上海交通大学

VE311 Hw9. 年 月 日

Question 1.

the current flow through M_2, M_3, M_5 are equal

$\begin{cases} V_{GS5} - V_{th} \le V_{DS5} \\ V_{G3} - V_{th} \le V_{D3} \\ V_{G2} - V_{th} \le V_{D2} \end{cases}$ → M_2, M_3, M_5 in saturation region

also, we have $V_{G2} = V_{G3} - V_{D2} = V_{G5} - V_{D3}$

$\Rightarrow V_{G3} \le V_{D3} + V_{th}$ $V_{G3} = V_{D2} + V_{G2} = V_{D2} + V_{D3} + V_{G1}$

$\begin{cases} V_{GS5} \le V_{th} + V_{DS5} \\ V_{G3} \le V_{th} + V_{GS5} - V_{G2} \\ V_{G2} \le V_{th} + V_{G3} - V_{G2} \Rightarrow 2V_{G2} \le V_{G3} + V_{th} \le V_{th} + V_{GS5} - V_{G2} \end{cases}$

$\Rightarrow 3V_{G2} \le V_{GS} + V_{th} \Rightarrow V_{GS5} \ge 3V_{G2} - V_{th}$

Since M_1, M_2 from a current mirror. $I_{out} = I_{ref} = 2 \cdot \frac{I_{ref}}{2}$

$\Rightarrow \frac{(V_{G2} - V_{th})^2}{L} = 2 \cdot \frac{(V_{GS5} - V_{th})^2}{L_7} \Rightarrow L_7 = 2L \cdot \frac{(V_{GS} - V_{th})^2}{(V_{G2} - V_{th})^2}$

$(V_{GS} = V_{G7})$

$\ge 2L \cdot \left(\frac{3V_{G2} - 3V_{th}}{V_{G2} - V_{th}}\right)^2 = 18.$

So $L_{7min} = 18L.$

for L_6: $\frac{(V_{G2} - V_{th})^2}{L} = 2 \cdot \frac{(V_{G3} - V_{th})^2}{L_6}$ $(V_{G3} = V_{G8})$ $\Rightarrow L_6 = 2L \cdot \left(\frac{V_{G3} - V_{th}}{V_{G2} - V_{th}}\right)^2$

$\ge 2L \cdot \left(\frac{2V_{G2} - 2V_{th}}{V_{G2} - V_{th}}\right)^2 = 2L \cdot 4$

$= 8L$

So $\begin{cases} L_{7min} = 18L \\ L_{6min} = 8L. \end{cases}$

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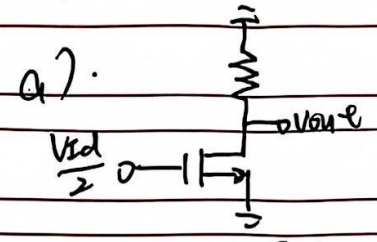
Question 2.

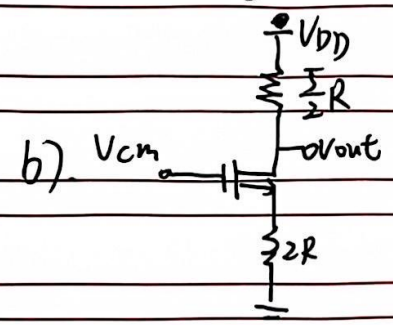
a). ($\lambda=0$)



$G_m = -g_m$. $R_{out} = R$.

$A_V = G_m R_{out} = -g_m R$.

b).



$G_m = -2g_m \cdot \frac{1}{1+4g_m R}$, $R_{out} = \frac{5}{2}R$.

$A_V = G_m R_{out} = -\frac{5g_m R}{1+4g_m R}$ $(\approx -\frac{5}{4})$.