Solution

(5) $I_{in} = \frac{K'}{2}\frac{W}{L}\left(1V - 0.54V\right)^2\left(1 + \lambda(1V)\right) = 170.9728\mu A$

$I_{out} = \frac{K'}{2}\frac{W}{L}\left(1V - 0.5V\right)^2\left(1 + \lambda(2V)\right) = 204\mu A$

V_{DS} mismatch 1.01 vs 1.02

V_T mismatch 0.46^2 vs 0.5^2

$= 0.2116$ vs 0.25 much bigger

(4) $I_1 = 10\mu A$

$I_2 = 40\mu A$

$I_3 = 160\mu A$

$I_4 = 60\mu A$

$I_5 = 100\mu A$

(3) $V_{ov\,load} = 0.5V \Rightarrow 0.5V = \sqrt{\frac{I_D}{\frac{K'}{2}\frac{W}{L}}} \Rightarrow 0.25 \cdot 25\mu = \frac{I_D}{(W/L)_{load}} = \frac{25\mu}{4} \Rightarrow \left(\frac{W}{L}\right)_{load} = \frac{4 I_D}{25\mu}$

$\frac{g_{m\,in}}{I_D} = \frac{\sqrt{2K'\frac{W}{L}I_D}}{I_D} = 20 \Rightarrow \frac{2 \cdot 160\mu \cdot \left(\frac{W}{L}\right)_{in}}{I_D} = 400 \Rightarrow \left(\frac{W}{L}\right)_{in} = \frac{5}{4}\mu\, I_D$

$$\left(40\,nV/\sqrt{Hz}\right)^2 = \frac{8}{3}kT\frac{1}{g_{m\,in}}\left(1 + \frac{g_{m\,load}}{g_{m\,in}}\right)$$

$$= \frac{8}{3} \cdot 1.38 \cdot 10^{-23} \cdot 300 \frac{1}{\sqrt{2K_n'\frac{W}{L}I_D}}\left(1 + \frac{\sqrt{2K_p'\frac{W}{L}I_D}}{\sqrt{2K_n'\frac{W}{L}I_D}}\right)$$

$$= (0.011\,n^2)\frac{1}{\underbrace{\sqrt{2 \cdot 160\mu \cdot \frac{5}{4}\mu}\, I_D}_{20}}\left(1 + \underbrace{\frac{\sqrt{100\mu \cdot 4/25\mu}}{\sqrt{320\mu \cdot \frac{5}{4}\mu}}}_{\cancel{1.1414}\ 1.2}\right) \Rightarrow I_D = \cancel{4.44\mu A}\ \cancel{27.75\mu A}\ 41.25\mu A$$

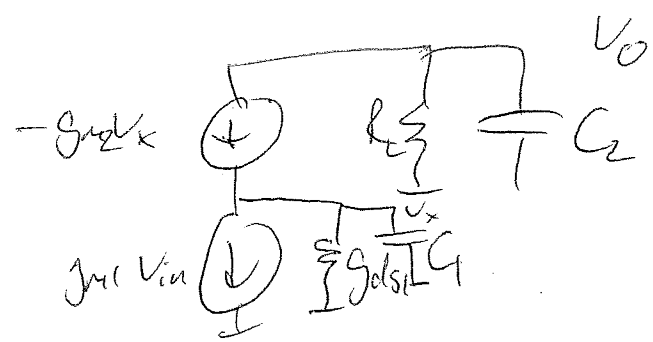
(3) $\Rightarrow \frac{W}{L}_{in} = 2051.56$

$\frac{W}{L}_{load} = \cancel{4.5}\ 6.6$

check $g_{m\,in} = \cancel{288\mu S}\ 825\mu S$ $\quad V_{ov\,in} = 50mV < 0.5V$ ok

$g_{m\,load} = \cancel{111.75\mu S}\ 165\mu S$ $\quad V_{ov\,load} = 0.5V$

(2)



$$-g_{m2}v_x + v_0\left(\frac{1}{R_L} + sC_2\right) = 0$$

$$\Rightarrow v_x = +v_0 \frac{\left(\frac{1}{R_L} + sC_2\right)}{g_{m2}}$$

$$g_{m1}V_{in} + g_{m2}v_x + g_{ds}v_x + sC_1v_x = 0$$

$$\Rightarrow g_{m1}V_{in} + v_0(g_{m2} + g_{ds1} + sC_1)\cdot\frac{\frac{1}{R_L} + sC_2}{g_{m2}} = 0$$

$$\frac{V_o}{V_{in}} = -\frac{g_{m1}g_{m2}}{\left(\frac{1}{R_L} + sC_2\right)(g_{m2} + g_{ds} + sC_1)}$$

DC gain: $g_{m1}R_L \cdot \frac{g_{m2}}{g_{m2} + g_{ds1}}$

V_{in}

① Assume all saturated

$M1: \quad I_D = \frac{K'}{2}\frac{W}{L}(V_{GS}-V_T)^2 = 80\mu \cdot 4 \cdot 0.25 = 80\mu A$

$M3: \quad I_D = \frac{K'}{2}\frac{W}{L}(V_{GS}-V_T)^2 = 25\mu \cdot 16 \cdot 6.25 = 2500\mu A$ will go ohmic

$M2$ is a cascode : $V_{GS} = V_T + \sqrt{\frac{I_D}{\frac{K'}{2}\frac{W}{L}}} = 0.85V$

$V_x = 2V - V_{GS2} = 1.15V$

$V_{DS1} = 1.15V > V_{ov1} = 0.5V$

$V_{out} = V_{DD} - V_{DS3}$

$V_{DS3} = \frac{I_D}{K'\frac{W}{L}V_{ov3}} = \frac{80\mu A}{50\mu A \cdot 16 \cdot 2.5V} = 40mV$

$V_{out} = 2.96V$

$V_{DS2} = 1.81V > 0.35V \Rightarrow$ saturated

M3: ohmic
M2: sat
M1: sat
$I_D = 80\mu A$
$V_x = 1.15V$
$V_{out} = 2.96V$