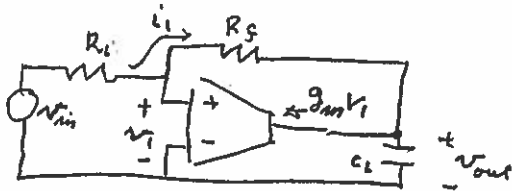


#1.



By KCL:  $i_{R_i} = i_{R_f} = i_i$  (1)

$i_i = G_i(v_{in} - v_i) = G_f(v_i - v_{out})$  (2)

$\Rightarrow (G_f + G_i)v_i = G_i v_{in} + G_f v_{out}$  (3)

$A C_L v_{out} = +i_i - g_m v_i$   
 $\stackrel{(2)}{=} + G_f v_i - G_f v_{out} - g_m v_i \stackrel{(3)}{=} + [G_f - g_m] \left\{ \frac{G_i v_{in} + G_f v_{out}}{G_f + G_i} \right\} - G_f v_{out}$  (4)

$\Rightarrow (A C_L - \frac{[G_f - g_m] G_f}{G_f + G_i}) v_{out} = + \frac{[G_f - g_m] G_i}{G_f + G_i} v_{in}$  (5)

$= (A C_L + \frac{[g_m + G_i] G_f}{G_f + G_i}) v_{out} \Rightarrow \frac{v_{out}}{v_{in}} = \frac{G_i [G_f - g_m]}{G_i (G_f + G_i) A + (g_m + G_i) G_f}$  (6)

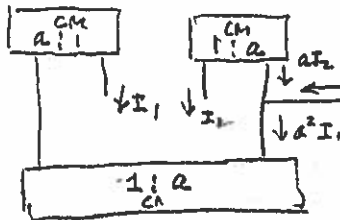
$= (A C_L + \frac{[g_m + G_i] G_f}{G_f + G_i}) v_{out} \Rightarrow \frac{v_{out}}{v_{in}} = \frac{G_i [G_f - g_m]}{G_i (G_f + G_i) A + (g_m + G_i) G_f}$  (7)

$\Rightarrow \frac{v_{out}}{v_{in}} = \frac{G_i [G_f - g_m]}{G_i (G_f + G_i) A + (g_m + G_i) G_f}$  (8)

#2.

$g_{mb} = \frac{\partial I_d}{\partial V_{sb}} = \frac{\partial I_d}{\partial V_{gs}} \cdot \frac{\partial V_{gs}}{\partial V_{sb}} = [2 \mu C_{ox} (V_{gs} - V_{th}) (1 + \lambda V_{DS})] \left[ \delta \cdot \frac{1}{2} (\phi + V_{sb})^{-1/2} \right]$   
 $= \frac{k I_D \delta}{(V_{gs} - V_{th}) \sqrt{\phi + V_{sb}}} = \frac{k \delta (V_{gs} - [V_{TO} + \delta \{ \sqrt{\phi + V_{sb}} - \sqrt{\phi} \}]) (1 + \lambda V_{DS})}{(\phi + V_{sb})^{1/2}}$

#3.



$i_{out} = a^2 I_1 - a I_2 = a [a I_1 - I_2]$   
 $= a [(a-1) I_1 + (I_1 - I_2)]$

where  $I_1 - I_2 = I_T \left( \frac{1}{1 + e^{-v_{id}/V_T}} - \frac{1}{1 + e^{+v_{id}/V_T}} \right)$

$= I_T \left( \frac{e^{v_{id}/V_T} - e^{-v_{id}/V_T}}{e^{v_{id}/V_T} + e^{-v_{id}/V_T} + 2} \right)$

$i_{out} = a I_T \left\{ \frac{(a-1)}{1 + e^{-v_{id}/V_T}} + \tanh\left(\frac{v_{id}}{2V_T}\right) \right\} \Leftrightarrow = I_T \left( \frac{(e^{v_{id}/2V_T} - e^{-v_{id}/2V_T})(e^{v_{id}/2V_T} + e^{-v_{id}/2V_T})}{(e^{v_{id}/2V_T} + e^{-v_{id}/2V_T})^2} \right)$

#4. as  $E > V$  the source is on the right so  $V_{sb} = V$  and  $V_{gs} = E - V = V_{DS}$

a)  $i_c = C \frac{dv}{dt} = k (E - v - \{V_{TO} + \delta [\sqrt{\phi + v} - \sqrt{\phi}] \})^2 (1 + \lambda [E - v])$  for  $t > 0$ ,  $v(0) = 0$ , and valid for  $V_{gs} - V_{th}(v) > 0$

b) when  $V_{gs} = V_{th}(v) \Rightarrow i_c = 0 \Rightarrow \frac{dv}{dt} = 0$ ,  $v = V_0$  when  $i_c = 0$

$\therefore E - V_0 = V_{TO} + \delta [\sqrt{\phi + V_0} - \sqrt{\phi}] \Rightarrow \left[ \frac{(E - V_{TO}) - V_0}{\delta} \right] + \phi = \sqrt{\phi + V_0} \Rightarrow$  square both sides

$\left[ \frac{(E - V_{TO}) + \gamma \phi}{\delta} \right]^2 - 2 \left[ \frac{(E - V_{TO}) + \gamma \phi}{\delta} \right] \cdot \frac{V_0}{\delta} + \frac{V_0^2}{\delta^2} = \phi + V_0 \Rightarrow$  quadratic in  $V_0$

$V_0^2 - 2 \left[ \frac{(E - V_{TO}) + \gamma \phi + \delta^2}{\delta} \right] V_0 + \left[ \frac{(E - V_{TO}) + \gamma \phi}{\delta} \right]^2 - \delta^2 \phi = 0$

$\Rightarrow V_0 = \left[ \frac{(E - V_{TO}) + \gamma \phi + \delta^2}{\delta} \right] \left[ 1 + \sqrt{1 + \frac{\delta^2 \phi - [(E - V_{TO}) + \gamma \phi]^2}{[(E - V_{TO}) + \gamma \phi + \delta^2]^2}} \right]$  (choose + sign as  $V_0 > V_{TO}$  when  $V_{SB} > 0$ )

at a check, @  $\delta = 0$

$V_{gs} - V_{TO} = E - V_0 - V_{TO} = 0 \Rightarrow V_0 = E - V_{TO}$