Analog Integrated Circuits Analysis and Design Midterm

Answer ver.1

1.

(a) A process of depositing films by reacting chemical vapors to produce a film on a substrate.

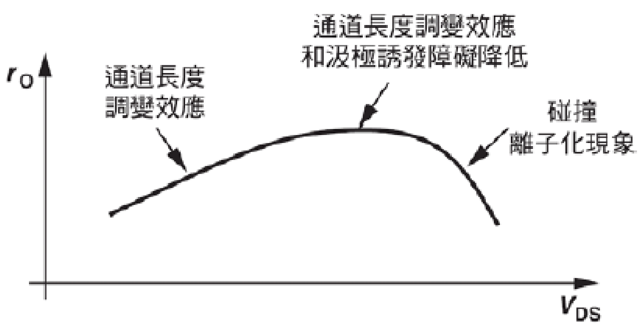
(b) DIBL: In short channel devices, the drain voltage makes the surface more positive by creating a two-dimensional field depletion region. The barrier to the flow charge and hence the V_{TH} are decreased.

(c) The number of transistors on a chip doubles every 18 months (12 months).

(d) High vertical electrical field E_{ver} between the gate and the channel confines the charge carriers to a narrow region below the oxide-silicon interface, leading to more scattering and hence lower mobility.

(e) Carriers may reach a saturated velocity v = uE at some point along the channel. In the case carriers experience velocity saturation along the entire channel. The current is proportional to the V_{ov} only and does not depend on the length. Devices with L < 1 μm reveal velocity saturation because equal increments in V_{GS}-V_{TH} result in roughly equal increments in I_D. The transconductance is a weak function of the I_D and channel length.

2.

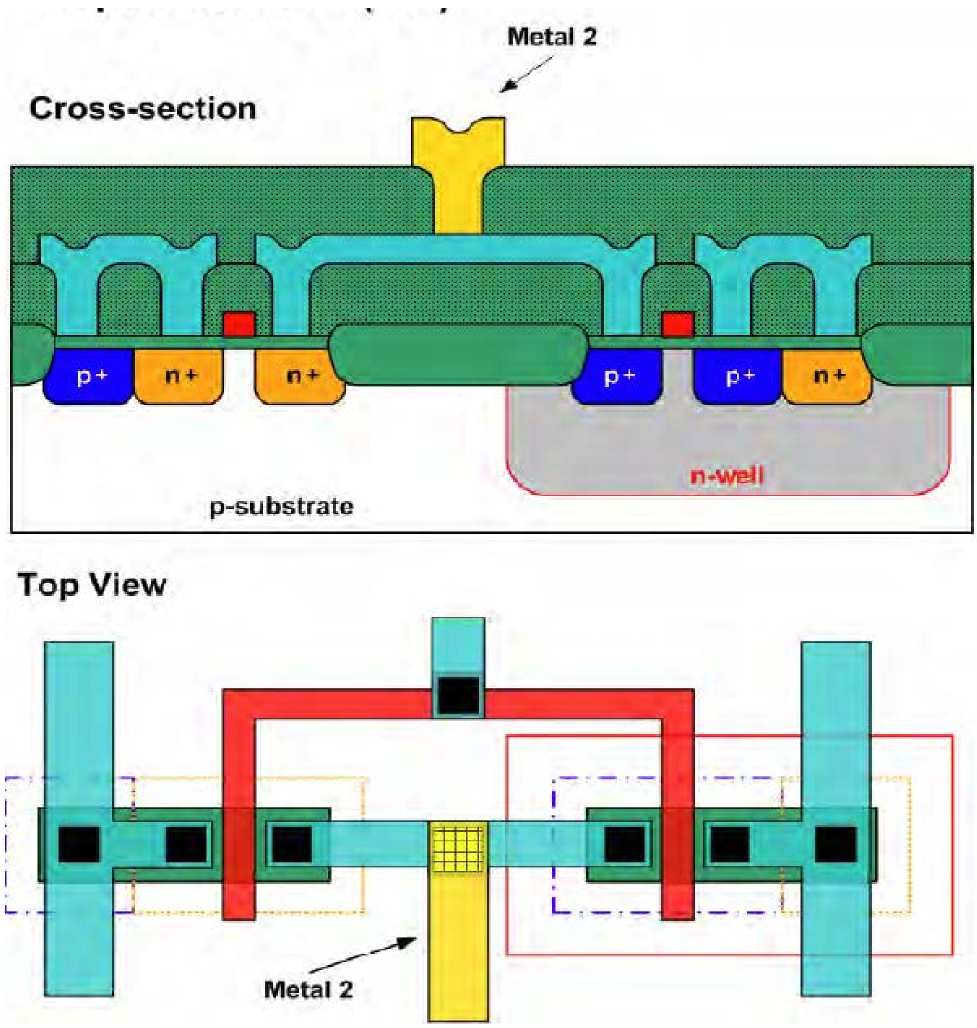


Region I: Channel length modulation--> r_{o1} 變大

Region II: Channel length modulation--> r_{o1} 變大 ， DIBL--> r_{o1} 變小

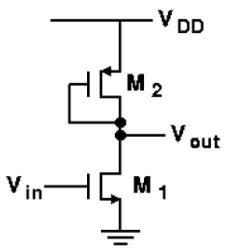
Region III: Impact ionization --> r_{o1} 變小

3.



(5% no partition)

4.

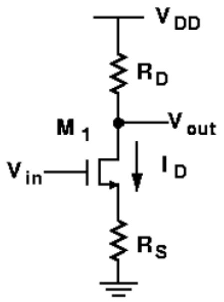


$$A_v \approx -g_{m1}\left(\frac{1}{g_{m2}} \parallel r_{o1} \parallel r_{o2}\right)$$

5.

$A_V = -g_{m1} \times (r_{o1} // r_{o2})$

6.



$$A_v = -G_m R_D = \frac{-g_m R_D}{1 + g_m R_S} = -\frac{R_D}{1/g_m + R_S}$$

7.

$$A_V = \frac{g_{m1} \times R_S}{1 + (g_{m1} + g_{mb1})R_S} = \frac{R_S // \frac{1}{g_{mb1}}}{\frac{1}{g_{m1}} + (R_S // \frac{1}{g_{mb1}})} = g_{m1} \times (\frac{1}{g_{m1}} // \frac{1}{g_{mb1}} // R_S)$$

8.

$R_{out} = \{[1 + (g_m + g_{mb})r_o]R_S + r_o\} \;//\; R_D$

(5%)

9.

$V_{gs}(V_{sg}) = |V_{ov}| + |V_{th}| = 0.9V$

$V_{b1} = |V_{ov1}| + V_{gs2} = 1.1\ V$ (1.5%)

$V_{b2} = V_{DD} - |V_{ov4}| - V_{sg3} = 0.7\ V$ (1.5%)

$|V_{ov1}| + |V_{ov2}| < V_{out} < V_{DD} - |V_{ov3}| - |V_{ov4}| \rightarrow 0.4V < V_{out} < 1.4V$

$\text{Max } V_{out} \text{ swing} = 1V$ (2%)

10.

(a)

$-\sqrt{(2 * 0.9)} \le Vid \le \sqrt{(2 * 0.9)}$

** or

$-\sqrt{(2)} \le Vid \le \sqrt{(2)}$

(b)

$V_{CMmax} = V_t + V_{dd} - (I/2 * R_D) = 1.5$

$V_{CMmin} = V_{ov} + V_t + V_{ov} = 1.1$

11.

(a)

$$\frac{V_{out1}-V_{out2}}{V_{in1}-V_{in2}}=A_{dm}=-g_m(R_D//r_o)=-10^{-3}\times 50\times 10^{3}=-50\,V/V \quad (2.5\%)$$

(b)

$$A_{cm}=-\frac{g_mR_D}{1+2g_mR_{SS}}$$

$$V_{out1}=-\frac{g_mR_{D1}}{1+2g_mr_o}V_{icm} \qquad V_{out1}=-\frac{g_mR_{D2}}{1+2g_mr_o}V_{icm}$$

$$\frac{V_{out1}-V_{out2}}{V_{icm}}=-\frac{g_m(R_{D1}-R_{D2})}{1+2g_mr_o}=-\frac{10^{-3}\times(110-100)\times 10^{3}}{1+2\times 10^{-3}\times 100\times 10^{3}}$$

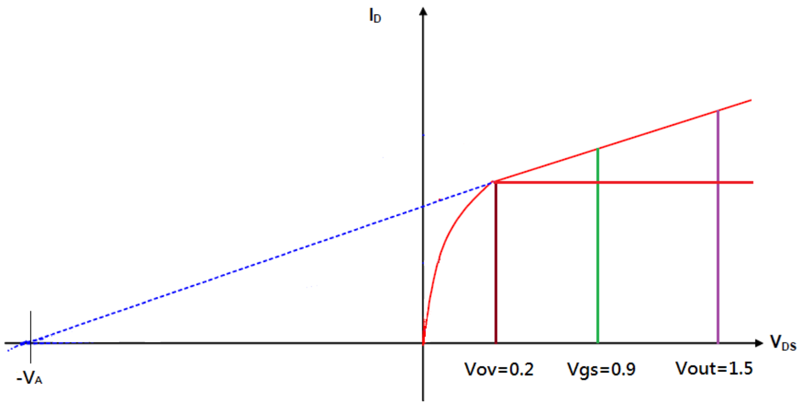
$$=-0.04975\ V/V \quad (2.5\%)$$

12.

(a) In order to operate as a current mirror correctly, MOSFET have to work in saturation region.

Minimal V_{out}=0.2V

(b)



$$\begin{cases} I_{out}=Kn'\times 4\times(\frac{W}{L})\times(V_{GS}-V_{th})^2\times(\frac{10+1.5}{10+0.2}) \\ I_{REF}=Kn'\times(\frac{W}{L})\times(V_{GS}-V_{th})^2\times(\frac{10+0.9}{10+0.2}) \end{cases},I_{out}=4\times(\frac{10+1.5}{10+0.9})\times I_{REF}$$

$$=42.2\mu A$$

13.

(a) V_b = 1.4V. $V_{out,min} = V_b - V_{th} + V_{ov}$. $V_{out,min}$ = 1.4 – 0.7 + 0.2 = 0.9 V.

(b) At matching, $V_{out} = V_X$ = 0.9V. With early effect, $\Delta i_{out} = \Delta V_{out} / R_{out}$. Δi_{out} = (1.5 – 0.9) / 1M = 0.6 uA. I_{out} = 40uA + 0.6uA = 40.6 uA.

14.

(a) $V_{in,dc\ min} = V_{ov} + V_{GS} = 2V_{ov} + V_{th}$ = 0.4 + 0.7 = 1.1 V

(b) $V_{out,max} = V_{DD} - V_{ov4}$ = 1.6V. $V_{out,min} = V_{ov5} + V_{ov2}$ = 0.4V Vout,swing = 1.6 - 0.4 = 1.2V.

(c) $A_{id} = g_m(r_{o2}//r_{o4}) = 10^{-3} * 5k$ = 5 V/V

(d) A_{id} = 5 V/V $A_{cm} = 1/(1+2g_mr_o)$ = 1/20 or 1/21 V/V. CMRR = $|A_{id}/A_{cm}|$ = 100 or 105 V/V.

15.

(a)~(j) T F F T F F F F T F

16.

(a)~(j) F T F F T F T T F F