that the load R_C is connected in series with the transistor output. The only difference between this circuit and the small-signal amplifier circuits considered previously is that the signals handled by the large-signal circuit are in the range of volts and the transistor used is a power transistor capable of operating in the range of few watts. This circuit is seldom used for power amplification because of its poor collector efficiency but will give clear understanding of class A operation to the readers. The output characteristics with operating point Q are shown in Fig. 16.6. I_{CQ} and V_{CEQ} represent no signal collector current and collector-emitter voltage respectively. When an input ac signal is applied to the amplifier given in Fig. 16.5, the output will vary from its dc bias operating voltage and current. A small input signal, as indicated in Fig. 16.6, will cause the base current to vary above and below the dc bias point, which will then cause the collector current (output) I_C to vary from the dc bias point set as well as the collector-emitter voltage V_{CE} to vary around its dc bias value. With the strengthening of the input signal, the output will vary around the established dc bias point until either the current or voltage attains a limiting condition. For the current this limiting condition is either zero current at the lower end or $\frac{V_{CC}}{R_C}$ at the upper end. For the collector-emitter voltage this limit is either 0 V or the supply voltage V_{CC}. Let the output current vary between limits $I_{C\ min}$ and $I_{C\ max}$ and similarly the collector-emitter voltage between limits $V_{CE\ min}$ and $V_{CE\ max}$.

16.6.1. Power Distribution. Input power from the collector supply V_{CC},

$$P_{in\ (dc)} = V_{CC}\, I_{CQ} \quad ...(16.5)$$

The power drawn from the collector supply is used in the following two components

(*i*) Power dissipated in collector load as heat,

$$P_{R_C\ (dc)} = I_{CQ}^2\, R_C \quad ...(16.6)$$

(*ii*) Power supplied to the transistor,

$$P_{tr\ (dc)} = P_{in\ (dc)} - P_{R_C\ (dc)} = V_{CC}\, I_{CQ} - I_{CQ}^2\, R_C \quad ...(16.7)$$

Power supplied to the transistor, $P_{tr\ (dc)}$ is further subdivided into

(*a*) ac power developed across the load resistor constituting ac power output and is given as

$$P_{out\ (ac)} = I_C^2\, R_C = I_C V_{CE} \quad ...(16.8\ a)$$

where I_C and V_{CE} are the rms values of collector current and collector-emitter voltage

$$= \frac{1}{2}\frac{I_{C(peak\text{-}to\text{-}peak)}}{\sqrt{2}} \times \frac{1}{2}\frac{V_{CE(peak\text{-}to\text{-}peak)}}{\sqrt{2}} \quad ...(16.8\ b)$$

$$= \frac{I_{C\ (peak\text{-}to\text{-}peak)} \times V_{CE\ (peak\text{-}to\text{-}peak)}}{8} \quad ...(16.8\ c)$$

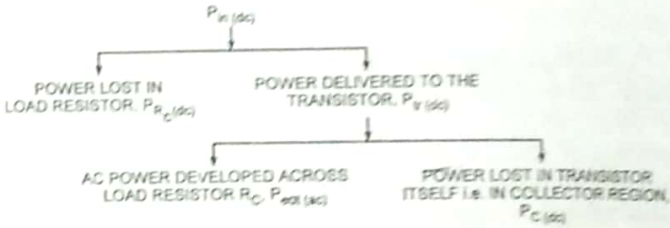
(*b*) Power dissipated, in the form of heat, by the transistor itself. The cause of power dissipation in transistor is explained below :

Consider an N-P-N transistor. The potential difference across the depletion layer formed near the collector junction is called the barrier potential. This potential gives the P-region (base) slightly more energy than N-region (collector). Thus when electrons emitted from emitter cross the base junction and enter the collector region, they give up energy in the form of heat and it is this energy that the transistor has to dissipate to the surrounding.

With zero signal applied at the input of the class A power amplifier, ac power developed across the load reduces to zero and therefore, all the power fed to the transistor is wasted in the form of heat. Thus, a *transistor dissipates* maximum power under zero-signal condition. Thus the device is cooler when delivering power to a load than with zero-signal condition.

Since in class A operation, maximum power dissipation in the transistor occurs under zero-signal condition, the power dissipation capacity of a power transistor, for class A operation, must be at least equal to the zero-signal rating.

Power flow diagram of a transistor is given below :



16.6.2. Collector Efficiency. The collector efficiency of a transistor is given as

$$\eta_{collector} = \frac{\text{Average ac power output, } P_{out\ (ac)}}{\text{Average dc power input to the transistor, } P_{tr\ (dc)}}$$

16.6.3. Power Efficiency. A measure of the ability of an active device to convert the dc power of supply into the ac (signal) power delivered to the load is called the *power* or *conversion* or *theoretical efficiency*. By definition the efficiency is

$$\eta = \frac{\text{AC power delivered to the load, } P_{out\ (ac)}}{\text{Total power drawn from dc supply, } P_{in\ (dc)}}$$

Now ac power delivered to the load,

$$P_{out\ (ac)} = \frac{I_{C\ (peak\text{-}to\text{-}peak)} \times V_{CE\ (peak\text{-}to\text{-}peak)}}{8}$$

...Refer to Eq. (16.8 c)

$$= \frac{(I_{C\ max} - I_{C\ min}) \times (V_{CE\ max} - V_{CE\ min})}{8}$$

and from Eq. (16.5), total power drawn from dc supply,

$$P_{in\ (dc)} = V_{CC}\, I_{CQ}$$

So power efficiency,

$$\eta = \frac{P_{out\ (ac)}}{P_{in\ (dc)}}$$

$$= \frac{(I_{C\ max} - I_{C\ min}) \times (V_{CE\ max} - V_{CE\ min})}{8\, V_{CC}\, I_{CQ}} \quad ...(16.9)$$

...4. Maximum Power and Efficiency. If the ...ing point Q is set at the midpoint of the maxi... signal swing, the resulting maximum power con... may be achieved. For the circuit shown in ...16.6, this would be determined using

Maximum $V_{CE\ (peak\ to\ peak)} = V_{CC}$

Maximum $I_{C\ (peak\ to\ peak)} = \frac{V_{CC}}{R_C}$

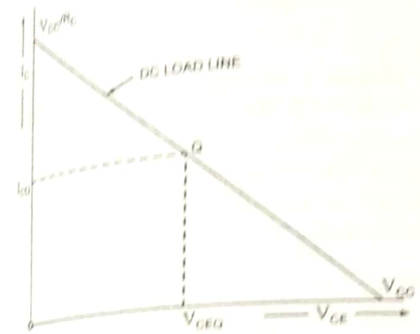


Fig. 16.7

...om Eq. (16.8 c) we have maximum ac power de... ...ed across the load resistor,

$$P_{out\ (ac)\ max} = \frac{1}{8} \cdot \frac{V_{CC}}{R_C} \times V_{CC} = \frac{V_{CC}^2}{8\,R_C} \quad ...(16.10)$$

...quiescent point Q,

$$I_{CQ} = \frac{V_{CC}/R_C}{2} \quad ...(16.11)$$

...power drawn from dc supply,

$$P_{in\ (dc)\ max} = V_{CC}\, I_{CQ} = \frac{V_{CC} \times V_{CC}/R_C}{2} = \frac{V_{CC}^2}{2\,R_C} \quad ...(16.12)$$

...supplied to the transistor,

$$P_{tr}(dc) = V_{CC} I_{CQ} - I_{CQ}^2 R_C \quad \text{...Refer to Eq. (16.7)}$$

$$= V_{CC} \cdot \frac{V_{CC}}{2 R_C} - \left(\frac{V_{CC}}{2\,R_C}\right)^2 R_C$$

$$= \frac{V_{CC}^2}{2\,R_C} - \frac{V_{CC}^2}{4\,R_C} = \frac{V_{CC}^2}{4\,R_C} \quad ...(16.13)$$

...maximum efficiency of an amplifier (class A ...) is given as

$$\eta_{max} = \frac{P_{out\ (ac)\ max}}{P_{in\ (dc)\ max}}$$

$$= \frac{V_{CC}^2/8\,R_C}{V_{CC}^2/2\,R_C} = \frac{2\,R_C}{8\,R_C} = 0.25 \text{ or } 25\% \quad ...(16.14)$$

...is the maximum percent efficiency for a series-...class A power amplifier. Since this maximum effi-...will occur only under ideal conditions and for the ...um ac signal swings, most series-fed class A ...amplifiers have power efficiencies much less than

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...value $= \frac{1}{2}\left[\frac{\text{peak-to-peak}}{\sqrt{2}}\right] = \frac{1}{2\sqrt{2}}$ peak-to-peak.

From Eqs. (16.10) and (16.13) we have

$$\frac{P_{out\ (ac)\ max}}{P_{tr\ (dc)}} = \frac{V_{CC}^2/8\,R_C}{V_{CC}^2/4\,R_C} = \frac{1}{2} \quad ...(16.15)$$

Thus, we see that a class A power amplifier with a direct-coupled resistive load can supply only one-half the amount of ac power to the load that the transistor can dissipate and the dc power input is four times the amount of ac signal power in the load.

Class A power amplifiers have got advantages of simple construction and distortionless output voltage.

The drawbacks of class A power amplifiers are very low efficiency and large power dissipation in the power transistors.

Example 16.1. A power transistor operating in class A operation has zero-signal power dissipation of 8 watts. If the ac power output is 2 W, determine the collector efficiency and power rating of transistor.

Solution : AC power output, $P_{out\ (ac)} = 2$ W

Power delivered to the transistor,

$$P_{tr\ (ac)} = \text{Zero-signal power dissipation} = 8 \text{ W}$$

Collector efficiency,

$$\eta_{collector} = \frac{P_{out\ (ac)}}{P_{tr\ (ac)}} \times 100 = \frac{2}{8} \times 100 = 25\% \textbf{ Ans.}$$

Since zero-signal condition represents worst condition for the transistor, the power dissipation capacity of the transistor should be at least equal to zero-signal power dissipation *i.e.* 8 W **Ans.**

Example 16.2. For class A series fed CE large signal amplifier using resistance load, the maximum and minimum values of collector-emitter voltages are 20 V and 10 V and maximum and minimum values of collector current are 10 mA and 5 mA when an ac signal is supplied to it. Determine rms values of collector voltage and collector current and ac power output. Also determine the power rating of the transistor.

Solution : RMS value of collector-emitter voltage,

$$V_{CE\ rms} = \frac{V_{CE\ (peak\text{-}to\text{-}peak)}}{2\sqrt{2}}$$

$$= \frac{V_{CE\ max} - V_{CE\ min}}{2\sqrt{2}} = \frac{20 - 10}{2\sqrt{2}} = 3.54 \text{ V } \textbf{Ans.}$$

Similarly rms value of collector current,

$$I_{C\ rms} = \frac{I_{C\ max} - I_{C\ min}}{2\sqrt{2}} = \frac{10 - 5}{2\sqrt{2}} = 1.77 \text{ mA } \textbf{Ans.}$$

Hence ac power output,

$$P_{out\ (ac)} = V_{CE\ rms} \times I_{C\ rms}$$

$$= 3.54 \times 1.77 \times 10^{-3} = 6.25 \text{ mW } \textbf{Ans.}$$

Example 16.3. Calculate the input power, output power delivered to the transistor, power lost in transistor, collector efficiency and overall efficiency of the amplifier shown in