HW 6 04/19/05 Solutions

ENEE302 spring 2005

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1. a) For PMOS, $|V_{GS}|_P = V_{dd} - V_o$

$|V_{DS}|_P = V_{dd} - V_o$

For NMOS, $V_{GSn} = V_o$, $V_{DSn} = V_o$

$I_{DP} = I_{DN} \Rightarrow$

$$\frac{1}{2} KP_P \frac{W_{Po}}{L_P} (|V_{GS}|_P - |V_{tP}|)^2$$

$$= \frac{1}{2} KP_n \frac{W_n}{L_n} (V_{GSn} - V_{tn})^2$$

$$\Rightarrow W_{Po} = \frac{KP_n}{KP_P} \left[\frac{(|V_{GS}|_P - |V_{tP}|)^2}{(V_{GSn} - V_{tn})^2} \right]^{-1} \cdot W_n \cdot \frac{L_P}{L_n}$$

$$= 5 \cdot \left[\frac{(3 - 1 - 0.5)^2}{(1 - 0.25)^2} \right]^{-1} \cdot 20u \cdot \frac{1}{2}$$

$$= 12.5\ u$$

b) Now, $\frac{1}{2} KP_P \frac{W_{Pn}}{L_P} \cdot (|V_{GS}|_P - |V_{tP}|)^2 (1 + |\lambda_P| \cdot |V_{DS}|_P)$

$$= \frac{1}{2} KP_n \frac{W_n}{L_n} (V_{GSn} - V_{tn})^2 (1 + \lambda_n V_{DSN})$$

$$\Rightarrow W_{Pn} = W_{Po} \cdot \frac{1 + \lambda_n V_{DSN}}{1 + |\lambda_P| \cdot |V_{DSP}|} = 12.1\ u$$

(c). Two possibilities for final states:

1. $V_a = V_b \leq 4.5\,V$

2. $V_a = 4.5\,V$, $V_b > 4.5\,V$

(For detailed analysis, see solutions for Midterm. Note here $V_{to} = 0.5\,V$ instead of $1\,V$)

Assume possibility 1 happens, then

$$C_{out} \cdot V_{b(t=0)} = C_{in} \cdot V_x + C_{out} \cdot V_x$$

here V_x is the final value of V_a and V_b.

$$V_x = \frac{C_{out}}{C_{in} + C_{out}} \cdot V_{b}(t=0)$$

$$= \frac{1\,pF}{21\,pF} \cdot 5\,V$$

$$= 0.238\,V$$

This result satisfies $V_x \leq 4.5\,V$,

so this should be the real case that happend. So the final values of V_a and V_b is $0.238\,V$. and since $V_a = V_b$, you can call either drain or source.

3. a) $I_R = I_{c_1} + I_{b_1} + I_{b_3}$

$= I_{c_1} + 2I_{b_1} \quad (I_{b_1} = I_{b_3})$

$= (1+\frac{2}{\beta}) I_{c_1} \quad (I_c = \beta I_b)$

$= (1+\frac{2}{\beta}) \frac{\beta}{\beta+1} I_{e_1} \quad (I_c = \frac{\beta}{\beta+1} I_e)$

to find I_{e_1},

$I_{e_1} + I_{e_3} = I_{c_2} + I_{b_2} + I_{b_4}$

$\Rightarrow 2I_{e_1} = I_{c_2} + I_{b_2} + I_{b_4} \quad (I_{e_1} = I_{e_3})$

$\Rightarrow I_{e_1} = \frac{1}{2}(I_{c_2} + I_{b_2} + I_{b_4})$

$= \frac{1}{2}(1+\frac{2}{\beta}) I_{c_2} \quad (I_{b_2} = I_{b_4},\ I_c = \beta I_b)$

$= \frac{1}{2}(1+\frac{2}{\beta}) I_{out_2}$

$\Rightarrow I_R = \frac{1}{2}(1+\frac{2}{\beta})^2 \frac{\beta}{\beta+1} I_{out_2}$

We know $I_R = \dfrac{V_{cc} - V_{be_1} - V_{be_2}}{R}$

$\Rightarrow I_{out_2} = 2 \cdot \frac{\beta+1}{\beta} \frac{1}{(1+\frac{2}{\beta})^2} \cdot \frac{V_{cc} - V_{be_1} - V_{be_2}}{R}$

where $V_{be_1} = V_T \log \frac{I_{e_1}}{1mA} + 0.6V$

$V_{be_2} = V_T \log \frac{I_{e_2}}{1mA} + 0.6V.$

PS

For detailed labeling of currents, see ~~sout~~ solutions for Midterm.

(b). If $I_{out2} = 0.3\ mA$

then, $I_R = \frac{1}{2}(1+\frac{2}{\beta})^2 \frac{\beta}{\beta+1} I_{out2}$

$= 0.208\ mA$

$I_{e1} = \frac{1}{2}(1+\frac{2}{\beta}) I_{out2} = 0.187\ mA$

$\Rightarrow V_{be1} = 0.026 \times \log \frac{I_{e1}}{1mA} + 0.6V$

$= 0.556\ V$

$I_{e2} = \frac{\beta+1}{\beta} I_{out2} = 0.337\ mA$

$\Rightarrow V_{be2} = 0.026 \times \log \frac{I_{e2}}{1mA} + 0.6V$

$= 0.571\ V$

$\therefore\ R = \frac{V_{cc} - V_{be1} - V_{be2}}{I_R}$

$= \frac{5V - 0.556V - 0.571V}{0.208\ mA}$

$= 18.62\ K\Omega$

(c) $I_{out} = I_{out1} + I_{out2}$

$$= \frac{\beta}{\beta+1} I_{e1} + 0.3\,mA$$

$$= 0.466\ mA$$