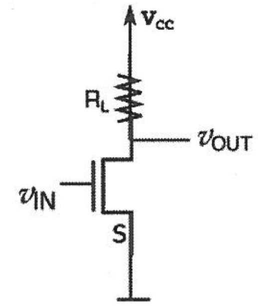
Solution attached

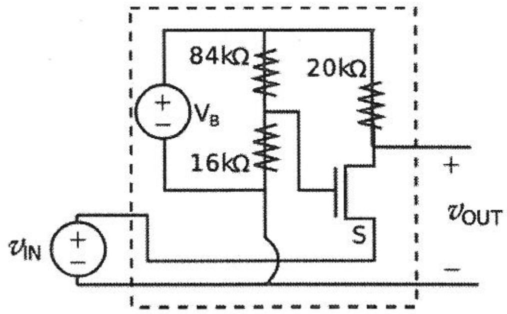
CSU0007 Basic Electronics, Final Exam

- Exam time: 3:30PM-5:30pm, Jan. 15th, 2021.
- 110 points in total.
- MOSFET parameters: K=1mA/V^2 and V_T=1V. For difference amplifiers, we assume identical MOSFETs.

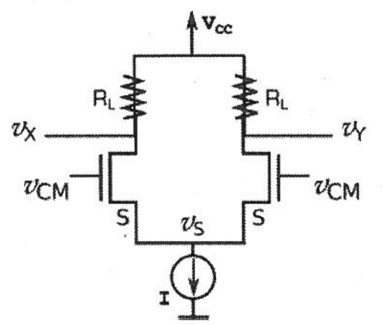
1. (20 points) Consider this specification: The noise margin is 0.5V for logical 0 and 0.5V for logical 1. The forbidden region is from 0.9V to 1.5V. In order to build a MOSFET inverter (shown in the following figure) to meet this specification, what would be the maximum feasible value of ratio $\frac{L}{W}$? Suppose R_N=5kΩ, R_L=8kΩ, and V_{cc}=3.3V, and consider the SR model:



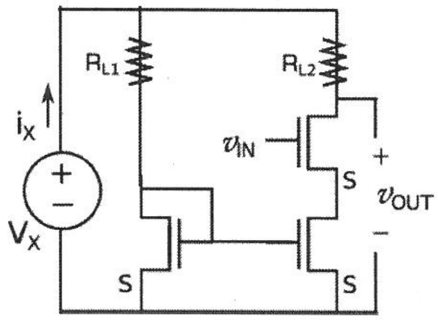
2. (30 points) For the MOSFET circuit in Question 1, now consider the SCS model.
   1. (20 points) We know that for the MOSFET to operate in the saturation region, input voltage v_{IN} should be constrained to a certain range. Given a constant V_{CC}, would the size of this range increase or decrease if we increase R_L? Explain your analysis.
   2. (10 points) Compute $\frac{V_{OUT}}{V_{IN}}$ the large-signal voltage gain, given $V_{IN} = 2$V. Suppose R_L =5kΩ and V_{cc}=5V.
3. (20 points) For the following non-inverting amplifier circuit, to make a small-signal ~~output~~ input resistance smaller than 50Ω, what should be the minimum value of V_B?



4. (20 points) For the following difference amplifier in the common mode, suppose that I =0.64mA, V_{CC}=3V, R_L=2kΩ, ~~and v_{CM}=2V~~. Does v_{CM}=3.5V violate the saturation discipline? Explain.

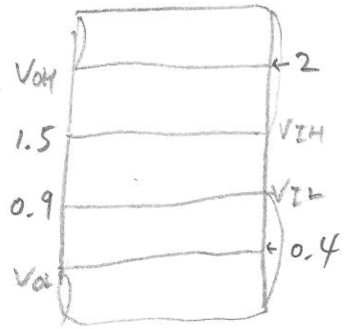


5. (20 points) For the following circuit, suppose R_{L1}=10kΩ and R_{L2}=5kΩ, and V_X=5V. If v_{IN} =0~20V, what would be the range of i_x?



Name: CSU0007 Student ID: Solution

(1) From Homework 4:



To make $V_{OL} > V_{CC} \times \dfrac{R_{ON}}{R_{ON}+R_L}$

$\Rightarrow 0.4 > 3.3 \times \dfrac{R_{ON}}{R_{ON}+8}$

$\Rightarrow R_{ON} < \dfrac{8}{7.25}$

$\Rightarrow 5 \times \dfrac{L}{W} < \dfrac{8}{7.25} \Rightarrow \dfrac{L}{W} < 0.22 \left(\dfrac{8}{36.25}\right)$ $\frac{32}{145}$ #

(2.1) From Homework 5: **Decrease.** See Question 3.1 in Homework 5 for detail.

(2.2) $i_D = \frac{1}{2}k(v_{IN} - V_T)^2 = \dfrac{V_{CC} - v_{OUT}}{R_L}$

$\Rightarrow \frac{1}{2} = \dfrac{5 - v_{OUT}}{5} \Rightarrow v_{OUT} = 2.5 \Rightarrow \dfrac{v_{OUT}}{v_{IN}} = \dfrac{2.5}{2} = \underline{1.25}$ #

(3) From Homework 6, Question 3:

$r_i = \dfrac{1}{g_m} = \dfrac{1}{k(V_{GS} - V_T)} < 50 \Rightarrow V_{GS} - V_T > 20$

$\Rightarrow V_B \times \frac{16}{100} - v_{IN} > 21$

$\Rightarrow V_B > \frac{100}{16}(v_{IN} + 21)$

(This time you will still receive score if you didn't put v_{IN} in the formula, because I think people might be misled by my mistake in the answer of Question 4.3 in Homework 6 (which I corrected now).)

(4) From Homework 7, Question 1.2:

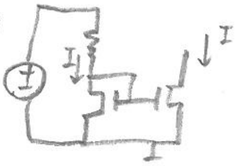
We should have

$v_{CM} < V_T + V_{CC} - \frac{I}{2}R_L = 3.36\,V$

$\Rightarrow v_{CM} = 3.5\,V$ violates the discipline. #

(5) This configuration is like:

where the current source is driven by



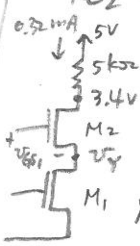
In any case, there will be some current flowing through R_{L1}

$\frac{1}{2}k(V_{DS} - V_T)^2 = \dfrac{V_X - V_{DS}}{R_{L1}}$

$\Rightarrow \frac{1}{2}(V_{DS} - 1)^2 = \dfrac{5 - V_{DS}}{10}$

$\Rightarrow V_{DS} = 1.8\,V \Rightarrow I = 0.32\,mA$

Now, the MOSFET at the lower-right corner ensure that the current flowing through R_{L2} will never be larger than 0.32 mA.



To ensure M_1 works in saturation, we must make $v_Y \geq 0.8\,V$

To ensure M_1 works in saturation, we must make $v_{GS1} \leq 3.4 - 0.8 = 2.6\,V$

Finally, we can determine v_{IN} to make everything work: $\frac{1}{2}k(v_{IN} - 0.8 - 1)^2 = 0.32$

$\Rightarrow v_{IN} = 2.6\,V$ and $v_{GS1} = 1.8\,V < 2.6\,V$

Therefore, $v_{IN} = 0 \sim 20\,V$ would make $\underline{i_X = 0.32 \sim 0.64\,mA}$ #