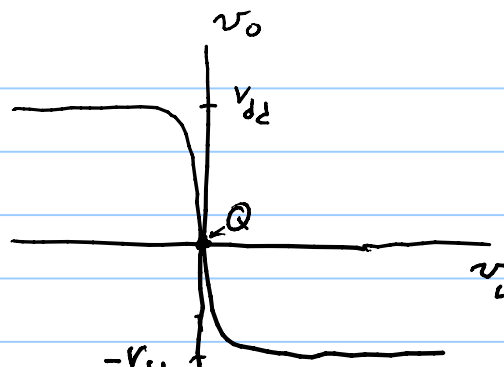
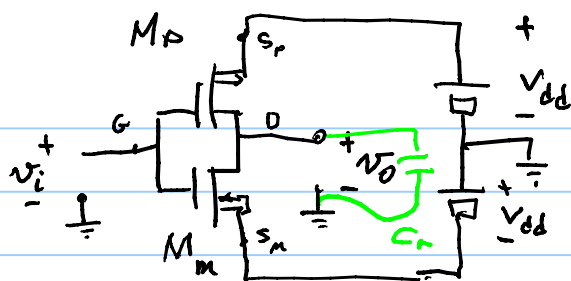


EE303
03/11/08



at Q point

$$v_o = v_i = 0$$

$$M_n: \begin{aligned} V_{GS} &= 0 - (-V_{dd}) = V_{dd} \\ V_{DS} &= 0 - (-V_{dd}) = V_{dd} \end{aligned} \quad ; \quad \left. \begin{aligned} V_{GS} - V_{TO} &< V_{dd} \\ V_{DS} &= V_{dd} > V_{GS} - V_{TO} \end{aligned} \right\} \text{as } V_{DS} = V_{dd} > V_{GS} - V_{TO}$$

M_n is in saturation

$$M_p: \begin{aligned} V_{GS} &= 0 - V_{dd} \\ V_{DS} &= -V_{dd} \end{aligned} \quad \begin{aligned} V_{GS} - V_{TO_p} & \\ V_{TO_p} &< 0 \text{ here } V_{DS} < V_{GS} - V_{TO_p} < 0 \end{aligned}$$

as M_p has $|V_{DS}| > |V_{GS} - V_{TO_p}|$

or M_p is in saturation.

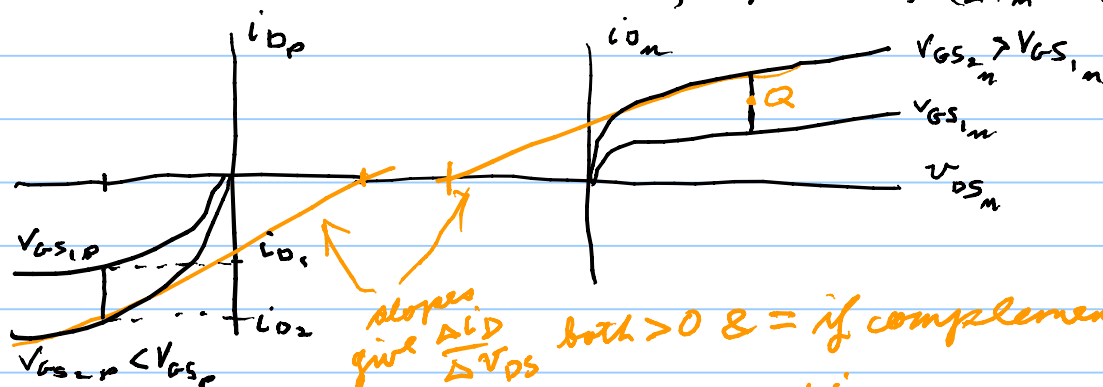
Here assume M_p & M_n are

completely complementary

$$I_{Dn} = \frac{K_{P_n}}{2} \left(\frac{W}{L}\right)_n (V_{GS_n} - V_{TO_n})^2 (1 + \lambda_n V_{DS_n})$$

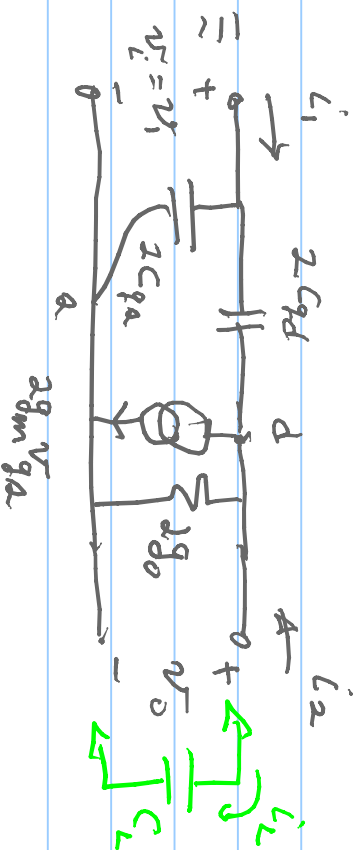
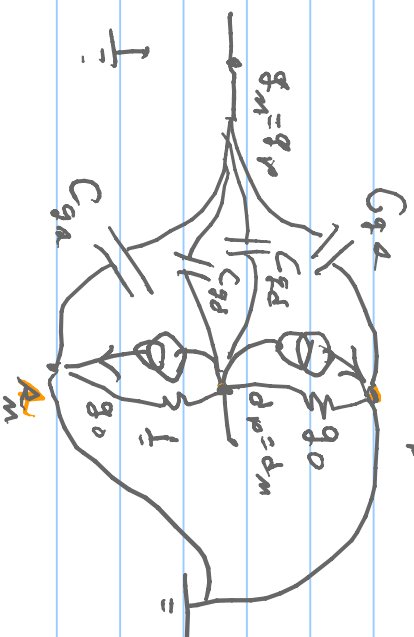
$$I_{Dp} = -\frac{K_{P_p}}{2} \left(\frac{W}{L}\right)_p (-V_{GS_p} + V_{TO_p})^2 (1 - \lambda_p V_{DS_p})$$

where $K_{P_n} = K_{P_p}$, $V_{TO_p} = -V_{TO_n}$, $\lambda_p = \lambda_n$, $\left(\frac{W}{L}\right)_n = \left(\frac{W}{L}\right)_p$



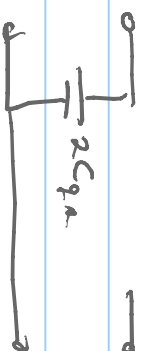
signs are the same also on $g_m = \left. \frac{\Delta i_D}{\Delta V_{GS}} \right|_{V_{DS}}$

$$g_m V_{gs}$$

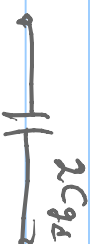


$$g_m V_{gs}$$

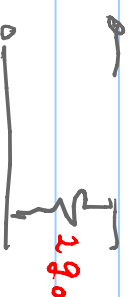
$$Y \Rightarrow$$



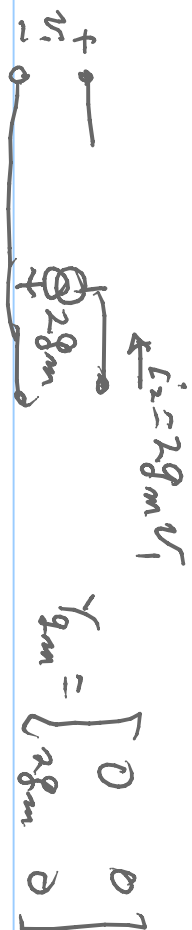
$$Y = \begin{bmatrix} 2sC_{gs} & 0 \\ 0 & 0 \end{bmatrix}$$



$$Y = \begin{bmatrix} sC_{gs} & -sC_{gd} \\ -sC_{gd} & sC_{gd} \end{bmatrix}$$

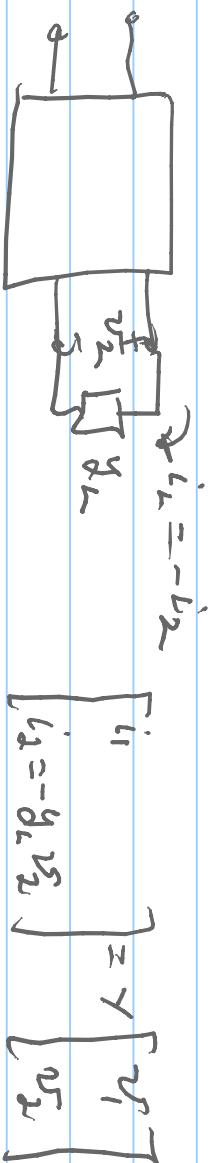


$$Y_{gs} = \begin{bmatrix} 0 & 0 \\ 0 & 2g_0 \end{bmatrix}$$



$$Y(s) = \begin{bmatrix} \alpha(C_{gs} + C_{gd}) & -\alpha C_{gd} \\ \alpha(g_m - \alpha C_{gd}) & \alpha(g_0 + \alpha C_{gd}) \end{bmatrix} = \alpha \begin{bmatrix} \alpha(C_{gs}) & -\alpha C_{gd} \\ g_m - \alpha C_{gd} & g_0 + \alpha C_{gd} \end{bmatrix} \quad ; \quad C_g = C_{gs} + C_{gd}$$

If load



$$-g_L v_2 = g_{21} v_1 + g_{22} v_2 \Rightarrow -(g_{22} + g_L) v_2 = g_{21} v_1$$

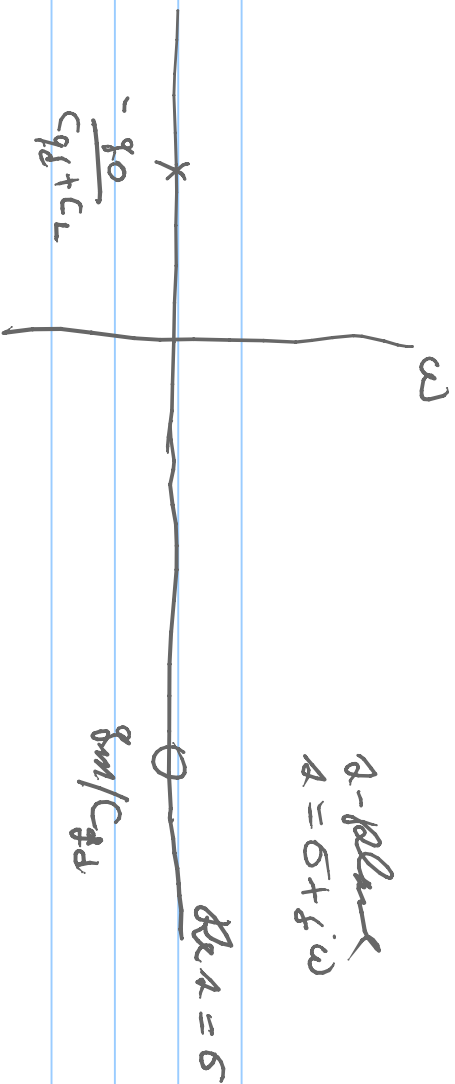
$$\left| \frac{v_2}{v_1} \right| = \frac{-g_{21}}{g_{22} + g_L} \quad \text{hence } \left| \frac{v_2}{v_1} \right| = \frac{-(g_m - \alpha C_{gd})}{g_0 + \alpha C_{gd} + \alpha C_L} = -\frac{g_m}{g_0} \quad \text{when } g_L = \alpha C_L$$

when load in \$g_L\$

$$= -\frac{g_m}{g_0} \left(\frac{1 - \alpha C_{gd}/g_m}{1 + \alpha(C_{gs} + C_L)/g_0} \right) \quad \text{port @ } \alpha = + g_m/C_{gd}$$

port @ \$\alpha = - g_0/(C_{gs} + C_L)\$

a-plane
 $a = \sigma + j\omega$



$$\textcircled{a} \quad Q, \quad I_{Dp} \approx -I_{Dn}, \quad I_{Dn} = \frac{K_P W}{2 L} (V_{GS} - V_{TO})^2 (1 + \lambda V_{DS}) \\
= \frac{K_P W}{2 L} (V_{DD} - V_{TO})^2 (1 + \lambda V_{DD})$$

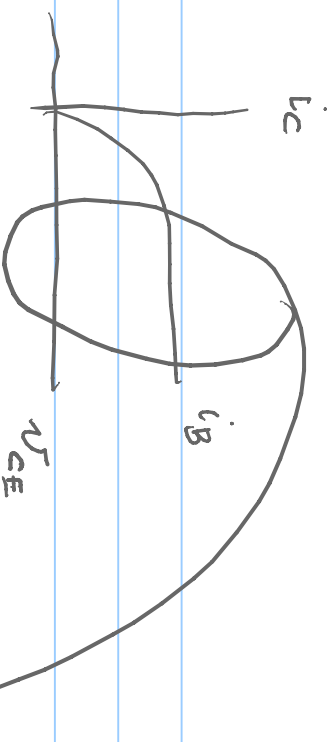
$$g_m = \left. \frac{\partial I_D}{\partial v_{GS}} \right| = 2 \left(\frac{K_P W}{2 L} \right) (v_{GS} - V_{TO}) (1 + \lambda v_{DS})$$

$$V_{DS} = \frac{2 I_D}{\lambda K_P W} = \frac{2 I_D}{\lambda K_P W} \quad v_{GS} = V_{GS} = V_{DD} \quad v_{DS} = V_{DD}$$

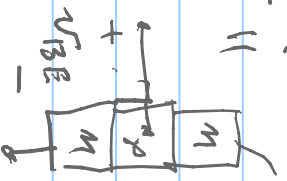
$$(V_{GS} - V_{TO}) (V_{DD} - V_{TO}) = \frac{2 K_P W}{\lambda L} (V_{DD} - V_{TO}) (1 + \lambda V_{DD})$$

$$g_0 = \left. \frac{\partial I_D}{\partial v_{DS}} \right|_{V_{GS}} = \lambda \frac{K_P W}{2 L} (V_{DD} - V_{TO})^2 = \lambda \frac{I_D}{1 + \lambda V_{DD}}$$

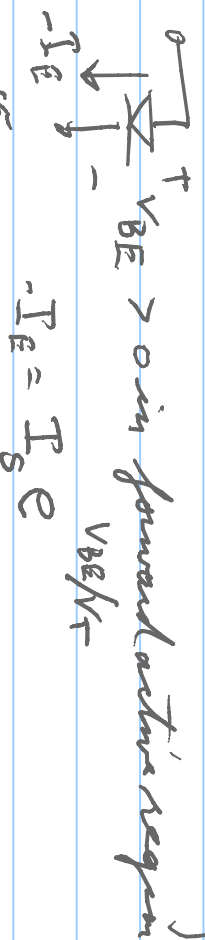
BJT emitter current:



$$V_{BE} = V_{BE} + V_{BE}$$



$\Rightarrow$



$$I_S \sim (1 - 100) \text{ amperes}, \quad f = 10^{-15}$$

$$\text{Let } V_{BE} = 0.65 \text{ V}, \quad I_S = 10 \times 10^{-15} \text{ A}, \quad V_T = 0.026 \text{ V}$$

$$e^{0.65/0.026} = e^{(25)} = 72,005 \text{ G} = 72 \times 10^9$$

$$I_E = 10 \times 10^{-15} \times 72 \times 10^9 = 72 \times 10^{-5} = 0.72 \times 10^{-3} = 0.72 \text{ mA}$$

$$\begin{aligned}
 g_{ce} &= \left(\frac{1}{V_T} \right) = - \frac{\partial I_E}{\partial V_{BE}} \bigg|_Q = \frac{\partial I_{SE}}{\partial V_{BE}} \bigg|_Q = \frac{1}{V_T} I_{SE} \bigg|_Q = \frac{0.72 \text{ mA}}{0.026 \text{ V}} = 27.7 \text{ V}
 \end{aligned}$$