2014 Analog IC: Midterm Examination Solution

1.

(a) Junction breakdown:

(1) Zener breakdown:

Reverse bias V_R ↑, E of depletion region ↑, covalent bond break, hole-electron pair generation in depletion region, electrons swept to n-type, holes swept to p-type.

(2) Avalence breakdown:

Reverse bias V_R ↑, minority swept by electric filed, kinetic energy break covalent bond, ionizing collision, hole-electron pair generation in depletion region.

(3) Punch trough

Two neighboring junction depletion regions meet

(b) Channel length modulation effect:

Consider transistor operate in saturation region, effective channel length decreased as voltage difference between source and drain increased. Drain current increased with V_{ds} which implied a finte output impedance called r_o.

(c) Mobility degration:

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.

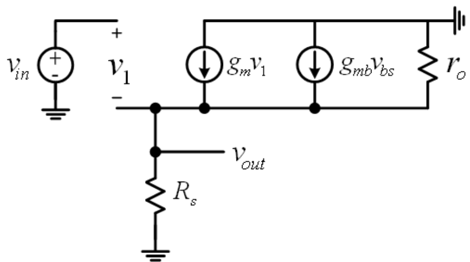
(d) Hot carrier effect:

While the average velocity of carrier saturates at high fields, the instantaneous velocity and hence the kinetic energy of the carries continue to increase, especially as they accelerate towards the drain.In the vicinity of the drain region, hot carrier may "hit" the silicon atoms at high speeds, thereby creating impact ionization.

(e) The mobility of carriers also depends on the lateral electrical field on the channel, beginning to drop as the field reaches level of 1 V/μm. Since the carrier velocity v=μE, we note that v approaches a saturated value for sufficiently high field.

2.

(a)



(b)

$$\frac{v_{out}}{v_{in}} = \frac{g_m R_s}{1+\left(g_m + g_{mb}\right) R_s + \frac{R_s}{r_o}} = \frac{1m \times 500k}{1+\left(1m+0.2m\right)\times 500k + \frac{500k}{100k}} = \frac{500}{1+600+5} \approx 0.825$$

3.

(a) $C_1 = \frac{2}{3}WLC_{OX} + WC_{OV}$, $C_2 = WC_{OV}$, $C_3 = \frac{1}{2}WLC_{OX} + WC_{OV}$

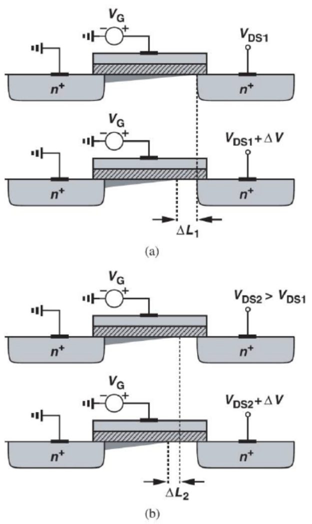
(b) I: cut off, II: saturation, III: triode

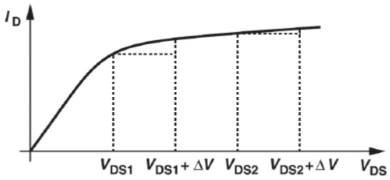
4.

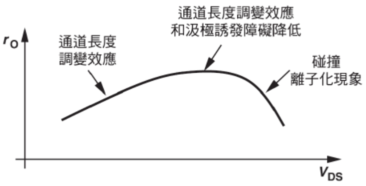
saturation：$I_D \approx \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{TH})^2(1+\lambda V_{DS})$

triode：$I_D = \mu_n C_{ox}\frac{W}{L}\left[(V_{GS} - V_{TH})V_{DS} - \frac{1}{2}V_{DS}^2\right]$

5.



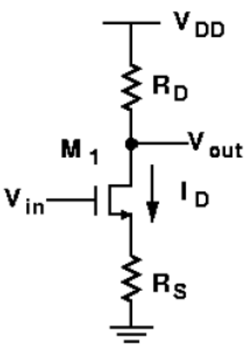




- As V_{DS} increases and the pinch off point moves toward the source, the rate at which the depletion region around the drain becomes wider decreases, resulting in a higher incremental output impedance.
- The W_{dep} is a strong function of the voltage of small $V_{reverse}$ and becomes weak with large $V_{reverse}$.
- ***Impact ionization*** limits the maximum gain that can be obtained from cascode structures because it introduces a small-signal resistance from ***the drain to the substrate*** rather than ***to the source***.

6. $Av = g_{m<n>}(\frac{1}{g_{m<p>}} \| r_{o<p>} \| r_{o<n>})$

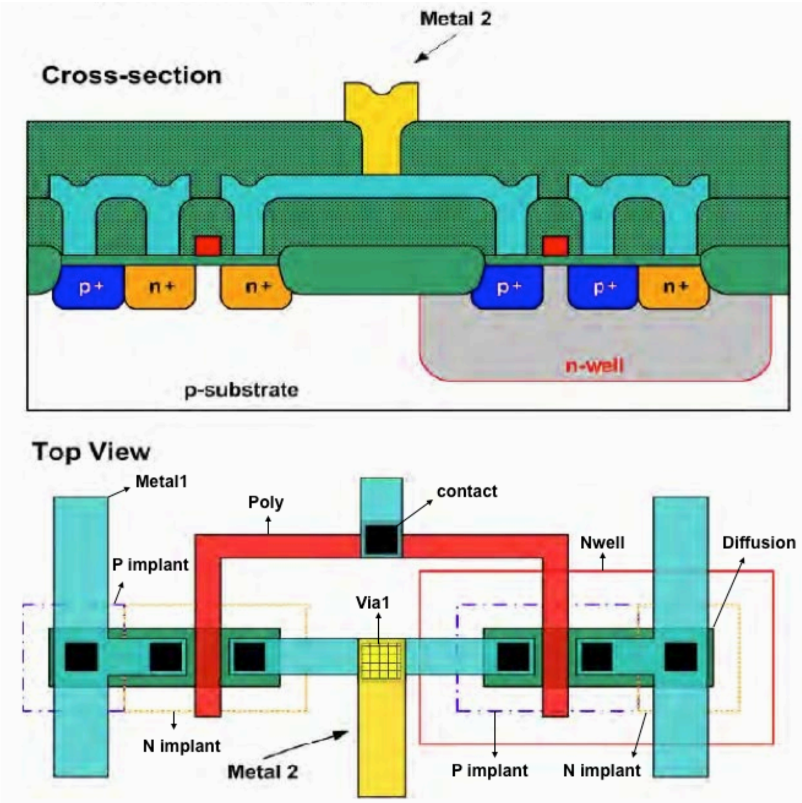
7.



(a) $G_m = \frac{g_m}{1+g_m R_S} = 4.7619\times10^{-5}$ A/V.

(b) $A_v = -\frac{g_m R_D}{1+g_m R_S} = -4.7619$ V/V

8.



9.

(a)

$-g_m(R_D \parallel r_o)$

$= -10^{-3} \times 50k$

$= -50$

(b)

$$A_{V.CM} = \frac{-R_D}{\frac{1}{g_m} + 2R_{SS}} = \frac{-100K}{1K + 2\times100K} = -0.4975$$

(C)

$$\Delta V_{in} = \sqrt{\frac{2I_{SS}}{\mu_n C_{ox}\frac{W}{L}}} = 0.2V \ or \ \sqrt{2}\times0.2\text{V}$$

(d)

$V_{gs1} + (V_{gs3} - V_{th3}) \leq V_{incm} \leq \min\,[vdd, vdd - I\times R_D + V_{th}]$

$1 \leq V_{incm} \leq 1.8$

10.

(a)

$$A_{V.CM.DM} = \frac{-g_m \Delta R}{1 + 2g_m R_{SS}} = \frac{-10}{201} = -0.04975$$

(b)

$$\frac{50}{10/201} = 1005$$

11.

(a)

$$\frac{1}{g_m + g_{mb}} + R_S = 10K + \frac{5K}{6} = 10833.3333$$

(b)

$$[1 + (g_m + g_{mb})r_O]R_S \parallel R_D = 92.366K$$

12.

(a)

$$g_m = \mu_n C_{OX} \frac{W}{L}(V_{gs} - V_{th})$$

$$g_{m3} = g_{m4} = 4g_{m1}$$

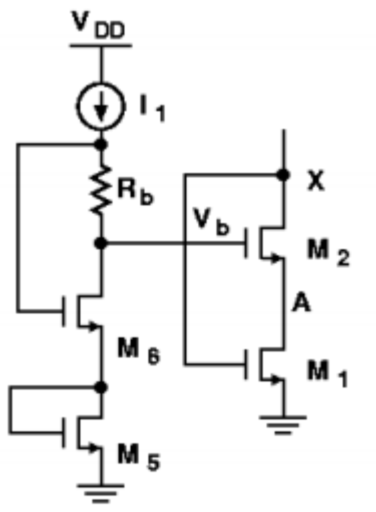
(b)

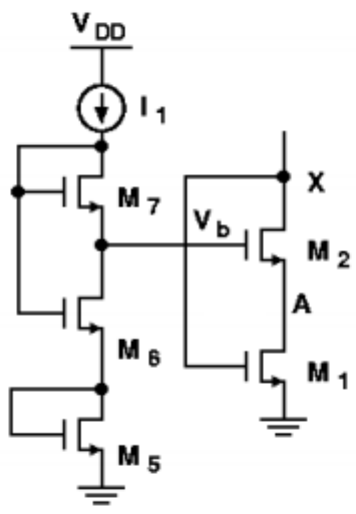
$$V_b = V_{ov} + V_{gs2} = 1V_{out} = 2V_{ov} = 0.4$$

(c)

$$R_{out} = (1 + g_m r_{o4})r_{o3} + r_{o4} = 100k + 100k + 4m \times 100k \times 100k = 40200k$$

(d)





13.

(a) Vin,dcmin =Vov +VGS =2Vov +Vth =0.4+0.6=1 V

(b) Vout/(Vin1-Vin2) = gm(ro2//ro4) = 20 V/V

14.

FTFTF

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