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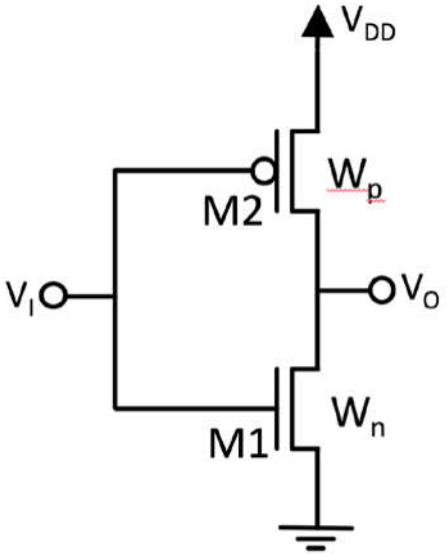
Homework 1 – due January 18, 2018 by 5:00pm

NOTE: For all the problems here, and from now on, we'll use the common terminology for K. Namely, we'll use $K_n = K_n' (W/L)$ for n-MOSFETs and $K_p = K_p'(W/L)$ for p-MOSFETs. $K_n' = \mu_n C_{ox}$ and $K_p' = \mu_p C_{ox}$.

1) For the CMOS inverter circuit shown below, assume the following: $K_n' = K_p'$, $L_n = L_p = 1\mu m$, and $|V_{TP}| = V_{TN} = V_T$. Let's define the threshold as the point ($v_I = V_{TH}$) in the v_O versus v_I transfer curve where $v_O = V_{DD}/2$.



a) Sketch the inverter transfer curve and mark the V_{TH} point.
b) Find an expression for the inverter threshold voltage V_{TH} in terms of V_{DD}, V_T, W_n and W_p.
c) If $W_n = W_p$, what is V_{TH}? In what mode of operation are M1 and M2 when $V_I = V_{TH}$?

d) Now assume V_{DD} = 5V. Fill in V_{TH} in the tables below for the cases when V_T = 0V and when V_T = 1V.

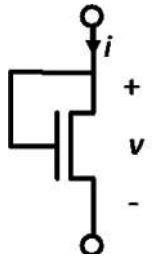
$V_T = 0\ V$

W_p \ W_n	1	4	16
1			
4			
16			

$V_T = 1\ V$

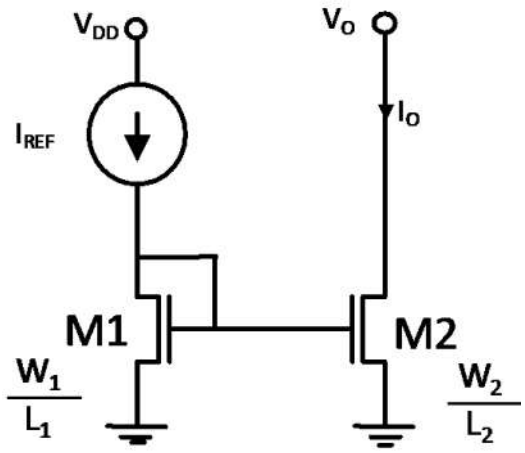
W_p \ W_n	1	4	16
1			
4			
16			

2. The configuration shown below, an n-MOSFET with its drain and gate terminals connected together, is called a **diode-connected MOSFET**.



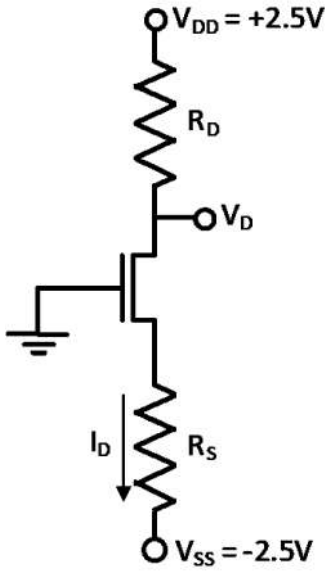
   a. In what mode does the MOSFET operate and why?
   b. Find the *i*-*v* characteristics of the two-terminal device in terms of the MOSFET parameters K and V_T.
   c. Plot the *i*-*v* characteristics if $K = 1\text{mA/V}^2$ and $V_T = 1\text{V}$ over the range of $v = 0$ to 5V (1V increments in voltage are sufficient)

3. Consider the circuit shown below. Assume that both of the transistors are matched, meaning: 1) K_n is the same for both devices M1 and M2, and is equal to 1mA/V^2; 2) $V_T = 0.5\text{V}$ for both M1 and M2. Recall that $K = K_n'(W/L)$, where W is the length and L is the width of the MOSFET. Further assume that $V_{DD} = 3\text{V}$ and V_O is large enough that M2 operates in the saturation regime.



a. In what mode does M1 operate and why?
b. Find the relationship between I_O and I_{REF} in terms of the MOSFET parameters.
c. Find V_{GS} if $I_{REF} = 10\text{mA}$, $W_1 = 10\mu\text{m}$, and $L_1 = 1\mu\text{m}$.
d. Find I_O under the conditions in part (c) if $W_2 = 20\mu\text{m}$ and $L_2 = 1\mu\text{m}$.
e. What is the minimum value for V_O to ensure M2 is in saturation under the conditions of part (d)?

4. Determine the Values of R_D and R_S such that the circuit below operates at I_D = 0.4 mA and V_D = +0.5V. Assume V_T = 0.7V, K_n = 100μA/V^2, L = 1 μm, and W = 32 μm.



5. Determine V_O in the circuit below in terms of the power supply voltages and MOSFET parameters (W_1, L_1, W_2, L_2, V_T). You can assume that K_n is the same for both of the n-MOSFETs and that both M1 and M2 are biased in the saturation region.