

**Homework Assignment 12**  
**(Due 4:10pm, Mar. 21, email to [daehyun@eecs.wsu.edu](mailto:daehyun@eecs.wsu.edu))**

The drain current formulae for an nFET are as follows:

- $I_{DS} = 0$  if  $V_{GS} \leq V_{tn}$
- $I_{DS} = \beta_n[(V_{GS} - V_{tn})V_{DS} - 0.5V_{DS}^2]$  if  $V_{GS} > V_{tn}$  and  $V_{GS} - V_{tn} > V_{DS}$
- $I_{DS} = 0.5\beta_n(V_{GS} - V_{tn})^2$  if  $V_{GS} > V_{tn}$  and  $V_{GS} - V_{tn} < V_{DS}$

The drain current formulae for a pFET are as follows:

- $I_{SD} = 0$  if  $V_{SG} \leq |V_{tp}|$
- $I_{SD} = \beta_p[(V_{SG} - |V_{tp}|)V_{SD} - 0.5V_{SD}^2]$  if  $V_{SG} > |V_{tp}|$  and  $V_{SG} - |V_{tp}| > V_{SD}$
- $I_{SD} = 0.5\beta_p(V_{SG} - |V_{tp}|)^2$  if  $V_{SG} > |V_{tp}|$  and  $V_{SG} - |V_{tp}| < V_{SD}$

- (1) **[DC Analysis, 20 points]** Derive the equation for  $V_{out}$  and  $V_{in}$  for Region B in Page 7 of Lecture Note 06 (06-Electronic\_Analysis.pdf).

$$V_{out} = (V_{in} - |V_{Tp}|) + \sqrt{(V_{in} - |V_{Tp}|)^2 - 2\left(V_{in} - \frac{V_{DD}}{2} - |V_{Tp}|\right)V_{DD} - \frac{\beta_n}{\beta_p}(V_{in} - V_{Tn})^2}$$

- (2) **[DC Analysis, 20 points]** Derive the equation for  $V_{out}$  and  $V_{in}$  for Region D in Page 9 of Lecture Note 06 (06-Electronic\_Analysis.pdf).

$$V_{out} = (V_{in} - V_{Tn}) - \sqrt{(V_{in} - V_{Tn})^2 - \frac{\beta_p}{\beta_n}(V_{in} - V_{DD} - |V_{Tp}|)^2}$$

- (3) **[DC Analysis, 10 points]** Answer the following questions for the inverter in the lecture note.

- (a) Upsizing the nFET of the inverter shifts the DC characteristic curve to the (left / right).
- (b) Upsizing the pFET of the inverter shifts the DC characteristic curve to the (left / right).

- (4) **[DC Analysis, 20 points]** Derive the equation for  $V_M$  for NAND2 in Page 20 of Lecture Note 06 (06-Electronic\_Analysis.pdf).

$$V_M = \frac{V_{DD} - |V_{tp}| + \frac{1}{2}V_{tn} \sqrt{\frac{\beta_n}{\beta_p}}}{1 + \frac{1}{2} \sqrt{\frac{\beta_n}{\beta_p}}}$$

- (5) **[DC Analysis, 10 points]** Answer the following questions for NAND2 in the lecture note (Page 20).

- (a) Upsizing the nFETs shifts the DC characteristic curve to the (left / right).
- (b) Upsizing the pFETs shifts the DC characteristic curve to the (left / right).