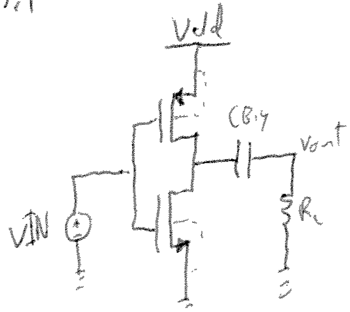
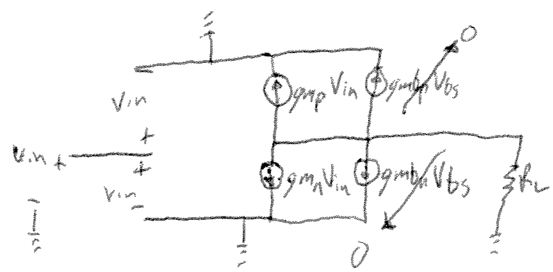
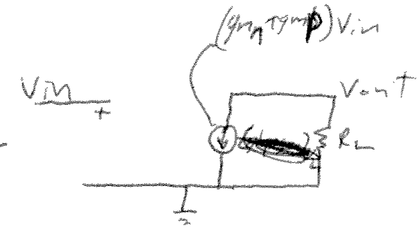
R3.1



Small signal model

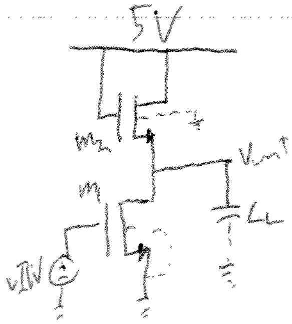




$Gm = g_{mn} + g_{mp}$ $\qquad A_v = -(g_{mn}+g_{mp})R_L$

$R_{in} = \infty \qquad R_{out} = R_L$

R3.2



Looking into the source of $m_2 \rightarrow R = \dfrac{1}{g_{m2}+g_{mb2}} = R_{out}$

$R_{in} = \infty \qquad G_m = g_{m1} \qquad A_v = -\dfrac{g_{m1}}{g_{m2}+g_{mb2}} = \dfrac{-g_{m1}}{g_{m2}(1+\eta)} \approx \dfrac{-\sqrt{W_1/L_1}}{\sqrt{W_2/L_2}(1+\eta)}$

$vIN = v_{in} + 2V$ (V_{gs_1})

$I_{D_1} = I_{D_2} = \frac{1}{2}K_n'\frac{W_1}{L_1}(V_{gs_1}-V_{tn})^2 = 8\mu A$

$V_{s_2} = V_{dd} \pm \left(\sqrt{\dfrac{I_{d_2}\cdot 2}{K_n' W_2/L_2}} + V_{tn}\right) = 2V$

$V_{gs_2} = V_{dd} - V_{s_2} = 3V$

$V_{ds_1} = V_{s_2} \qquad V_{ds_2} = V_{dd} - V_{s_2} = 3V$

$V_{ds_1} > V_{gs_1} - V_{tn}$ ✓

$V_{ds_2} > V_{gs_2} - V_{tn}$ ✓

$g_{m1} = \dfrac{2I_{D_1}}{(V_{gs_1}-V_{tn})} = 16\mu\mho$

$g_{m2} = \dfrac{2I_{D_2}}{(V_{gs_2}-V_{tn})} = 8\mu\mho$

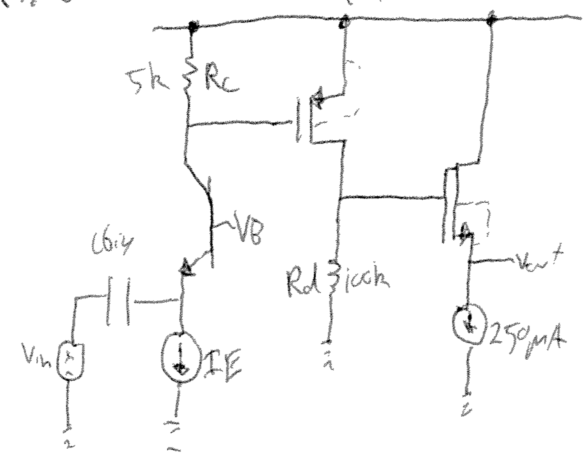
$G_m = 16\mu\mho$

$R_{out} = 113.64\ k\Omega$

$R_{in} = \infty$

$A_v = -1.8182$

R3.3



a) stage 1 = C-B

stage 2 = C-S

stage 3 = C-D

b) $R_{in} = 50\text{ ohms} = \frac{1}{g_{m_1}}$

$g_{m_1} = \frac{1}{50} = \frac{I_c}{V_t}$ $\quad I_c \approx I_E$

$I_E = \frac{V_t}{50} = 500\mu A$

stage 1

c) V_B = arbitrary $\quad r_{pi} = \frac{\beta}{g_{m_1}} = 7.55\text{ k}\Omega$

$V_c = V_{dd} - I_c R_c \approx 9.5166\text{ V}$

stage 2

$V_{g_2} = V_c$

$V_{gs_2} = V_{g_2} - V_{dd} = -2.4834\text{ V}$

$I_{d_2} = \frac{1}{2} K_p (V_{gs_2} - V_{tp})^2 = 44.01\mu A$

$V_{d_2} = I_{d_2} R_d = 4.4\text{ V}$

$V_{ds_2} = V_{d_2} - V_{dd} = -7.5988\text{ V}$

$|V_{ds_2}| > |V_{gs_2} - V_{tp}|$ ✓

$g_{m_2} = \frac{2I_{D2}}{|V_{gs_2} - V_{tp}|} = 59.3\,\mu\mho$

stage 3

$V_{g_3} = V_{d_2}$

$V_{gs_3} = \sqrt{\frac{2(250\mu A)}{K_n}} + V_{tn} = 3.887\text{ V}$

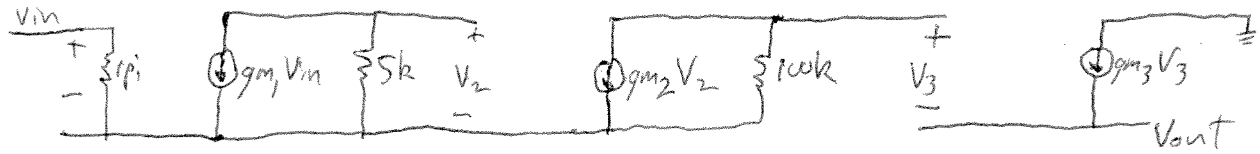
$V_{s_3} = V_{g_3} - V_{gs_3} = 0.5145$

$V_{ds_3} = V_{dd} - V_{s_3} = 11.4855$

$V_{d_{s_3}} > V_{gs_3} - V_{TN}$ ✓

$g_{m_3} = \frac{2I_{D3}}{V_{gs_3} - V_{TN}} = 173.2\,\mu\mho$

d)

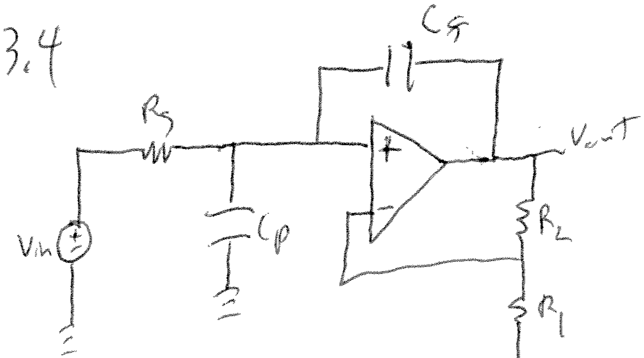


e) $R_{in} = 50$ ohms

$R_{out} = \frac{1}{g_{m3}} = 5.774\ k\Omega$

$A_v = (C\text{-}B)(C\text{-}S)(C\text{-}D) \approx (g_{m1}R_c)(-g_{m2}R_d)(1) = -589.45$

R3.4



Non-inverting op-amp

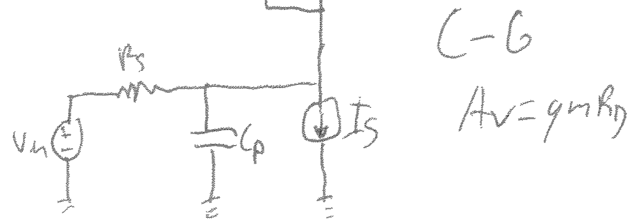
$A_v = 1 + \frac{R_2}{R_1}$

$C_{in} = C_p + C_f(1 - A_v) = 0$

$C_{in} = C_p + C_f(-R_2/R_1) = 0$

$C_p = C_f R_2/R_1 \Rightarrow \frac{R_2}{R_1} = \frac{C_p}{C_f}$

R3.5



C-G

$A_v = g_m R_D$

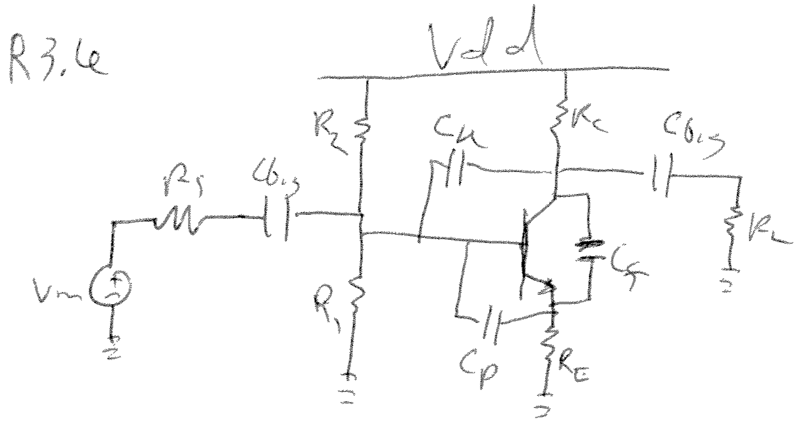
$C_p = -C_f(1 - g_m R_D)$

$\cancel{\frac{C_p + C_f}{C_f} = g_m R_D}$

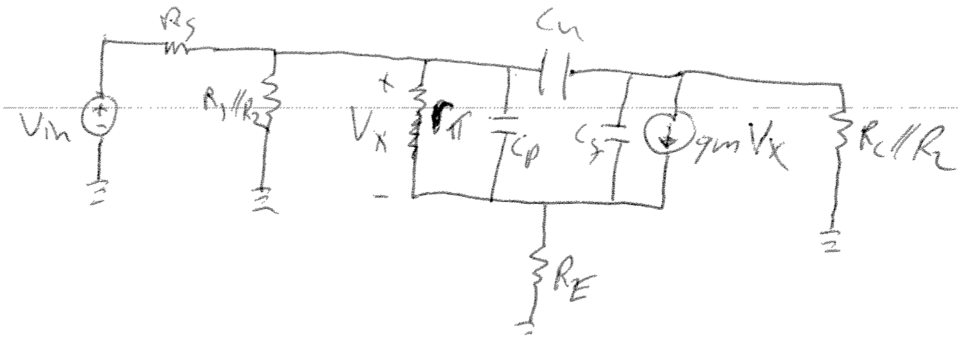
trick Question

$I_{in} \neq 0$; miller multiplication can't be used

R3.6



Small signal



$$R_{\mu o} = R_1//R_2//R_S//(r_\pi(1+g_mR_E)) + R_C//R_L + \left(\frac{g_m}{1+g_mR_E}\right)(R_C//R_L)\left(R_1//R_2//R_S//(r_\pi(1+g_mR_E))\right)$$

$$R_{po} = r_\pi // \left[\frac{R_1//R_2//R_S + R_E}{1+g_mR_E}\right]$$

$$R_{\gamma o} \doteq \frac{R_C//R_L(R_E + r_\pi + R_S//R_1//R_2) + R_E(r_\pi + R_S//R_1//R_2)}{R_E + r_\pi + R_S//R_1//R_2 + g_mR_Er_\pi}$$

$$f_{3dB} \approx \frac{1}{2\pi\left[C_\mu R_{\mu o} + C_p R_{po} + C_\gamma R_{\gamma o}\right]}$$