BJT (Bipolar junction Transistor)

Active mode

$V_{BE} = 0.7V$

$i_c = \alpha i_E$

$i_E = i_b + i_c$

$i_c = \beta i_b$

check $V_{CE} > 0.2V$ or $V_{BC} < 0.5V$

Saturation mode

$V_{BE} = 0.8\,V$

$V_{CE} = 0.2V$

$i_e = i_b + i_c$

check $i_c < \beta i_B$

$\beta = \frac{\alpha}{1-\alpha}$

Cut-off

$V_{BE} < 0.5V$

$V_{CE} = V_{cc}$

$i_c = 0$

$i_B = 0$

$i_E = 0$

JFET (Junction Field Effect Transistor) or depletion MOSFET

if $V_{GS} < V_P$: Cutoff mode

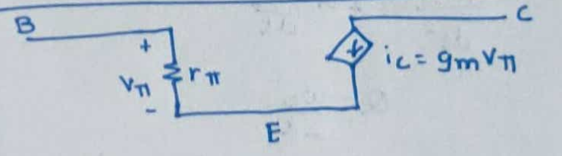
$I_D = 0$

if $V_{GS} > V_P$ and $V_{DS} < V_{GS} - V_P$: Ohmic mode

$$I_D = I_{DSS}\left[2\left(1 - \frac{V_{GS}}{V_P}\right)\left(\frac{V_{DG}}{-V_P}\right) - \left(\frac{V_{DS}}{V_P}\right)^2\right]$$

if $V_{GS} > V_P$ and $V_{DS} > V_{GS} - V_P$: active / saturation mode

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$



$g_m = \frac{I_c}{V_T}$ $r_\pi = \frac{\beta}{g_m}$

Small signal analysis

$NM_L = V_{IL} - V_{OL}$

$NM_H = V_{OH} - V_{IH}$

enhancement mosfet

if $V_{GS} < V_T$: cutoff mode

$I_D = 0$

if $V_{DS} < V_{GS} - V_T$: Ohmic mode

$$I_D = K\left[2(V_{GS} - V_T)V_{DS} - (V_{DS})^2\right]$$

if $V_{DS} > V_{GS} - V_T$: active / Saturation mode

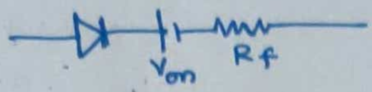
$$I_D = K(V_{GS} - V_T)^2$$

$\beta i_B > i'_N + i_R$

i_R ↳ current to Vout

i'_N ↳ N. i' current going out

Diode



$V_{on} \approx 0.7\,V$

$$i = I_S \left(e^{V/\eta V_T} - 1 \right)$$

I_S : saturation current (few nA)

$\eta \sim 2$ for Si
emission coeff

$V_T - 25\,mV$ @ 300 K

$= \frac{K_B T}{q}$

Semiconductors

$J = ne\mu_n E + pe\mu_p E = \sigma E$

$n = p = n_i \rightarrow \sigma = n_i e(\mu_p + \mu_n)$

$np = n_i^2$

5.22×10^{23} atoms/cm^3

n type

$n \approx N_D$

$p = \frac{n_i^2}{N_D}$

p type

$p \approx N_A$

$n = \frac{n_i^2}{N_A}$

$J = q D_n \frac{dn}{dx}$

$, - q D_p \frac{dp}{dx}$

$V_2 - V_1 = V_T \ln\left(\frac{P_1}{P_2}\right)$

$V_2 - V_1 = V_T \ln\left(\frac{N_2}{N_1}\right)$

$$\frac{d^2 v_c}{dt^2} + 2\alpha \frac{dv_c}{dt} + w_0^2 V_c = 0$$

$Q = \frac{w_0}{2\alpha}$

$\alpha < w_0$ undamped

$\alpha = w_0$ critically damped

$\alpha > w_0$ overdamped

$P_{avg} = \frac{1}{2} V I \underbrace{\cos(\theta_V - \theta_I)}_{\text{power factor}}$

$V_{rms} = \frac{V}{\sqrt{2}}$ $\quad I_{rms} = \frac{I}{\sqrt{2}}$

$\frac{\text{avg Power}}{\text{Apparent Power}} = \cos\theta$

$\theta > 0$ inductive load (lagging p.f)

$\theta < 0$ capacitive load (leading p.f)

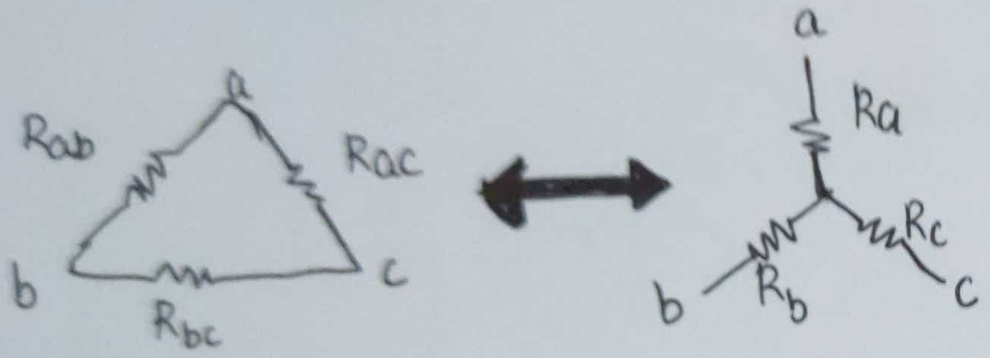
$\text{Power gain} = \frac{P_2}{P_1}$

in dB $= 10 \log\left(\frac{P_2}{P_1}\right) = 20 \log\left(\frac{V_2}{V_1}\right) = 20 \log |H|$

10 : decade $\quad -20$ in P.G

2 : octave $\quad -6$ in P.G

* <u>Delta to Y</u>



$$R_a = \frac{R_{ab} R_{ac}}{R_{ab} + R_{ac} + R_{bc}}$$

$$R_b = \frac{R_{bc} R_{ab}}{R_{ab} + R_{bc} + R_{ac}}$$

$$R_c = \frac{R_{ca} R_{bc}}{R_{ab} + R_{bc} + R_{ac}}$$

$$R_{ab} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$$

$$R_{bc} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_a}$$

$$R_{ac} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b}$$

$\frac{1}{S}$ $\frac{1}{S-a}$ e^{a} $\frac{1}{S^2}$

$L(y'') = s^2$