Chapter 12

Power Amplifiers

Class A: 360° Variation of output - DC bias at midpoint

Class B: 180° Variation biased at OV - 1/2 Cycle
Push-pull 1/2+, 1/2 - gives full cycle

Class AB: Bias @ DC level above Vcc/2
between 180° and 360°

Class C: <180° TUNED Ckt (Resonant)
Provides a full cycle of operation @ tuned freq.

Class D: DIGITAL ON TIME < OFF SMALL POWER USAGE

\[
\begin{align*}
\text{A} & \quad \text{LOWEST EFFICIENCY} \\
\text{AB} & \quad \text{T} \\
\text{B} & \quad 78.5\% \\
\text{C} & \quad X \\
\text{D (PULSED)} & \quad 90\%
\end{align*}
\]

Class A

[Diagram showing Class A circuit with Ic, Vcc, and load resistance]

[Graph showing Ic variation with Vc]

[Graph showing Vc variation with Ic and Vcc]

[Graph showing Vce variation with time]

[Graph showing Vo variation with time]
Power Considerations

\[ I_{IN} = I_{CQ} \quad \therefore P_i(\text{dc}) = VccI_{CQ} \]

\text{INPUT POWER}

\text{POWER IS DELIVERED TO THE LOAD - RC}

\text{USING RMS}

\[ P_0(\text{ac}) = V_{CE_{\text{RMS}}}I_{C_{\text{RMS}}} = I_{C_{\text{RMS}}}^2RC \]

\text{NOTE:}

\[ V_{CE} = V_{OUT} \]

\[ = \frac{V_{CE_{\text{RMS}}}}{RC} \]

\text{Efficiency}

\[ \eta = \frac{P_0(\text{ac})}{P_i(\text{dc})} \times 100\% \]

\text{MAXIMUM EFFICIENCY}

\[ V_{CE(\text{P-P})_{\text{MAX}}} = V_{cc} \]

\[ I_{C(\text{P-P})_{\text{MAX}}} = \frac{V_{cc}}{RC} \]

\text{MAX POWER OUT} \Rightarrow \text{PEAK VOLTAGE - } V_m = \frac{V_{cc}}{2}

\[ V_{RMS} = \frac{V_{cc}}{\sqrt{2}} = \frac{\sqrt{2}}{4} V_{cc} \]

\[ P_0(\text{ac}) = \left( \frac{V_{CE_{\text{RMS}}}}{RC} \right)^2 = \left( \frac{\sqrt{2}}{4} V_{cc} \right)^2 \frac{1}{RC} = \frac{V_{cc}^2}{16} \frac{V_{cc}}{RC} = \frac{V_{cc}^2}{8RC} \]

\[ \text{MAX } P_i = VccI_{CQ} = Vcc \left( \frac{V_{cc}}{2RC} \right) = \frac{V_{cc}^2}{2RC} \]

\text{MAX EFF,} \quad \therefore \quad \frac{P_0(\text{ac})}{P_i(\text{dc})} = \frac{V_{cc}^2/8RC}{V_{cc}^2/2RC} = 25\%
-20V + I_B(1kΩ) + 0.7V = 0

I_B = 19.3 mA

I_C = βI_B = 0.48 A

V_CEQ = 20V - I_CQ(20) = 10.4V

Input Voltage gives a peak, I_B = 10 mA peak

I_peak can be calculated using

\[ I_{C_{peak}} = βI_{B_{peak}} \]

\[ \beta(10mA) = 250 \text{mA peak} \]

\[ I_C = \frac{I^2}{2} \]

\[ P_C(\text{ac}) = I_C^2 \text{rms}R_C = (250 \text{ mA})^2 \times 20 = 0.625 \text{W} \]

\[ P_C = V_{cc}I_{CQ} = 20V(0.48A) = 9.6 \text{W} \]

\[ \eta = \frac{P_C(\text{ac})}{P_C(\text{dc})} = \frac{0.625}{9.6} = 6.5\% \]
12.3 Transformer-Coupled Class A Amp.

\[
\text{MAX } \text{S.D} = \eta
\]

\[
N = \# \text{TURNS}
\]

\[
\frac{V_2}{V_1} = \frac{N_2}{N_1}
\]

\[
\frac{I_2}{I_1} = \frac{N_1}{N_2}
\]

\[
R_L = \left(\frac{N_2}{N_1}\right)^2 R_L'
\]

\[
\alpha = N_1 / N_2
\]

\[
R_L = \alpha^2 R_L
\]

**Ex 12.2**

Calculate effective resistance looking into the primary of a 15:1 transformer with \( R_L = 8 \, \Omega \)

\[
R_L' = \frac{8 \, \Omega}{15} \text{ from eq 12.22, } R_L' = \left(\frac{15}{1}\right) R_L = 1.8 \, K\Omega
\]

**Ex 12.3**

16 \text{ } R = \text{ SPEAKER WANT LOAD RESISTANCE } \quad R_L = 10 \, K\Omega

\[
\frac{R_L}{R_L'} = \left(\frac{N_2}{N_1}\right) = \frac{16}{10 \, K} = \frac{1}{625}
\]

\[
\left(\frac{N_1}{N_2}\right)^2 = 625
\]

\[
\frac{N_1}{N_2} = \sqrt{625} = 25:1
\]
Calculate $I_B$

$I_CQ = B I_B Q$

$R_0 = \frac{0.0V}{N_1}$

slope of ac load line $= \frac{1}{R_L}$ where

$V_{CE_{pp}} = V_{CE_{max}} - V_{CE_{min}}$

$I_{CP_{pp}} = I_{C_{max}} - I_{C_{min}}$

$P_0 (ac) = \frac{V_{CE_{pp}} I_{CP_{pp}}}{8}$

Transformer

$V_L = \frac{N_2}{N_1} V_1$

$P_L = \frac{V_L^2 (\text{rms})}{R_L}$ and

$I_L = I_2 = \frac{N_1}{N_2} I_C$

$P_L = I_L^2 (\text{rms}) R_L$
Ex 12.4  \[ R_L = 8 \Omega \quad I_B = 6 \text{mA} \quad I_{B_{\text{PEAK}}} = 4 \text{mA} \]
\[ V_{CC} = 10 \text{V} \]

1. Draw \( V_{CE} \) vs \( I_C \) Curves for Transistor

2. At \( V_{CC} \), draw \textbf{VOLTAGE LINE} \( (\text{DC LOAD LINE}) \) \[ (\text{on VEE axis}) \]

3. \( I_B = 6 \text{mA} \rightarrow \text{Q-point where DC LOAD LINE crosses} \]

4. Calculate \[ R'_L = \left( \frac{N_1}{N_2} \right)^2 \cdot R_L = (3)^2 \cdot (8) = 72 \text{\Omega} \]

5. Draw slope (at Q/PT) of \(-1/72 \text{\Omega}\)

6. Swing of \( I_B \) from \(+4 \text{mA} \) gives \( V_{CE \text{min}}, V_{CE \text{max}} \)
\[ \text{OR} \]
\[ I_{C_{\text{MAX}}}, I_{C_{\text{MIN}}} \]

7. \[ P_0(\text{ac}) = \frac{(V_{CE})(\Delta I_C)}{8} \]

Efficiency:
\[ P_L(\text{dc}) = V_{CC} \cdot I_C \]
\[ P_Q = P_{L(\text{dc})} - P_0(\text{ac}) \]
\[ \% \eta = \frac{P_0(\text{ac})}{P_L(\text{dc})} \]
MAX EFFICIENCY - TRANSFORMER-COUPLED AMP

\[ \eta = 50 \left( \frac{(V_{CE}^{\text{max}} - V_{CE}^{\text{min}})}{(V_{CE}^{\text{max}} + V_{CE}^{\text{min}})} \right)^2 \]

12.4 CLASS B AMPLIFIER

PUSH-PULL CONFIG. EACH 1/2 CYCLE

\[ P_c(\omega) = V_{cc} I_{dc} \]

\[ I_{dc} = \frac{2}{\pi} I_{\text{peak}} \]

\[ P_0(\text{ac}) = \frac{V_L^{\text{rms}}}{R_L} = \frac{V_L(p-p)}{2RL} = \frac{V_L(p)}{2RL} \]

\[ \eta = \frac{P_0(\text{ac})}{P_L(\text{dc})} \times 100\% = \frac{V_L(p)/2RL}{V_{cc}(2/\pi)I_p} = \frac{\pi}{4} \frac{V_L(p)}{V_{cc}} \times 100\% \]

POWER DISIPATED

\[ P_{2Q} = P_c(\text{dc}) - P_0(\text{ac}) \]

\[ \frac{P_{2Q}}{2} = P_Q \]

POWER DISIPATED BY 1 TRANSISTOR
**Max Power - Class B**

\[
\max P_o(\text{ac}) = V_{cc} \frac{I_c}{2} = V_{cc} \left(\frac{V_{cc}}{2RL}\right)
\]

\[
\max P_l(\text{dc}) = \frac{2V_{cc}^2}{\pi RL}
\]

\[
\max \eta = \frac{P_o(\text{ac})}{P_l(\text{dc})} \times 100\% = \frac{\pi}{4} \times 100\% = 78.54\%
\]

**Max Power Dissipated by Transistor is**

When \( V_L(p) = 0.636Vcc = \frac{2}{\pi}Vcc \)

\[
\max P_{2Q} = \frac{2Vcc^2}{\pi^2 RL}
\]
CLASS B AMPLIFIER

1/2 WAVE

INPUT CONFIG:

\[ \text{INPUT} - 180^\circ \text{ Phase shift between 2 inputs} \]

\( \text{TRANSFORMER (OUTPUT TAPPED (1/2))} \)

\( \text{TRANSISTOR - VC} \neq \text{VE} \)

\( \text{OP AMPS (delay?)} \)

TRANSFORMER-COUPLED PUSH-PULL

COMPLEMENTARY - NPN-PNP

\( \text{CROSS-OVER DISTORTION} \)

\( \text{FIX with } 180^\circ \text{ OPERATION} \)

QUASI-COMPLEMENTARY PUSH-PULL

DARLINGTON PAIR