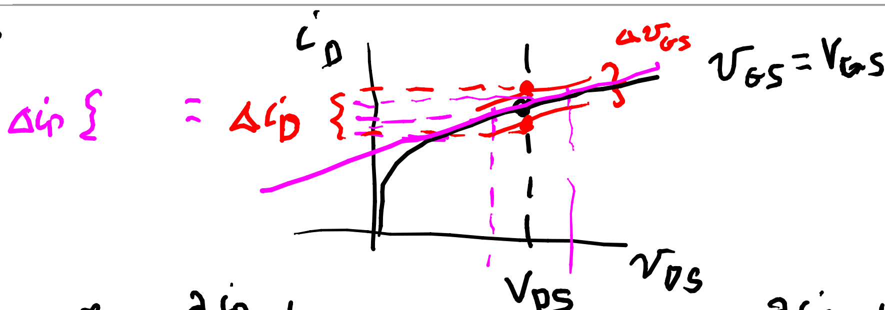
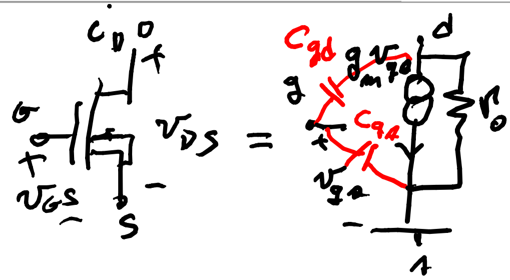
EE303
02/13/12

Note Title 2/13/2012

MOS





$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{\substack{Q \\ v_{DS}=V_{DS}}} \qquad g_o = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_{\substack{Q \\ v_{GS}=V_{GS}}} \; ; \quad r_o = \frac{1}{g_o}$$

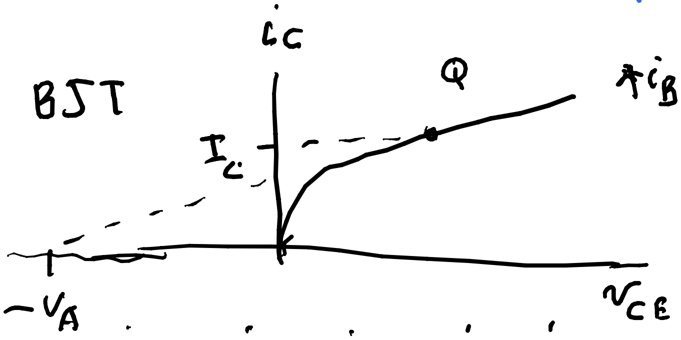
in saturation

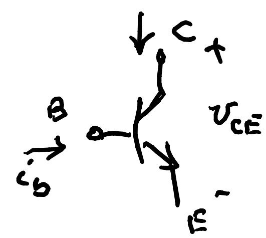
$$i_D = \frac{KP}{2}\cdot\frac{W}{L}\left(v_{GS}-V_{th}\right)^2\left(1+\lambda v_{DS}\right)$$

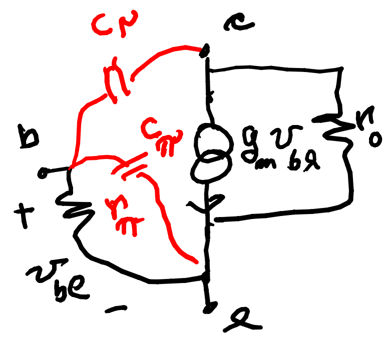
$$\frac{\partial i_D}{\partial v_{GS}} = 2\left(\frac{KP}{2}\frac{W}{L}\right)\frac{\left(v_{GS}-V_{th}\right)^2\left(1+\lambda v_{DS}\right)}{\left(v_{GS}-V_{th}\right)}\Bigg|_Q = \frac{2\,I_D}{\left(V_{GS}-V_{th}\right)} = \frac{2\,I_D}{V_{OD}}$$

$$\frac{\partial i_D}{\partial v_{DS}} = \frac{KP}{2}\cdot\frac{W}{L}\left(v_{GS}-V_{th}\right)^2\lambda\Big|_Q = \frac{I_D\times\lambda}{1+\lambda V_{DS}} \approx \lambda I_D$$

BJT







π equivalent circuit

$$i_C = \beta i_B, \quad i_E = -i_C - i_B = (1+\beta)(-i_B)$$

BE diode; $i_{diode} = I_{SE}\left(e^{v_{BE}/V_T} - 1\right) \approx I_{SE}\, e^{v_{BE}/V_T}$ in forward active region

$$\frac{\partial(-i_E)}{\partial v_{be}} = \left.\frac{\partial i_{diode}}{\partial v_{BE}}\right|_Q = \left.\frac{i_{diode}}{V_T}\right|_Q = -\frac{I_E}{V_T} = \frac{(1+\beta)I_B}{V_T} \approx \frac{I_C}{V_T}\; ; \quad \frac{\partial i_B}{\partial v_{BE}} = \frac{I_C}{\beta V_T} = g_\pi$$

and $g_m = \dfrac{I_C}{V_T}$, $g_o = \dfrac{I_C}{V_A}$, $V_T = \dfrac{kT}{|q|} \approx 26mV$ @ room T

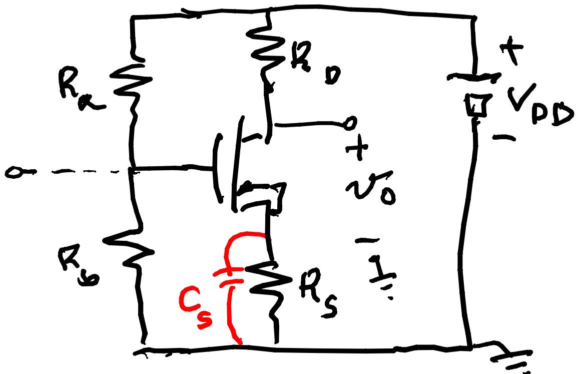
V_A = Early voltage

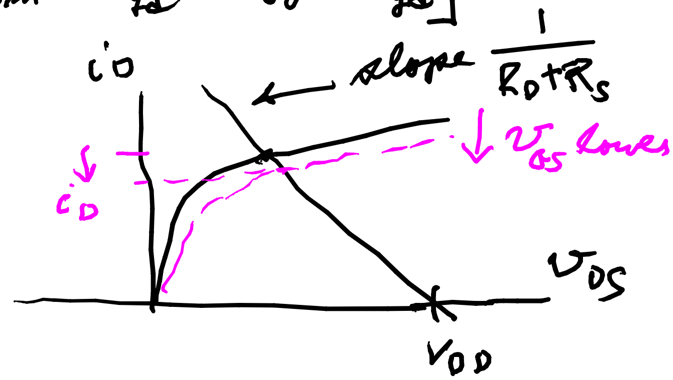
$$g_\pi = \frac{\partial i_b}{\partial v_{be}} = \frac{g_m}{\beta} = \frac{I_C}{\beta V_T}$$

$$Y(s)\Big|_{BJT} = \begin{bmatrix} g_\pi + sC_\pi + sC_\mu & 0 - sC_\mu \\ g_m - sC_\mu & g_o + sC_\mu \end{bmatrix}$$

$$Y(s)\Big|_{MOS} = \begin{bmatrix} s(C_{gs}+C_{gd}) & -sC_{gd} \\ g_m - sC_{gd} & g_o + sC_{gd} \end{bmatrix}$$

Bias





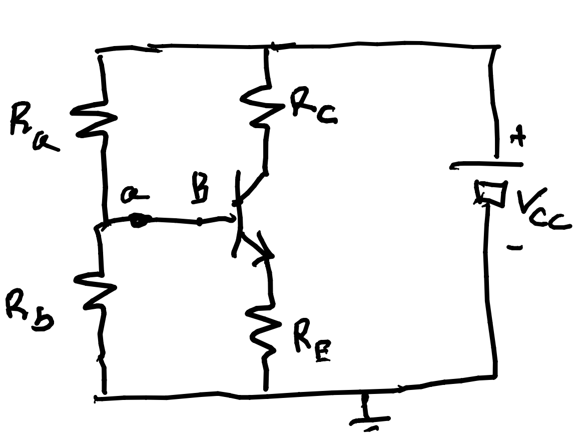
R_S stabilizes thermal behavior

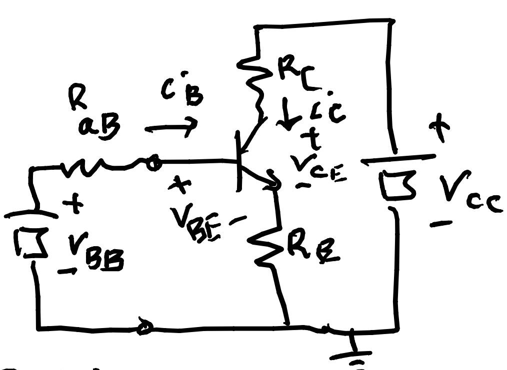
for signal choose C_S large so R_S is shorted.
@ DC C_S is open so does not affect bias.

Effective input voltage, $V_{Geq} = \frac{R_b}{R_a+R_b} \cdot V_{DD} = \frac{1}{1+\frac{R_a}{R_b}} \cdot V_{DD}$

input $R_{in} = \frac{R_a R_b}{R_a + R_b} = \frac{R_a}{1 + R_a/R_b}$ to keep large choose R_a large (10 Meg Ω)

Biasing the BJT



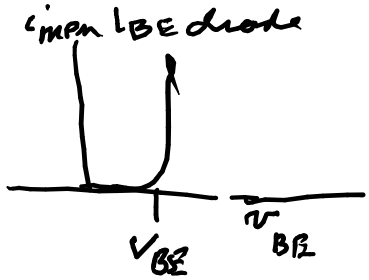


Thevenin's equivalent

$V_{oc} = \frac{R_b}{R_a+R_b} V_{cc}$

$I_{sc} = V_{cc}/R_a$

$\Rightarrow Z_{th} = R_{eq} = \frac{V_{oc}}{I_{sc}} = \frac{R_a R_b}{R_a + R_b}$



if choose V_{BE} then can find I_B from KVL around the BE loop

$$-V_{BB} + R_{aB} I_B + V_{BE} + R_E(\underbrace{-I_E}_{= +I_C/\alpha})$$

usually choose R_E

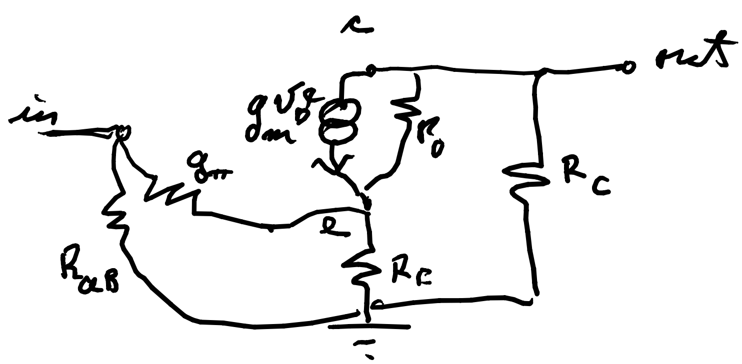
gives again 1 eq in 2 unknowns, R_a & R_b

choose one, say R_b in Meg Ω's then have 1 eq. 1 unknown

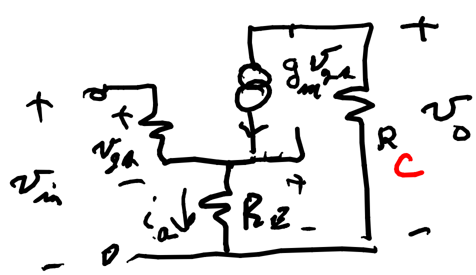
(need $R_a > 0$)

gain $\frac{v_o}{v_i} = -g_m R_{Load} = -\frac{I_C}{V_T} \cdot R_C$ if bypass R_S

look at equivalent circuit with R_S present



ignore r_o



$$R_E i_a = v_{in} - v_{ga}$$

$$R_E i_E = (g_\pi v_{ga} + g_m v_{ga}) R_E$$

$$\approx (g_m R_E) v_{ga}$$

$$\Rightarrow v_{in} = (1 + g_m R_E) v_{ga}$$

$$v_o = -g_m R_C v_{ga} = \frac{-g_m R_C v_{in}}{1 + g_m R_E}$$

$$\frac{v_o}{v_{in}} = -g_m \cdot \frac{R_C}{1 + g_m R_E}$$ } feedback factor