Electronic Fundamentals II — Formula Sheet

Bipolar Junction Transistors

$I_E = I_B + I_C$ $\quad I_C = \beta I_B$ $\quad I_C \cong I_E$ $\quad I_B = I_E(1 - \alpha)$

$I_E = I_B(1 + \beta)$ $\quad I_E = \dfrac{I_C}{\alpha}$ $\quad I_C = \alpha I_E$ $\quad \beta = \dfrac{I_C}{I_B}$

$\alpha = \dfrac{\beta}{(1 + \beta)}$ $\quad I_{B(max)} = \dfrac{I_{C(max)}}{\beta_{(max)}}$

General Amplifier

$A_v = \dfrac{v_{out}}{v_{in}}$ $\quad A_i = \dfrac{i_{out}}{i_{in}}$

$A_p = \dfrac{p_{out}}{p_{in}}$ $\quad A_{v(eff)} = \dfrac{v_L}{v_S}$

$v_L = \dfrac{R_L}{Z_{out} + R_L} v_{out}$ $\quad v_{in} = \dfrac{Z_{in}}{R_S + Z_{in}} v_S$

$A_p = A_v A_i$ $\quad A_{p(dB)} = 10 \log A_p$ $\quad A_{V(dB)} = 20 \log A_V$

h Parameters

$A_i = h_{fe}\left(\dfrac{Z_{in}\ r_c}{h_{ie}\ R_L}\right)$ $\quad A_v = \dfrac{h_{fe}\ r_c}{h_{ie}}$ $\quad r'_e = \dfrac{h_{ie}}{h_{fe}}$ $\quad Z_{in(base)} = h_{ie}$

DC Analysis

$R_{base} = h_{FE} R_E$ $\quad V_B = \dfrac{R_2}{R_1 + R_2} V_{CC}$ $\quad V_E = V_B - 0.7\ V$

$I_E = \dfrac{V_E}{R_E}$ $\quad I_B = \dfrac{I_E}{h_{FE} + 1}$

$V_{TH} = \dfrac{R_2}{R_1 + R_2} V_{CC}$ $\quad I_{CQ} = \dfrac{V_{TH} - V_{BE}}{\dfrac{R_{TH}}{h_{FE}} + R_E}$ $\quad R_{TH} = R_1 \| R_2$

$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_E)$ $\quad V_{CE} = V_{CC} - V_E$ $\quad V_C = V_{CC} - I_C R_C$ $\quad V_{CE} = V_{CC} - I_C R_C$

$r'_e = \dfrac{25\ mV}{I_E}$ $\quad r'_e = \dfrac{h_{ic}}{h_{fc}}$

$R_E = (R_E + r_E)$ $\quad I_{C(SAT)} = \dfrac{V_{CC}}{R_C + R_E}$ $\quad V_{CE(off)} = V_{CC}$

C.E. Amplifier

$A_v = \dfrac{r_c}{r'_e}$ $\quad A_v = \dfrac{r_c}{r'_e + r_E}$ $\quad A_v = \dfrac{v_{out}}{v_{in}}$

$A_{iT} = (A_{i1})(A_{i2})(A_{i3})$ $\quad A_{vT} = (A_{v1})(A_{v2})(A_{v3})$ $\quad A_{pT} = (A_{vT})(A_{iT})$ $\quad v_b = \dfrac{Z_{in}}{Z_{in} + R_S} v_S$

$A_p = \dfrac{p_{out}}{p_{in}}$ $\quad A_i = \dfrac{i_{out}}{i_{in}}$ $\quad i_c = A_i i_b$ $\quad v_{out} = A_v v_{in}$

$Z_{in(base)} = h_{fe}(r'_e)$ $\quad Z_{in(base)} = h_{fe}(r'_e + r_E)$ $\quad r_C = R_C \| R_L$ $\quad Z_{in} = R_1 \| R_2 \| Z_{in(base)}$

$I_{C(sat)} = \dfrac{V_{CC}}{R_C + R_E}$ $\quad V_{CE(off)} = V_{CC}$

Emitter Follower

$A_i = h_{fc}\left(\dfrac{Z_{in}\ r_E}{Z_{in(base)}\ R_L}\right)$ $\quad A_v = \dfrac{r_E}{(r'_e + r_E)}$ $\quad Z_{out} = R_E \,\|\, \left(r'_e + \dfrac{R'_{in}}{h_{fc}}\right)$

$Z_{in(base)} = h_{fc}(r'_e + r_E)$ $\quad Z_{in} = R_1 \| R_2 \| Z_{in(base)}$ $\quad r_E = R_E \| R_L$ $\quad A_p = A_i A_v$

$V_{CEQ} = V_{CC} - V_E$ $\quad I_{C(sat)} = \dfrac{V_{CC}}{R_E}$ $\quad V_{CE(off)} = V_{CC}$

Darlington Amplifier Quick Analysis

$A_i = h_{fc1} h_{fc2}\left(\dfrac{Z_{in}\ r_E}{Z_{in(base)}\ R_L}\right)$

$Z_{in(base)} \cong h_{fc1} h_{fc2} r_E$

$Z_{out} \cong r'_{e2} + \dfrac{r'_{e1}}{h_{fc2}}$ $\quad A_V \cong 1$

Compliance, ac Load lines, Efficiency, Power & Others

$I_1 = \dfrac{V_{CC}}{R_1 + R_2}$ $\quad I_{CC} = I_{CQ} + I_1$ $\quad P_S = V_{CC} I_{CC}$

$PP = 2V_{CEQ}$ $\quad PP = 2I_{CQ} r_C$ $\quad P_{L(max)} = \dfrac{PP^2}{8R_L}$

$P_L = \dfrac{(0.707\ V_{pk})^2}{R_L}$ $\quad = \dfrac{P_L}{P_S} \times 100$ $\quad h_{fe} = \dfrac{i_c}{i_b}$

$A_i = \dfrac{i_{out}}{i_{in}}$ $\quad P_L = \dfrac{V_{PP}^2}{8R_L}$ $\quad P_L = \dfrac{V_L^2}{R_L}$

$v_{ce(off)} = V_{CEQ} + I_{CQ} r_C$ $\quad i_{c(sat)} = I_{CQ} + \dfrac{V_{CEQ}}{r_C}$

Class AB & Class B etc

$V_{B(Q2)} = \dfrac{R_2}{R_1 + R_2}(V_{CC} - 1.4\ V)$

$V_{B(Q2)} = V_{CEQ} - 0.7\ V \mid (R_1 = R_2)$

$V_{CEQ} = \dfrac{V_{CC}}{2}$ $\quad V_{CE(off)} = \dfrac{V_{CC}}{2}$

$I_{CQ} \cong I_1$ (Class AB)

$i_{C(sat)} = \dfrac{V_{CC}}{2R_L}$ $\quad I_{CQ} \cong 0$ (Class B)

$PP = 2V_{CEQ}$ $\quad PP \cong V_{CC}$

$A_V = \dfrac{R_L}{R_L + r'_e}$ $\quad A_i = h_{fc}\left(\dfrac{Z_{in}}{Z_{in(base)}}\right)$ $\quad A_P = A_V A_i$ $\quad Z_{in(base)} = h_{fc}(r'_e + R_L)$

$P_{L(max)} = \dfrac{PP^2}{8R_L}$ $\quad P_L = \dfrac{V_{P\text{-}P}^2}{8R_L}$ $\quad P_D = \dfrac{V_{P\text{-}P}^2}{40R_L}$ $\quad Z_{out} = r'_e + \dfrac{R'_{in}}{h_{fc}}$ $\quad R'_{in} = R_1 \| R_4 \| R_S$

$I_{CC} = I_{C1(ave)} + I_1$

$I_{C1(ave)} = \dfrac{0.159\ V_{CC}}{R_L}$ or $I_{C1(ave)} = \dfrac{V_{CC}}{2\pi R_L}$

$I_{C1(ave)} = \dfrac{0.159\ V_{PP(out)}}{R_L}$ or $I_{C1(ave)} = \dfrac{V_{PP(out)}}{2\pi R_L}$

$I_1 = \dfrac{V_{CC} - 1.4\ V}{R_1 + R_2}$ $\quad P_S = V_{CC} I_{CC}$

Field Effect Transistors

$I_D = I_{DSS}\left(1 - \dfrac{V_{GS}}{V_{GS(off)}}\right)^2$ $\quad g_m = g_{m0}\left(1 - \dfrac{V_{GS}}{V_{GS(off)}}\right)$

$V_G = \dfrac{R_2}{R_1 + R_2} V_{DD}$ $\quad V_S = V_G - V_{GS}$ $\quad I_D = \dfrac{V_G - V_{GS}}{R_S}$

$A_V = g_m r_D$ $\quad I_D = \dfrac{-V_{GS}}{R_S}$ $\quad I_D = \dfrac{V_G}{R_S}$

$g_{m0} \cong \dfrac{2I_{DSS}}{V_{GS(off)}}$ $\quad A_V = \dfrac{r_D}{r_S + (1/g_m)}$ $\quad A_V = \dfrac{r_S}{r_S + (1/g_m)}$

$V_{DS} = V_{DD} - I_D(R_D + R_S)$ $\quad V_{DS} = V_{DD} - I_D R_D$ $\quad V_D = V_{DD} - I_D R_D$ $\quad V_{GS} = V_G - V_S$ $\quad V_{GS} = V_{GG}$