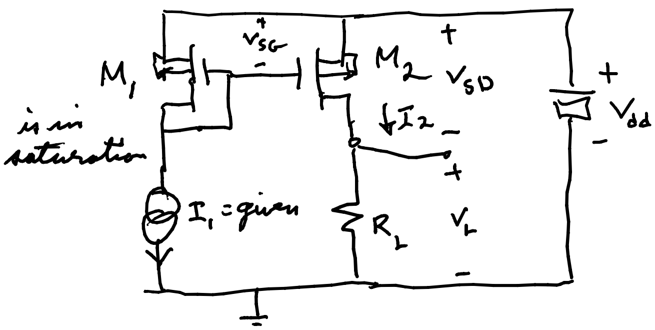
EE303
03/23/10
corrected

Exam next period
open book open notes calculators
- current mirrors = CMOS
- biasing of BJT's
- small signal equivalents
- Y matrix
- CMOS equations
- bulk use for VTO adjust
- poles & zeros
- inverters

current mirror

assume $M_1 = M_2$



Here $I_2 = I_1$ if $V_{dd} - V_L \geq V_{SG} - |V_{TO}|$

$$v_{SG} \Rightarrow \quad I_1 = I_{SD} = \frac{KP_P}{2}\frac{W}{L}\left(V_{SG} - |V_{TO}|\right)^2$$

$$V_{SG} = |V_{TO}| + \sqrt{\frac{I_1}{\frac{KP}{2}\frac{W}{L}}}$$

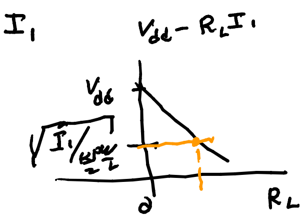
choice of $\pm$ as M_1 on if $I_1 > 0$

$$V_{dd} - V_L \overset{?}{\geq} V_{SG} - |V_{TO}| = \sqrt{\frac{I_1}{\frac{KP}{2}\frac{W}{L}}}$$

if M_2 is in saturation
$$V_L = R_L I_2 = R_L \frac{KP_P}{2}\frac{W}{L}\left(V_{SG} - |V_{TO}|\right)^2 = R_L I_1$$

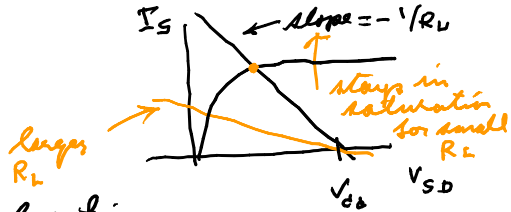
∴ have a good current mirror ($I_2 = I_1$)

$$V_{dd} - R_L I_1 \geq \sqrt{\frac{I_1}{\frac{KP}{2}\frac{W}{L}}}$$



∴ require R_L small enough

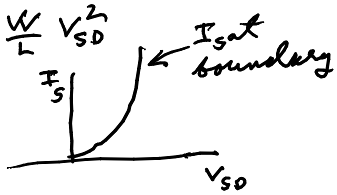
$$\frac{V_{dd} - \sqrt{\dfrac{I_1}{\frac{KP}{2}\frac{W}{L}}}}{I_1} \geq R_L$$

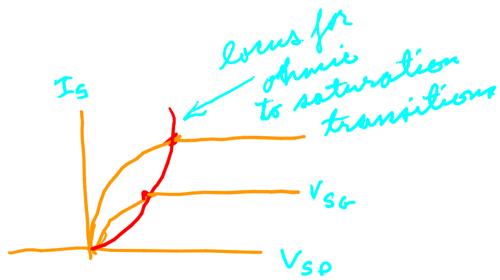


Boundary ohmic vs saturation

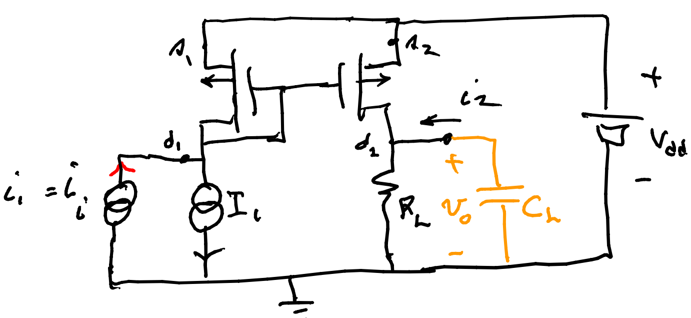
$$V_{SG} - |V_{TO}| = V_{SD} \quad ; \quad I_S = \frac{KP}{2}\frac{W}{L}\left(V_{SG} - |V_{TO}|\right)^2$$

$$\text{at boundary} = \frac{KP}{2}\frac{W}{L} V_{SD}^2$$

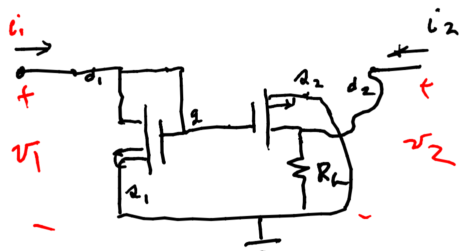


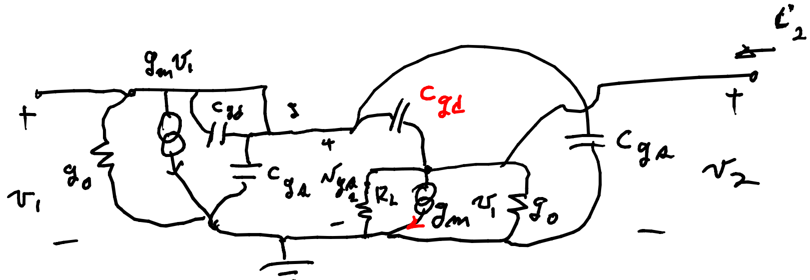


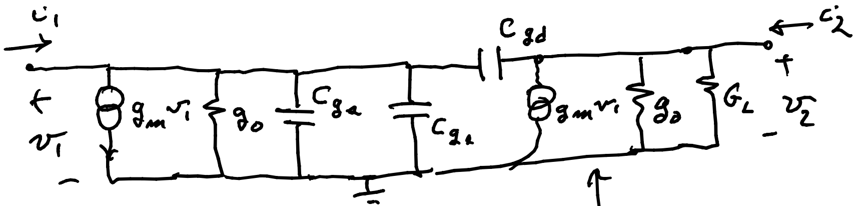
Inserting signal



for signal







$y_{11} = g_o + g_m + s(2C_{gs} + C_{gd})$

$y_{12} = -sC_{gd}$; $y_{21} = g_m - sC_{gd}$

$y_{22} = g_o + G_L + sC_{gd} = \left.\dfrac{i_2}{v_2}\right|_{v_1=0}$

$$Y(s) = \begin{bmatrix} (g_o+g_m) + s(2C_{gs}+C_{gd}) & -sC_{gd} \\ g_m - sC_{gd} & (g_o+G_L) + sC_{gd} \end{bmatrix}$$

$$= s\begin{bmatrix} 2C_{gs}+C_{gd} & -C_{gd} \\ -C_{gd} & C_{gd} \end{bmatrix} + \begin{bmatrix} g_o+g_m & 0 \\ g_m & g_o+G_L \end{bmatrix}$$

If load is C_L, desire v_2/v_1

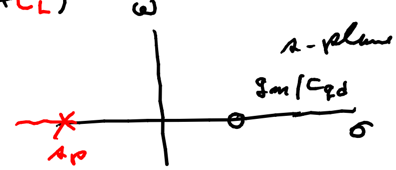
$-i_2 = C_L s \cdot v_2$

$-C_L s v_2 = i_2 = (g_m - sC_{gd})v_1 + [(g_o+G_L) + sC_{gd}]v_2$

$\dfrac{v_2}{v_1} = \dfrac{-(g_m - sC_{gd})}{(g_o+G_L) + s(C_{gd}+C_L)}$; DC gain $= \dfrac{v_2}{v_1}(s=0) = \dfrac{-g_m}{g_o+G_L}$

zero @ $s = g_m/C_{gd}$

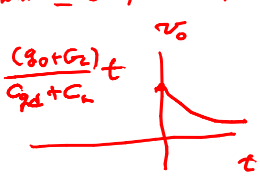
poles @ $s_p = -\dfrac{(g_o+G_L)}{C_{gd}+C_L}$



if $v_i = e^{-s_p t}$ ⇒ "infinite" output "gain" ≡ 0 input ⇒ ≠ 0 output

if $v_i = e^{(g_m/C_{gd})t}$ ⇒ $v_o = 0$

natural response is $e^{s_p t} = e^{-\frac{(g_o+G_L)}{C_{gd}+C_L}t}$



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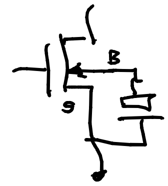
matching of NMOS & PMOS

$I_{D_n} = \dfrac{KP_n}{2}\left(\dfrac{W}{L}\right)_n (V_{GS} - V_{Th_n})^2$

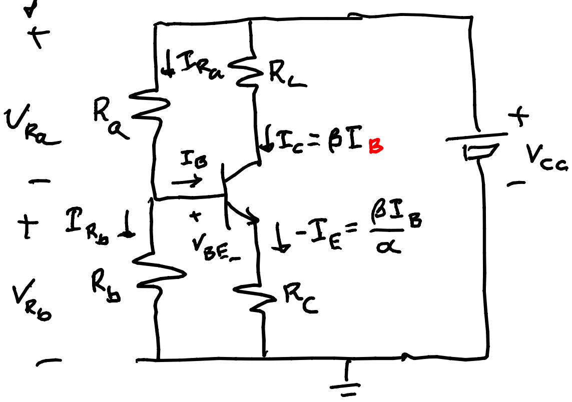
$I_{S_p} = \dfrac{KP_p}{2}\left(\dfrac{W}{L}\right)_p (V_{GS} - |V_{Th_p}|)^2$ $\quad V_{TO_n} \leq |V_{TO}|_p$

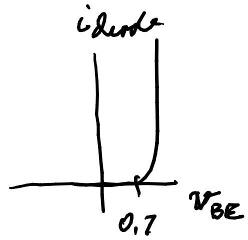
$$V_{TO_p} = V_{th_M} = V_{TO_M} + \underbrace{\gamma\left[\sqrt{\phi_s + V_{SB}} - \sqrt{\phi_s}\right]}_{\text{can be} > 0}$$



by choice of V_{SB} can usually get $V_{th_M} = V_{TO_p}$

Biasing:





$V_{BE} = 0.7$

$I_{R_a} = I_B + I_{R_B}$

$V_{R_b} = R_b I_{R_B} = V_{BE} + R_C \frac{\beta I_B}{\alpha}$

$V_{CC} = V_{R_a} + V_{R_b}$

$= R_a I_{R_a} + V_{R_b}$

$= R_a I_B + \underbrace{R_a I_{R_b}}_{\frac{R_a}{R_b} V_{R_b}} + V_{R_b}$

correction →

$= R_a I_b + \left(1 + \frac{R_a}{R_b}\right)\left(V_{BE} + R_C (1+\beta) I_B\right)$ let $r_{ab} = \frac{R_a}{R_b}$

$\Rightarrow \quad I_b = \frac{V_{CC} - (1 + r_{ab}) V_{BE}}{R_a + R_C (1+\beta)[1 + r_{ab}]}, \quad I_C = \beta I_B$

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

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

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

From this if given R's can determine the Q point or if given Q point can solve for R's