Large Signal Amplifiers

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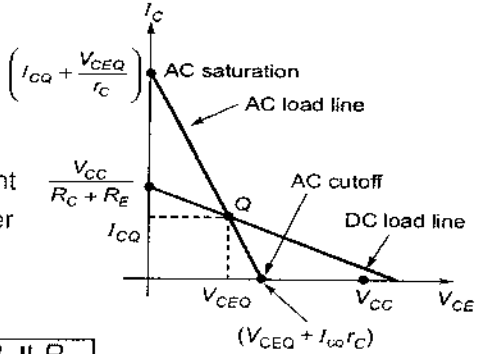
Load Line Analysis

For Common Emitter Amplifier



AC load line

where,

I_{CQ} = Quiescent collector current

V_{CEQ} = Quiescent collector-emitter voltage

Thevenin resistance driving base

$$r_B = R_s \,\|\, R_1 \,\|\, R_2$$

AC load resistance seen by collector

$$r_C = R_C \,\|\, R_L$$

Equation of AC load line

$$I_C = I_{CQ} + \frac{V_{CEQ}}{r_C} - \frac{V_{CE}}{r_C}$$

where, I_{CQ} = DC collector current

V_{CEQ} = DC collector emitter voltage

r_c = AC resistance seen by collector

AC saturation current

$$I_{C(sat)} = I_{CQ} + \frac{V_{CEQ}}{r_C}$$

Note:

When the transistor goes into saturation, $V_{CE} = 0$.

AC cutoff voltage

$$V_{CE(\text{cut})} = V_{CEQ} + I_{CQ} r_C$$

AC output compliance of a CE amplifier

$$PP \cong \min.(2I_{CQ} r_C, 2V_{CEQ})$$

Note:

AC output compliance is the maximum unclipped peak to peak ac voltage that an amplifier can produce.

For Emitter Follower Amplifier

Effective ac load resistance

$$r_E = R_E \parallel R_L$$

AC saturation current

$$I_{C(sat)} = I_{CQ} + \frac{V_{CEQ}}{r_E}$$

AC cut-off voltage

$$V_{CE(cut)} = V_{CEQ} + I_{CQ}r_E$$

AC output compliance of an emitter follower

$$PP \cong \min.(2I_{CQ}r_E, 2V_{CEQ})$$

For Common Base Amplifier

AC load resistance of CB amplifier

$$r_C = R_C \parallel R_L$$

Note:

AC load line and ac output compliance of CB amplifier are same as that of CE amplifier.

For Swamped Amplifier

AC saturation current

$$I_{C(sat)} = I_{CQ} + \frac{V_{CEQ}}{r_C + r_E}$$

AC cut-off voltage

$$V_{CE(cut)} = V_{CEQ} + I_{CQ}(r_C + r_E)$$

AC output compliance of a swamped amplifier

$$PP \cong \min.\left(2I_{CQ}r_C, 2\,V_{CEQ}\frac{r_C}{r_C + r_E}\right)$$

For maximum AC output compliance

$$I_{CQ}r_C = V_{CEQ} \text{ .... (CE stage)}$$

$$I_{CQ}r_E = V_{CEQ} \text{ .... (CC stage)}$$

$$I_{CQ}\,r_C = V_{CEQ}\frac{r_C}{r_C + r_E} \text{ .... (Swamped)}$$

Power Amplifiers

It is a large signal amplifier which has greater AC output voltage and greater AC output current hence it can provide greater AC output power to load.

Conversion Efficiency

It is the ability of power amplifier to convert DC power into AC power:

$$\eta = \frac{P_{AC}}{P_{DC}} \times 100\%$$

Harmonic Distortion

The harmonic distortion means the presence of the frequency components in the waveform, which are not present in the input signal.

If $I_C = I_o + B_0 + B_1\cos\omega t + B_2\cos 2\omega t + \cdots + B_n\cos n\omega t$

then $\% D_n = \frac{|B_n|}{|B_1|} \times 100\%$; where, $n = 1, 2, 3,$ and so on

Here, fundamental frequency component has an amplitude B_1 and n^{th} harmonic component has an amplitude of B_n.

Thus, total harmonic distortion is

$$\%D = \sqrt{D_2^2 + D_3^2 + D_4^2 + \cdots + D_n^2} \times 100\%$$

Classification of Power Amplifier

Class-A Operation

- Transistor operates in active region at all times.
- Collector current flows for 360° of the AC cycle.

Unloaded voltage gain of CE amplifier

$$A = -\frac{R_C}{r_e'}$$

Loaded voltage gain

$$A_v = -\frac{r_C}{r'_e}$$

Current gain of the transistor

$$A_i = \frac{i_c}{i_b}$$

where, A_i = Current gain
i_c = AC collector current
i_b = AC base current

Note:

$A_i \cong \beta$; In most of the circuits you can use the approximation.

Power gain

$$A_p = -A_v A_i$$

Load power

$$P_L = \frac{V_L^2}{R_L} = \frac{V_{PP}^2}{8R_L}$$

where, P_L = AC load power
V_L = RMS load voltage
V_{PP} = Peak-to-peak load voltage
R_L = Load resistance

Transistor power Dissipation

$$P_{DQ} = V_{CEQ} I_{CQ}$$

where, P_{DQ} = Quiescent power dissipation
V_{CEQ} = Quiescent collector-emitter voltage
I_{CQ} = Quiescent collector current

Total DC power supplied to an amplifier

$$P_S = V_{CC} I_S$$

Maximum AC load power

$$P_{L(max)} = \frac{PP^2}{8R_L}$$

where, PP = Maximum unclipped value of V_{PP}

Stage efficiency

$$\eta = \frac{P_{L(max)}}{P_S} \times 100\%$$

where, η = Stage efficiency
P_S = DC input power

Remember:

- Class-A amplifier produces least distortion in the output among all power amplifier.
- Power drain is present.
- The maximum efficiency of class-A amplifier is 25%.

Class-B Operation

- Collector current flows for only 180° of the AC cycle.
- Q-point is located approximately at cutoff on both the DC and AC load lines.

Collector-emitter voltage at Q-point

$$V_{CEQ} = \frac{V_{CC}}{2}$$

AC load power of a class B push-pull amplifier

$$P_L = \frac{V_{PP}^2}{8R_L}$$

Remember:

- Output signal is half sinusoidal.
- Quiescent power dissipation/power drain is almost zero.
- The maximum efficiency of class-B amplifier is 78.5%.

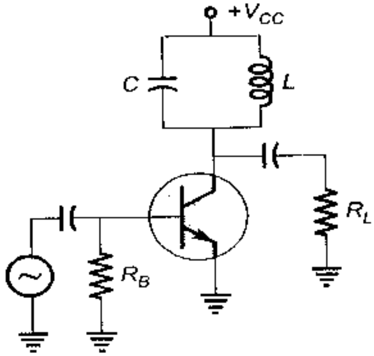
Class AB Operation

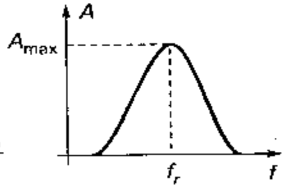
- Operating point is located between the limits of class-A and class-B.
- Collector current flows for more than half sinusoidal but not fully sinusoidal.
- Distortion in class-AB amplifier is more than class-A but less than class-B.
- Power drain is more than class-B but less than class-A.

Class C Operation

- It is operated either in deep saturation or in deep cut-off region.
- The collector current flows for less than 90° of the AC cycle.

Tuned Amplifier





Resonant frequency of tank circuit

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

where, L = Inductance ; C = Capacitance

AC load power class C amplifier

$$P_L = \frac{V_{PP}^2}{8R_L}$$

Remember:

- It has highest conversion efficiency among all power amplifiers.
- Output is heavily distorted.
- It is used in tuned power amplifiers and radio frequency amplifier.
- The maximum efficiency of class-C amplifier is 87.5%.