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Question #1: Assuming an n-type transistor with V_{ds} of 1.8V and V_t of 0.7V find the ranges of V_{gs} to put the transistor in cutoff, linear, and saturation regions.

Answer: n-type $V_{ds} = 1.8V$ $V_t = 0.7V$

From lecture: 2.1
Cutoff = $V_{gs} < V_t$
Linear = $V_{gs} \geq V_t$ $V_{DS} < V_{gs} - V_T$
Saturation = $V_{gs} \geq V_t$ $V_{ds} \geq V_{gs} - V_t$

Cutoff region: $V_{gs} < V_t$

$V_{gs} < 0.7V$

Linear region: $V_{gs} \geq 0.7V$

$1.8V < V_{gs} - 0.7V$
$+0.7$ $+0.7$

$2.5V < V_{gs}$ still holds!

$V_{gs} > 2.5V$

Saturation region: $V_{gs} \geq 0.7$

$1.8V \geq V_{gs} - 0.7$
$+0.7$ $+0.7$

$2.5 \geq V_{gs}$

$0.7 \leq V_{gs} \leq 2.5$

Question 2

Assume a NMOS has $V_t = 0.6V$ and $\frac{W}{L} = \frac{5}{2}$, $K_n = \frac{73\mu A}{V^2}$

Find Ids

From Lecture 2.1:

Cutoff = $v_{as} < v_t$

Linear = $v_{gs} \geq v_t$ $v_{ds} < v_{gs} - v_t$

Saturation = $v_{as} \geq v_t$ $v_{ds} \geq v_{gs} - v_t$

a) $v_{ds} = 1.5V$, $v_{gs} = 1V$ $\lambda = 0$

$1 > 0.6$ & $1.5 > 1 - 0.6$

v_{as} v_t v_{ds} $v_{gs} - v_t$

Saturation mode

$I_{ds} = \frac{1}{2} K_n \left(\frac{W}{L}\right)(v_{gs} - V_t)^2$

$= \frac{1}{2}\left(\frac{73\mu A}{V^2}\right) \cdot \frac{5}{2} \cdot (1 - 0.6)^2 V^2$

$I_{ds} = 14.6\,\mu A$

b) $v_{ds} = 1V$, $v_{as} = 0.5V$

$0.5 < 0.6$

v_{as} v_t

Cutoff mode

$I_{ds} = 0$

c) $v_{ds} = 0.2V$ and $v_{gs} = 1V$

$1 > 0.6$ $0.2 < 0.4$

v_{as} v_t v_{ds} $v_{as} - v_t$

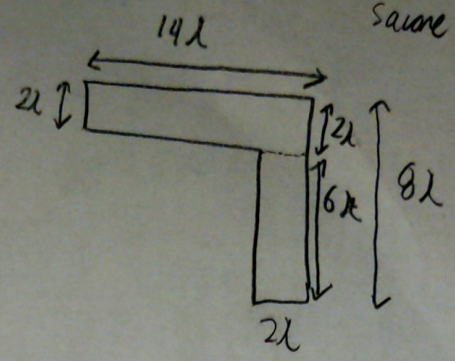
Linear mode

$I_{ds} = K_n \left(\frac{W}{L}\right)\left((v_{gs} - v_t) v_{as} - 0.5 v_{ds}^2\right)$

$I_{ds} = \frac{73\mu A}{V^2}\left(\frac{5}{2}\right)\left((0.4) \cdot 0.2 - 0.5(0.2)^2\right)$

$I_{ds} = 10.95\,\mu A$

Question 3 Compute the parasitic resistance of the following metal 1 wire. Where the sheet resistance ($R_\square$) of metal 1 is $0.08\ \frac{\Omega}{\square}$



$$\text{Resistance} = R_\square \cdot \frac{L1}{W} + R_{corner} + R_\square \cdot \frac{L2}{W}$$

$$R_{corner} = 0.5 \cdot 0.08\ \frac{\Omega}{\square}$$

$W = 2\lambda$

$L1 = 12\lambda$

$L2 = 6\lambda$

$$R = 0.08\ \frac{\Omega}{\square} \cdot \frac{12\lambda}{2\lambda} + 0.5 \cdot 0.08\ \frac{\Omega}{\square} + 0.08\ \frac{\Omega}{\square} \cdot \frac{6\lambda}{2\lambda}$$

$R = 0.76\ \Omega$

Question 4 Predict how interconnect resistance, interconnect capacitance and RC delay would change for a 90nm processing from the 180nm process: Table omitted

a) Ideal scaling $S = 0.5$

resistance: $R' = \frac{R}{S^2} = \frac{R}{(0.5)^2} = 4R$ – Resistance Increases by 4 times

capacitance: $C' = C$ – capacitance has No change

RC delay: $RC' = \frac{RC}{S^3} = 8RC$ – RC delay Increases by 8 times

b) Constant dimension scaling

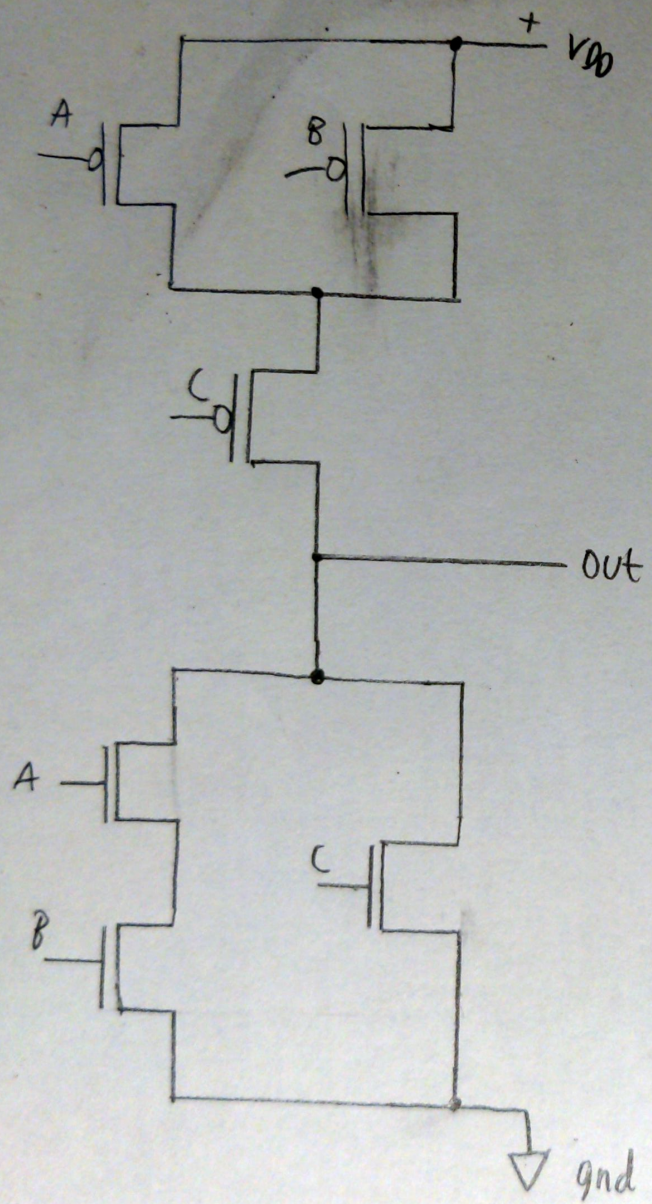
resistance: $R' = R$ – Resistance has No change

capacitance: $C' = C$ – capacitance has No change

RC delay $RC' = \frac{RC}{S} = \frac{RC}{0.5} = 2RC$ – RC delay Increases by 2 times

Question 5 Consider the following stick diagram. Draw the electrically equivalent transistor-level schematic. Stick diagram omitted

Identify transistor locations and route wires.
Match pmos and nmos with pdiff and ndiff

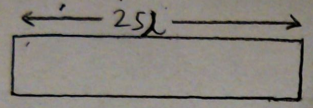


Question: Draw layouts for:

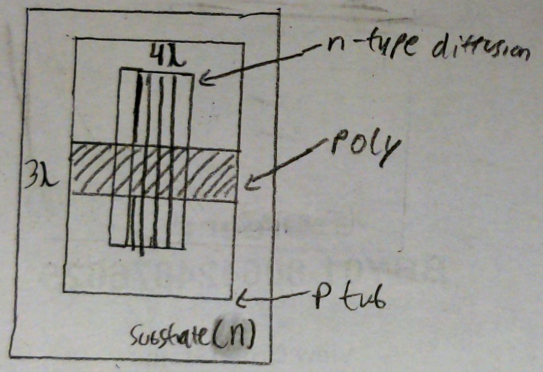
a) A metal-1 wire to n-diffusion wire through a via

2D Top view

b) A poly wire with width of 2$5\lambda$



c) A $\frac{W}{L} = \frac{4}{3}$ n-type MOSFET transistor



d) A $\frac{W}{L} = \frac{6}{2}$ p-type MOSFET transistor