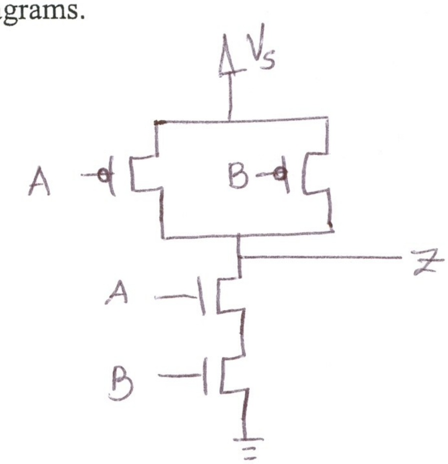
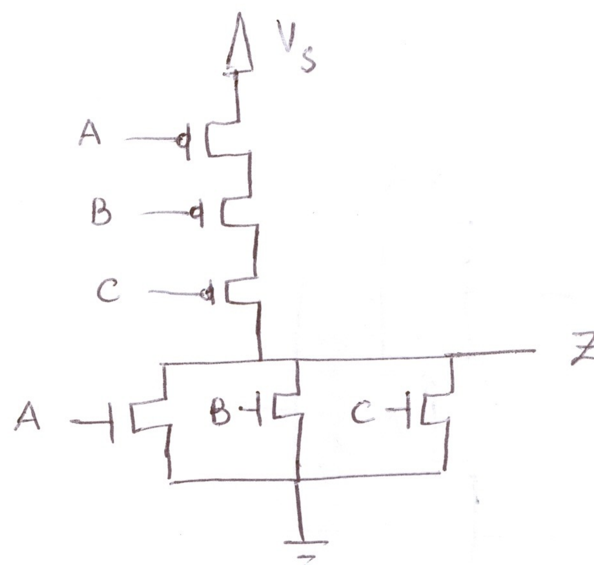
ECE 53A Fall 2007, Midterm 2, November 13, 2007, Name SOLUTIONS

1. Use complementary CMOS logic to design the following two Boolean functions. Draw the schematic diagrams.

i) (AB)'

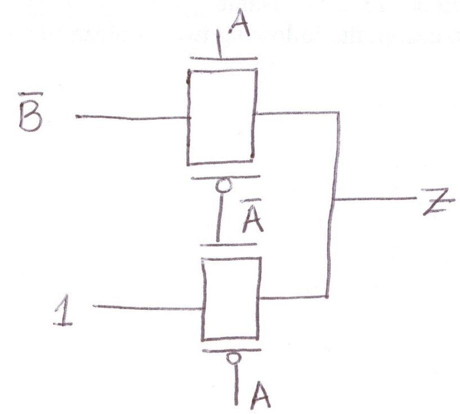


ii) (A+B+C)'.

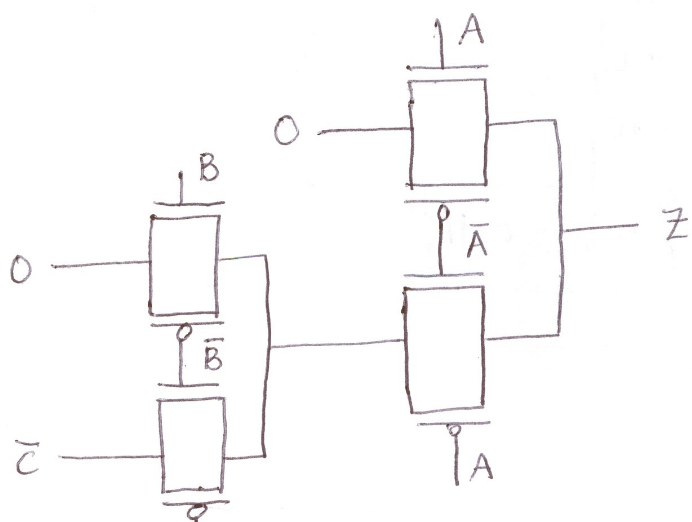


2. Use transmission gates to design two Boolean functions. Draw the schematic diagrams.

i) (AB)'



ii) (A+B+C)'. = A' (B+C)'



3. Describe the three regions of operations of an nMOS transistor. Express the drain current I_D as a function of voltages V_{GS} and V_{DS}.

Cut off: $V_{GS} < V_T$ $I_D = 0$

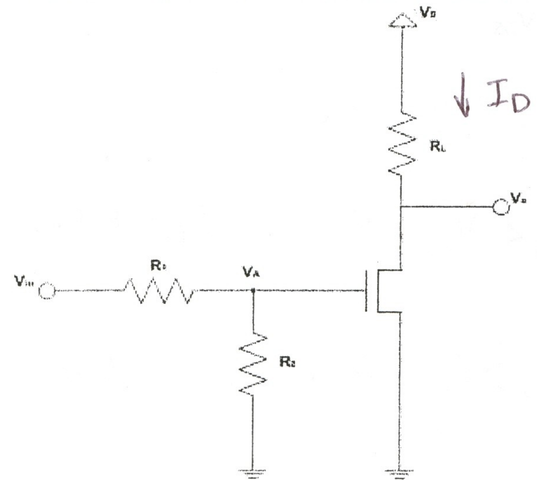
Linear: $V_{GS} > V_T$; $V_{DS} < V_{GS} - V_T$; $I_D = K\left(V_{GS} - V_T - \frac{V_{DS}}{2}\right) V_{DS}$

Saturation: $V_{GS} > V_T$; $V_{DS} > V_{GS} - V_T$; $I_D = \frac{K}{2}(V_{GS} - V_T)^2$

4. Describe the three regions of operations of a pMOS transistor. Express the drain current I_D as a function of voltages V_{GS} and V_{DS}.

Switch signs of I_D, V_{DS} and V_{GS} in the above solution.

5. Biased Transistor: Assume that the transistor operates in saturation region.



i). Represent voltages V_o and V_A as functions of V_{in}.

$$V_A = \frac{V_{in} R_2}{R_1 + R_2}$$

$$V_o = V_S - I_D R_L \quad \text{where } I_D = \frac{K}{2}(V_A - V_T)^2$$

$$= V_S - \frac{K}{2}\left[\frac{V_{in} R_2}{R_1 + R_2} - V_T\right]^2 R_L$$

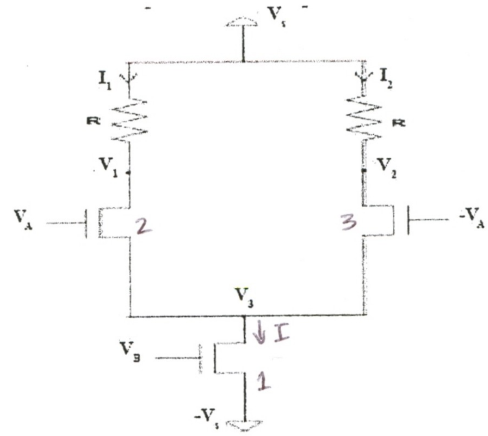
ii). Find the constraint so that the saturation region assumption holds.

$$V_{GS} > V_T \Rightarrow V_A > V_T$$

and

$$V_{DS} > V_{GS} - V_T \Rightarrow V_o > V_A - V_T.$$

6. Differential Amplifier: Assume that the transistors operate in saturation region. Voltage V_B is a constant and voltage V_A is the input.



i). Find V_1-V_2, and V_3 as functions of V_A and V_B.

$$I_1 = \frac{K}{2}(V_A - V_3 - V_T)^2$$
$$I_2 = \frac{K}{2}(-V_A - V_3 - V_T)^2$$
$$I_1 + I_2 = I = \frac{K}{2}(V_B + V_S - V_T)^2$$

$$V_1 - V_2 = [V_S - I_1 R] - [V_S - I_2 R]$$
$$= (I_2 - I_1)R$$
$$= \frac{K}{2}(4V_A V_3 + 4V_A V_T)R = 2RKV_A(V_3 + V_T) \rightarrow (1)$$

In (1) V_3 can be obtained from:

$$V_3^2 + 2V_T V_3 + V_A^2 + V_T^2 - \frac{1}{2}(V_B + V_S - V_T)^2 = 0$$

ii). Find the constraint so that the saturation region assumption holds.

(1) $V_B + V_S > V_T$; $V_3 + V_S > V_B + V_S - V_T$

(2) $V_A - V_3 > V_T$; $V_1 - V_3 > V_A - V_3 - V_T$

(3) $-V_A - V_3 > V_T$; $V_2 - V_3 > -V_A - V_3 - V_T$