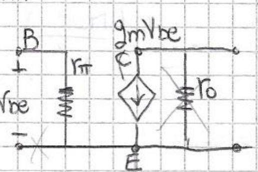
PUNTO DI LAVORO => CONTINUA => Condensatori
DC circuiti aperti

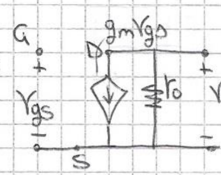
Guadagno in tensione => ALTERNATA => Condensatori + modelli
AC circuiti chiusi

$A_V = \frac{V_{OUT}}{V} \cdot \frac{V}{V_{IN}}$

• BJT



• MOS



BJT	MOS	
I_C/V_T	$2I_D/V_{GS}-V_{TH}$	g_m
V_A/I_C	$1/\lambda I_D$	r_o
V_A/V_T	$\frac{1}{\lambda}\sqrt{\frac{2K_n}{I_D}}$	μ_F
β_F/g_m	∞	r_π
$V_{be} \leq 5mV$	$V_{gs} \leq 0{,}2[V_{gs}-V_{TH}]$	cond piccolo segnale

$A_V = \frac{V_{OUT}}{V_B} \cdot \frac{V_B}{V_{IN}}$

$V_{B/G} = V_{gs}/V_{be} + R_s/R_E \, g_m V_{gs}/V_{be}$

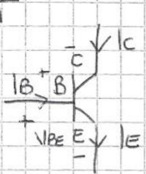
• $V_{OUT} = -R_L g_m V_{gs}/V_{be}$

$g_m r_\pi = \beta_F$

BJT => $V_B = I_B r_\pi + (R_E \ldots)$ $R_{iB} = \frac{V_B}{I_B}$ $V_B = V_I = \frac{R_{iB} \| R_B}{R_i + R_{iB} \| R_B}$

MOS V_B sarebbe V_G, $V_G = V_i \frac{R_B}{R_B + R_i}$

BJT



• INTERDIZIONE BE OFF BC OFF

• SAT BE ON BC ON • V_{CE} è molto piccolo

• RAD BE ON BC OFF
$V_{BE} = 0{,}7$

$I_E = (\beta_F + 1) I_B$
$I_C = \beta_F I_B$
$I_E = I_C + I_B$

$\beta_F = \frac{\alpha_F}{1-\alpha_F} = h_{FE}$ guadagno in corrente

$10 < \beta_F < 500$
$0{,}9 < \alpha_F < 0{,}99$

• RAI BE OFF BC ON
$V_{BC} = 0{,}7$ $0 < \beta_R < 10$ $I_E = -\beta_R I_B$
$I_E = \alpha_R I_C$

$$I_C = I_S\left[e^{V_{BE}/V_T} - e^{V_{BC}/V_T}\right] - \frac{I_S}{\beta_R}\left[e^{V_{BC}/V_T} - 1\right]$$

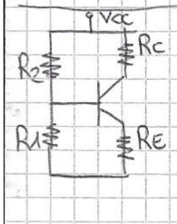
$$I_E = I_S\left[e^{V_{BE}/V_T} - e^{V_{BC}/V_T}\right] + \frac{I_S}{\beta_F}\left[e^{V_{BE}/V_T} - 1\right]$$

$$I_B = \frac{I_S}{\beta_F}\left[e^{V_{BC}/V_T} - 1\right] + \frac{I_S}{\beta_R}\left[e^{V_{BC}/V_T} - 1\right]$$

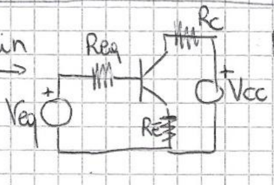
$$I_T = I_S\left[e^{V_{BE}/V_T} - e^{V_{BC}/V_T}\right]$$

$I_{S npn} = \frac{qAD_n n_i^2}{W_B N_A}$

$I_{S pnp} = \frac{qAD_p n_i^2}{W_B N_D}$



Thevenin →



$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$

$V_{eq} = \frac{R_1}{R_1 + R_2} V_{CC}$

• tempo di transito $T_F = \frac{W_B^2}{2D_n}$

• Capacità di diffusione $C_D = \frac{I_T}{V_T} T_F$, $I_T = I_C$

• $V_{BC} = V_{BE} - V_{CE}$

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mobilità elettroni $\mu_n = 1350\ cm^2/Vs$
" lacune $\mu_p = 550\ cm^2/Vs$

$n \simeq N_D$
$p \simeq N_A$

ricombinazione $R = rnp$
generazione $G_i = r n_i^2$

$np = n_i^2$ → elettroni ionizzati

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{KT}{q} = V_T = 26m\ V$$

$p = \frac{n_i^2}{N_D \simeq n}$ $\quad n = \frac{n_i^2}{N_A \simeq p}$

• $\tau = \frac{1}{rN_A}$

• K: Boltzmann = $8{,}62 \cdot 10^{-5}$
• $q = 1{,}6 \cdot 10^{-19}$

• $L_n = \sqrt{\tau D_n}$

regione di svuotamento $W = X_p + X_n = \sqrt{\frac{2\varepsilon}{q}\varphi\left[\frac{1}{N_A}+\frac{1}{N_D}\right]}$
+ grande − drogaggio

potenziale di giunzione $\varphi = V_T \ln\left(\frac{N_D N_A}{n_i^2}\right)$

$\to N_D X_n = N_A X_p$

$$n_i^2 = T^3 e^{-\frac{E_g}{2KT}}$$

• $T = 300K$

• E_g potenziale di banda proibita ($\simeq 1{,}12$)

conducibilità
$\sigma = (n\mu_n + p\mu_p)q$

densità di corrente $J = qE n_i(\mu_n + \mu_p)$

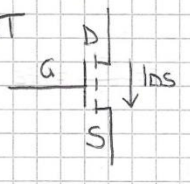
DIODO

$\circ \overset{+}{-}\!\triangleright\!|\!\overset{-}{-}\circ$

• $V=0 \Rightarrow i=0$
• $V<0$ PI $\Rightarrow i=0$
• $V>0$ PD $\Rightarrow i = I_s(e^{V/V_T} \cancel{-1})$
$V = 0{,}6\ V$

$I_s = \frac{qSD_n}{L_n}\frac{n_i^2}{N_A}$

MOSFET



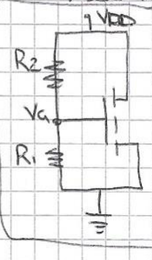
1. Conduzione $V_{GS} > V_{TH}$
2. Saturazione $V_{DS} \geq V_{GS} - V_{TH} \Rightarrow I_{DS} = \frac{K_n}{2}(V_{GS}-V_{TH})^2$ *
3. LINEARE $\longrightarrow I_{DS} = K_n\left((V_{GS}-V_{TH})V_{DS} - \frac{1}{2}V_{DS}^2\right)$

↓ ma se $V_{DS} \ll 2(V_{GS}-V_{TH}) \Rightarrow I_{DS} = K_n(V_{GS}-V_{TH})V_{DS}$

tensione di soglia $V_{TH} = (2\varphi_F) + d\sqrt{\frac{2qN_A}{\varepsilon}(2\varphi_F)}$

$K_n = \frac{C_{ox}'' \mu_n W}{L}$ $\quad$ • $C_{ox}'' = \frac{\varepsilon}{d}$

$* \ I_{DS} = K_n(V_{GS}-V_{TH})^2(1+\lambda V_{DS})$



$V_G = \frac{R_1}{R_2+R_1} V_{DD}$

Specchio di corrente
$V_{GS}^1 = V_{GS}^2$
$\Rightarrow I_{DS}^1 = I_{DS}^2$

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