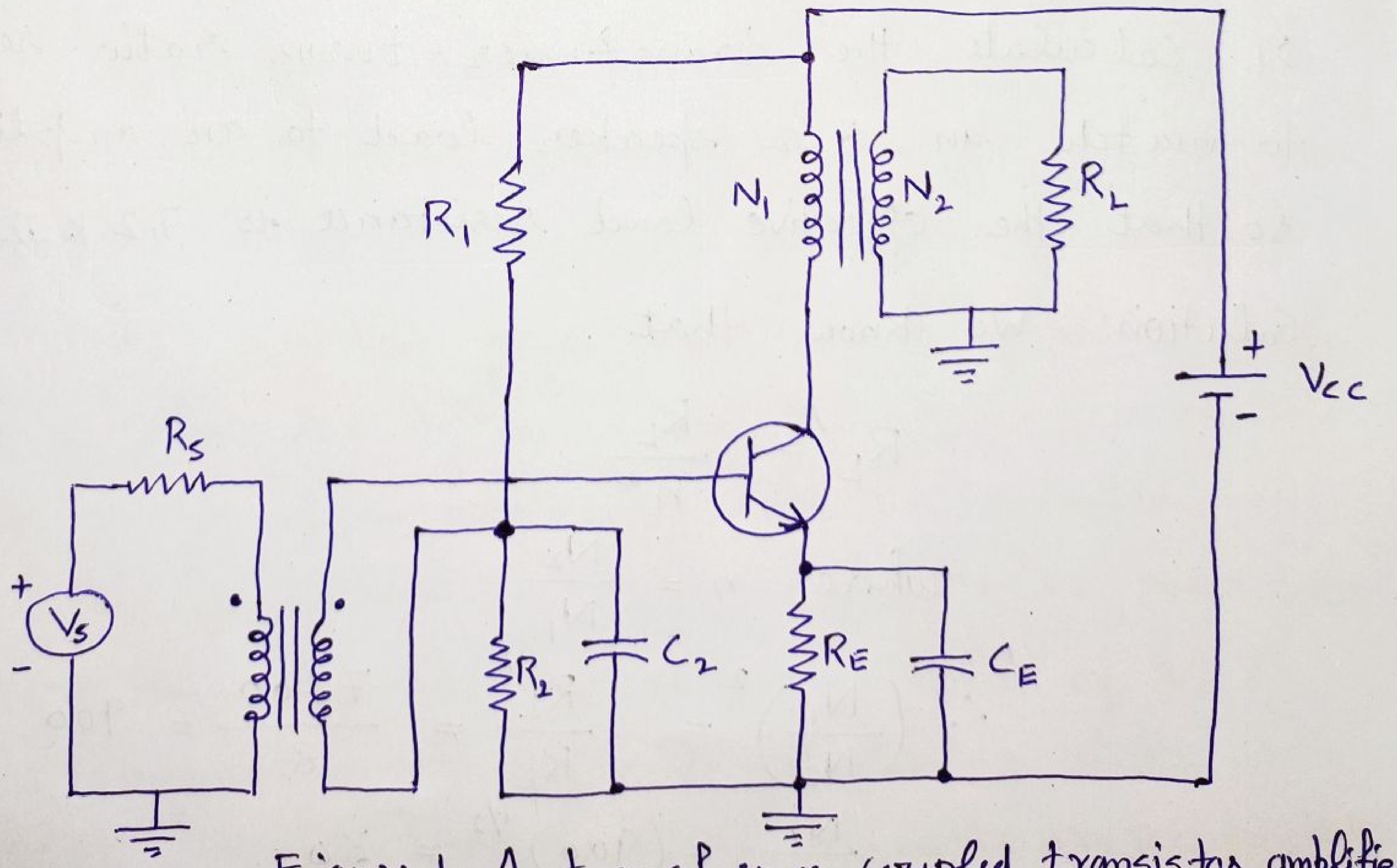

Figure 1. A transformer coupled transistor amplifier

Therefore, the transformer substitutes the dc load with an ac load.

To transfer a significant amount of power to a practical load such as loudspeaker with a voice coil impedance of 4 to 20 Ω, it is necessary to use an output-matching transformer. Otherwise, the internal device resistance which might be higher than that of the speaker will lead to most of the power generated be lost in the active device.

The secondary load R_L when reflected into the primary becomes $R_L' = \frac{R_L}{n^2}$, where n = Voltage transformation ratio = $\frac{N_2}{N_1}$, where N_2 = number of secondary turns, and N_1 = Number of primary turns. By taking N_2 lesser than N_1, n can be made much less than unity and R_L can be made to look much bigger than the actual value.

Q1. Calculate the transformer-turns ratio required to match an 8 Ω speaker load to an amplifier so that the effective load resistance is 7.2 KΩ.

Solution: We know that

$$R_L' = \frac{R_L}{n^2}$$

where $n = \frac{N_2}{N_1}$

$$\therefore \left(\frac{N_1}{N_2}\right)^2 = \frac{R_L'}{R_L} = \frac{7200}{8} = 900$$

$$\frac{N_1}{N_2} = (900)^{1/2} = 30$$

Hence $N_1 : N_2 = 30:1$

Efficiency of Class A Amplifiers

To determine efficiency, the various components of power in an amplifier circuit are considered. Assume that the amplifier is supplying power to a pure resistive load. The average power input from the dc supply is $V_{cc} \times I_c$. The power absorbed by the output circuit is $I_c^2 R_L + I_c V_c$, where I_c and V_c are the RMS output current and voltage, respectively, and R_L is the static load resistance. If P_{DV} is taken as the average power dissipated by the active device, then from the principle of conservation of energy,

$$V_{cc} I_c = I_c^2 R_L + I_c V_c + P_{DV}$$

Under dc condition from figure of Class A large-signal amplifier,

$$V_{cc} = V_c + I_c R_L$$

Substituting for V_{cc}, we have

$$P_{DV} = V_c I_c - V_c I_c$$

The above equation gives the amount of power that must be dissipated by the active device. It represents the kinetic energy of the electrons which is converted into heat. For no applied input signal, the ac power output is zero, then P_{DV} has its maximum value of $V_c I_c$. For an applied input signal, the heating of the device is reduced by the amount of ac power converted by the stage and supplied to the load. Hence, the amplifying device is cooler when delivering power to the load than when there is no such ac power transfer.

Conversion Efficiency

It is a measure of the ability of an active device in converting the dc power of the supply into the ac power delivered to the load. Conversion efficiency is also referred to as theoretical efficiency or collector circuit efficiency (for transistor amplifier) and is denoted by η. By definition, the percentage efficiency is

$$\eta = \frac{\text{Signal power delivered to the load}}{\text{dc power supplied to output circuit}} \times 100$$

$$= \frac{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}}{V_{cc} I_c} \times 100 \,\%$$

$$\eta = 50 . \frac{V_m I_m}{V_{cc} I_c} \,\% \quad \text{——} \quad (1)$$

where I_m and V_m represent the peak sinusoidal output current and voltage swings respectively.

The collector-circuit efficiency differs from the overall efficiency because the power taken by the base is not included in the denominator of the above equation.

Maximum Value of Efficiency

With certain idealizations made in the characteristic curves, it is possible to obtain an approximate expression for the maximum value of efficiency. Though these assumptions introduce errors in the analysis, the results permit a rapid estimate of the numerical value of efficiency and furnishes an upper limit for this figure of merit. It is assumed that the static curves are equally spaced in the region of the load line for equal increments in the excitation (base current).

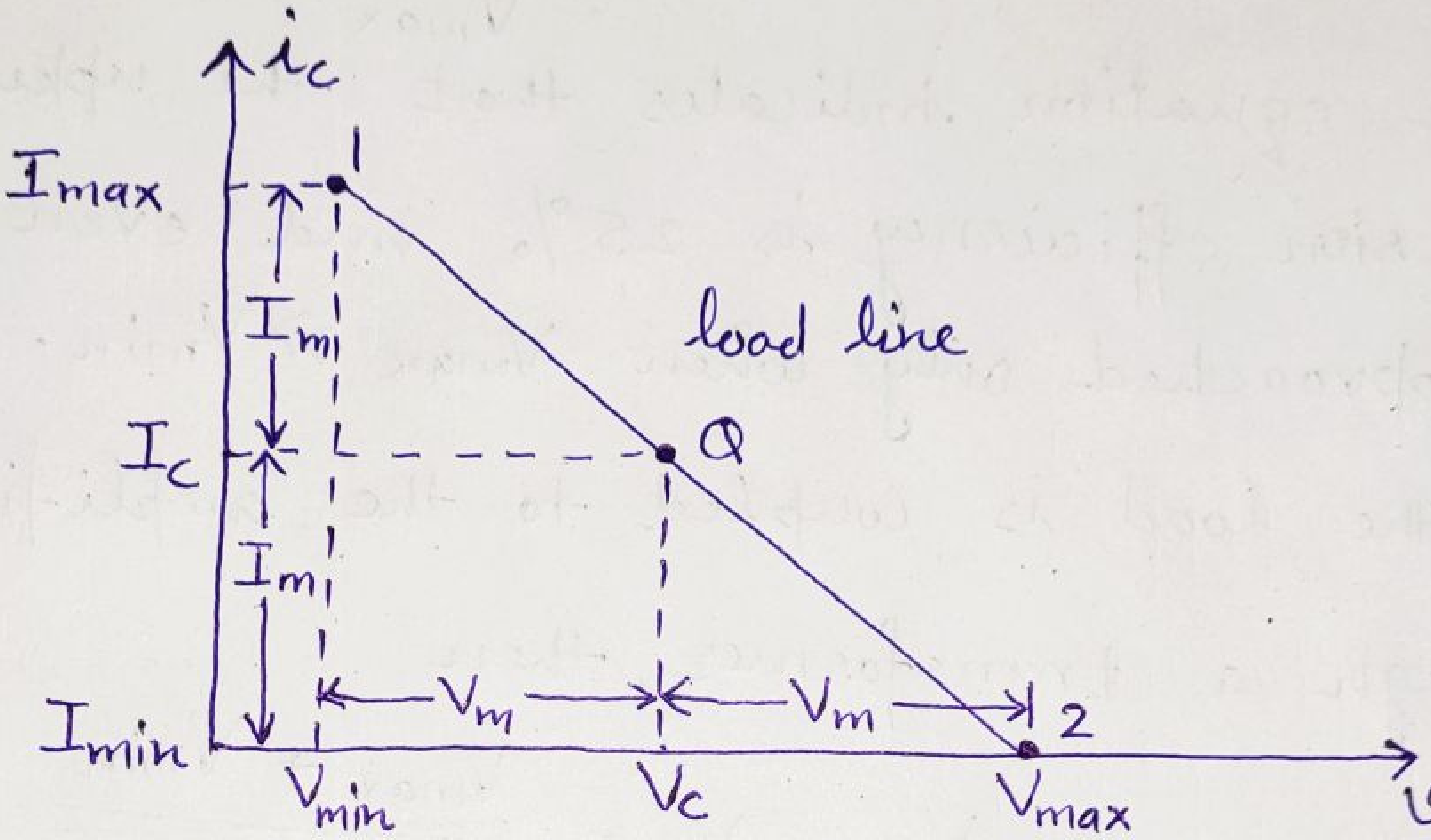

Fig: 2. Calculation of conversion efficiency of an ideal distortionless amplifier

Referring to Fig. 2, the distance from 1 to Q is equal to that from Q to 2. Further, it is assumed that the excitation is such as to give zero minimum current. Figure 2, may be used to analyze either a simple series-fed amplifier or a transformer-coupled amplifier. The only difference between these two circuits is that the supply voltage $V_{cc} = V_{max}$ in the series fed case, where as V_{cc} = quiescent voltage V_c in the transformer coupled amplifier.

Under these idealized conditions,

$$I_m = I_c \text{ and } V_m = \frac{V_{max} - V_{min}}{2}$$

Hence equation 1 becomes,

$$\eta = 25 \times \frac{(V_{max} - V_{min})}{V_{cc}} \%$$

The type of coupling used must now be taken into account for the series fed load, $V_{cc} = V_{max}$

$$\eta = 25 \times \frac{(V_{max} - V_{min})}{V_{max}} \%$$

Above equation indicates that the upper limit of the conversion efficiency is 25% and even this low value is approached only when $V_{max} \gg V_{min}$.

If the load is coupled to the amplifier stage through a transformer, then

$$V_{cc} = V_c = \frac{V_{max} + V_{min}}{2}$$

and,

$$\eta = 50 \times \frac{(V_{max} - V_{min})}{V_{max} + V_{min}} \%$$

The above equation shows that the upper limit of theoretical efficiency for a transformer coupled power amplifier is 50%, which is twice that of a series-fed circuit. For a transistor amplifier, V_{min} occurs near the saturation region and hence, $V_{min} \ll V_{max}$, the collector circuit efficiency may approach the upper limit of 50% under the idealized conditions.

Q.2. In a Class A amplifier, $V_{CE(max)} = 15$ V, $V_{CE(min)} = 1$ V. Find the overall efficiency for (a) series-fed load, (b) transformer-coupled load.

Solution: (a) Series-fed load

Overall efficiency, $\eta = 25\left(\frac{V_{max} - V_{min}}{V_{max}}\right)\%$

$\therefore \quad \eta = 25\frac{(15-1)}{15} = 23.33\%$

(b) Transformed-coupled load

Overall efficiency, $\eta = 50\left(\frac{V_{max} - V_{min}}{V_{max} + V_{min}}\right)\%$

$\therefore \quad \eta = 50\left(\frac{15-1}{15+1}\right) = 43.75\%$