EECS 168 Introduction to VLSI Design Sheldon Tan

Quiz 1

Name: ________________________________

Student ID: ________________________________

1. (10pts)

(a) Explain the Moore's law.

Semiconductor technology will double its effectiveness every 18 months.

(b) List 3 reliability issues.

EM, TDDB, HCI, BTI

2. (10pts) Give the conditions of linear region and saturation region for both NMOS and PMOS transistors.

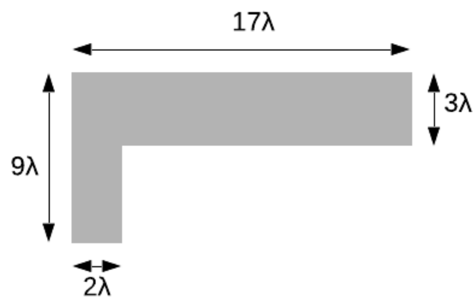
	NMOS	PMOS
linear	$V_{gs} > V_t, V_{ds} < V_{gs} - V_t$	$V_{sg} > \lvert V_t \rvert, V_{sd} < V_{sg} - \lvert V_t \rvert$
saturation	$V_{gs} > V_t, V_{ds} \geq V_{gs} - V_t$	$V_{sg} > \lvert V_t \rvert, V_{sd} \geq V_{sg} - \lvert V_t \rvert$

3. (10pts) Give the typical design abstraction levels for VLSI design.

higher ↕ lower

system level
register-transfer level
gate level
circuit level
device level

4. (15 pts). Compute the parasitic resistance of the following metal1 wire, where the sheet resistance ($R_\square$) of metal1 is $0.08\Omega/\square$, $R_{corner} = R_\square \left(0.46 + 0.1 \cdot \frac{W_{large}}{W_{small}}\right)$.



$$R_{corner} = R_\square \left(0.46 + 0.1 \cdot \frac{W_{large}}{W_{small}}\right)$$

$$\begin{aligned} R &= R_\square \cdot \frac{L_1}{W_1} + R_{corner} + R_\square \cdot \frac{L_2}{W_2} \\ &= R_\square \left(\frac{17\lambda - 2\lambda}{3\lambda}\right) + R_\square \left(0.46 + 0.1 \cdot \frac{3\lambda}{2\lambda}\right) + R_\square \left(\frac{9\lambda - 3\lambda}{2\lambda}\right) \\ &= R_\square (5 + 0.61 + 3) \\ &= 8.61 R_\square \\ &= 0.6888\Omega \end{aligned}$$

5. (20 pts). Assuming V_{gs} is 3V, compute the drain current through an n-type transistor at a V_{ds} of 1.8V, where W/L is 6/2, k' is 73µA/V^2, and V_t is 0.7V.

$$\left.\begin{array}{r} V_{gs} > V_t \\ V_{ds} < V_{gs} - V_t \end{array}\right\} \Rightarrow \text{linear region}$$

$$\begin{aligned} I_d &= k' \frac{W}{L} \left[\left(V_{gs} - V_t\right) V_{ds} - \frac{1}{2} V_{ds}^2 \right] \\ &= 73 \times \frac{6}{2} \times \left[(3 - 0.7) \times 1.8 - \frac{1}{2} \times 1.8^2 \right] \\ &= 551.88\mu\text{A} \end{aligned}$$

6. (20 pts). Predict how linear and saturation drain current of an MOSFET would change for a 90nm ($\lambda = 45$ nm) process from 180nm: (a) ideal scaling and (b) fixed-voltage scaling. Assume that $S = 0.5$, $k' = \frac{\mu_{eff}\varepsilon_{ox}}{t_{ox}}$.

Parameter	ideal scaling	fixed-voltage scaling
W, L, t_{ox}	S	S
V_{gs}, V_{ds}, V_t	S	1
$\mu_{eff}, \varepsilon_{ox}$	1	1

lengths and widths: $\frac{\hat{W}}{W} = S, \frac{\hat{L}}{L} = S$

oxide thickness: $\frac{\hat{t}_{ox}}{t_{ox}} = S$

transistor conductance: $k' = \frac{\mu_{eff}\varepsilon_{ox}}{t_{ox}} \rightarrow \frac{\hat{k}'}{k'} = \frac{1}{S}$

(a) ideal scaling

voltage: $\frac{\hat{V}}{V} = S$

saturation drain current:

$$\frac{\hat{I}_d}{I_d} = \left(\frac{1/2}{1/2}\right)\left(\frac{\hat{k}'}{k'}\right)\left(\frac{\hat{W}/\hat{L}}{W/L}\right)\left[\frac{(\hat{V}_{gs} - \hat{V}_t)^2}{(V_{gs} - V_t)^2}\right] = \frac{1}{S}\left(\frac{S}{S}\right)S^2 = S = 0.5$$

linear drain current:

$$\frac{\hat{I}_d}{I_d} = \left(\frac{\hat{k}'}{k'}\right)\left(\frac{\hat{W}/\hat{L}}{W/L}\right)\left[\frac{(\hat{V}_{gs} - \hat{V}_t)\hat{V}_{ds} - (1/2)\hat{V}_{ds}^2}{(V_{gs} - V_t)V_{ds} - (1/2)V_{ds}^2}\right] = \frac{1}{S}\left(\frac{S}{S}\right)S^2 = S = 0.5$$

(b) fixed-voltage scaling

voltage: $\frac{\hat{V}}{V} = 1$

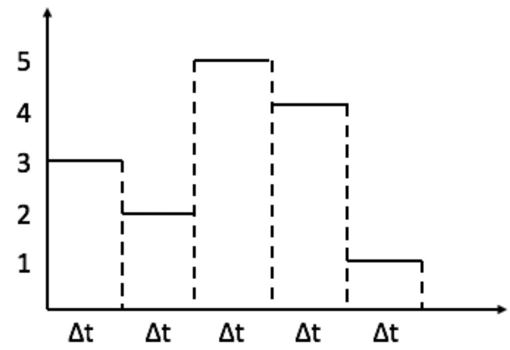
saturation drain current:

$$\frac{\hat{I}_d}{I_d} = \left(\frac{1/2}{1/2}\right)\left(\frac{\hat{k}'}{k'}\right)\left(\frac{\hat{W}/\hat{L}}{W/L}\right)\left[\frac{(\hat{V}_{gs} - \hat{V}_t)^2}{(V_{gs} - V_t)^2}\right] = \frac{1}{S}\left(\frac{S}{S}\right)1^2 = \frac{1}{S} = 2$$

linear drain current:

$$\frac{\hat{I}_d}{I_d} = \left(\frac{\hat{k}'}{k'}\right)\left(\frac{\hat{W}/\hat{L}}{W/L}\right)\left[\frac{(\hat{V}_{gs} - \hat{V}_t)\hat{V}_{ds} - (1/2)\hat{V}_{ds}^2}{(V_{gs} - V_t)V_{ds} - (1/2)V_{ds}^2}\right] = \frac{1}{S}\left(\frac{S}{S}\right)1^2 = \frac{1}{S} = 2$$

7. (15 pts). The TTF (time to failure in years) of a system is changing with time as the graph shows, then what is the effective TTF for the system over the total time period? $\Delta t = 1$



Compute the failure rate for each period:

$$\Delta t_1 : \lambda_1 = \frac{1}{3}$$

$$\Delta t_2 : \lambda_2 = \frac{1}{2}$$

$$\Delta t_3 : \lambda_3 = \frac{1}{5}$$

$$\Delta t_4 : \lambda_4 = \frac{1}{4}$$

$$\Delta t_5 : \lambda_5 = 1$$

$$\lambda_{avg} = \frac{\left(\frac{1}{3} + \frac{1}{2} + \frac{1}{5} + \frac{1}{4} + 1\right)}{5} = \frac{137}{300}$$

$$MTTF = \frac{1}{\lambda_{avg}} = \frac{300}{137} \approx 2.19$$