2012 AIC Midterm Solutions

1.

(a) A shortening of the length of the inverted channel region with increase in drain bias which is an increase in current with drain bias and a reduction of output resistance.

(b) High vertical electrical field 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.

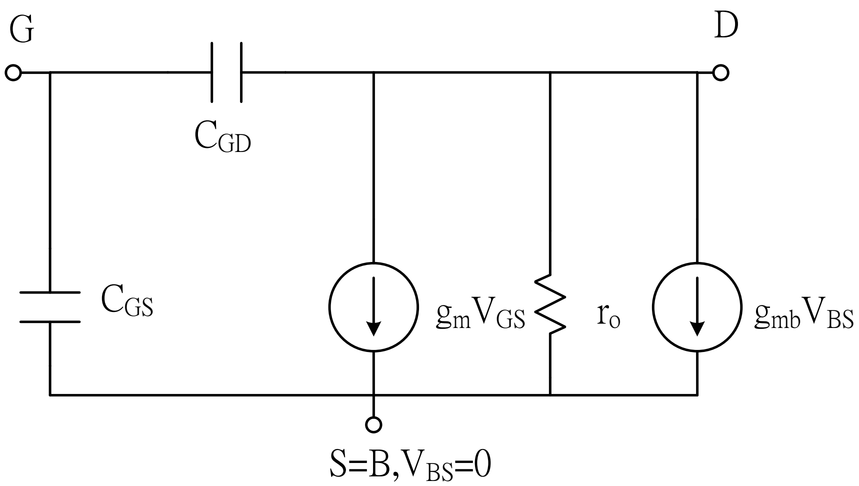
(c) As drain voltage is increased, the depletion region between drain and body increases and extends under the gate. To retain charge balance, the channel attracts more carriers. Therefore, it's an effect equivalent to lowering the threshold voltage.

(d) Source to body reverse bias introduces a split between the Fermi levels for electrons and holes, moving the Fermi level for the channel from the band edge, lowering the occupancy of the channel.

(e) The carrier velocity is proportion to mobility and results in velocity saturation due to mobility degradation.

2.

(至少要畫出這樣)



3.

(a)

C1=$\frac{2}{3}\mathrm{WLCox} + \mathrm{WCov}$

C2=WCov

C3=$\frac{1}{2}\mathrm{WLCox} + \mathrm{WCov}$

(b)

I:Cut off

II:Saturation

III:Triode

4.

Triode region:

$$I_D = \mu C_{ox}\frac{W}{L}[(V_{GS} - V_{TH})V_{DS} - \frac{1}{2}V_{DS}{}^2]$$

Saturation region:

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

5.

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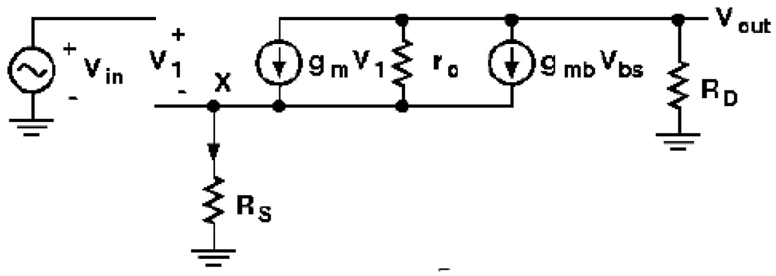
6.

$$A_V = \frac{V_{out}}{V_{in}} = -g_{m1}\left(\frac{1}{g_{m2}} \parallel \frac{1}{g_{mb2}} \parallel r_{o1} \parallel r_{o2}\right)$$

7.

(a)



(b)

$$G_m = \frac{I_{out}}{V_{in}} = \frac{g_m}{1 + (g_m + g_{mb})R_S + R_S / r_O}$$

(c)

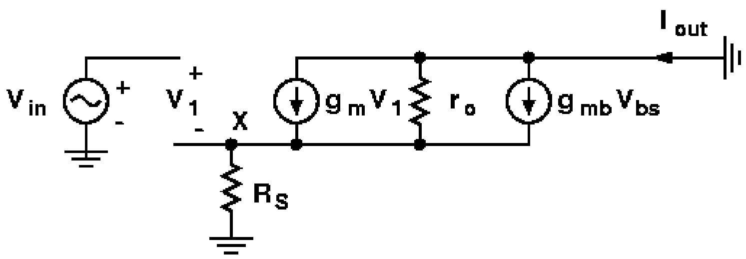
$$\frac{V_{out}}{V_{in}} = -\frac{g_m r_O R_D}{R_D + R_S + r_O + (g_m + g_{mb})R_S r_O}$$

$$= -\frac{g_m r_O}{R_S + r_O + (g_m + g_{mb})R_S r_O} \cdot \frac{R_D\left[R_S + r_O + (g_m + g_{mb})R_S r_O\right]}{R_D + R_S + r_O + (g_m + g_{mb})R_S r_O}$$

$$= -G_{meff} R_O = -G_{meff}\{R_D \,||\, \left[R_S + r_O + (g_m + g_{mb})R_S r_O\right]\}$$

8.

(a)



(b)

$$A_v = \frac{V_{out}}{V_{in}} = \frac{g_m R_S}{1 + (g_m + g_{mb})R_S}$$

(c)

$$R_{out} = \frac{1}{g_m + g_{mb}}$$

9.

(a)

$$|A_v| = \sqrt{\mu_n C_{ox}(W/L)I_{SS}}R_D = G_m R_D$$

$$= 100 \text{ V/V}$$

(b)

$$A_{v,CM} = \frac{V_{out}}{V_{in,CM}} = -\frac{R_D/2}{1/(2g_m) + R_{SS}}$$

$$\approx -0.5$$

(c)

$$\Delta V_{in} = \sqrt{2I_{SS}/(\mu_n C_{ox} W/L)}$$

$$= 283\text{mV}$$

(d)

$$V_{GS1} + (V_{GS3} - V_{TH3}) \le V_{in,CM} \le \min\left[V_{DD} - R_D\frac{I_{SS}}{2} + V_{TH}, V_{DD}\right]$$

➔ $0.9\text{V} < V_{in,CM} < 1.3\text{V}$

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(a)

$$A_{CM-DM} = -\frac{g_{m1} - g_{m2}}{(g_{m1} + g_{m2})R_{SS} + 1}R_D = \frac{-\Delta g_m R_D}{(g_{m1} + g_{m2})R_{SS} + 1}$$

$$= \frac{-1\text{m}\times 100\text{k}}{3\text{m}\times 100\text{k}+1} = -0.332225914\frac{\text{V}}{\text{V}}$$

(b)

$$\text{CMRR} = \frac{A_{v.DM}}{A_{v.CM-DM}} = \frac{100}{0.3322} = 301$$

11.

Minimum Vp:

$$V_{GS2} + V_{DS3} = V_{GS1} + V_{GS0} - V_{TH} = 0.7 + 0.7 - 0.5 = 0.9V$$

Optimum Vp:

$$V_{GS2} + V_{DS3} = V_{GS1} + V_{GS0} = 0.7 + 0.7 = 1.4V$$

12.

(a)

$V_{b,min} = V_{ov} + V_{GS,M2} = 2V_{ov} + V_{th,M2} = 2 \cdot 0.2 + 0.5 = 0.9\ V$

$V_{out} = 2V_{ov} = 2 \cdot 0.2 = 0.4\ V$

(b)

$$R_{out} = r_{o3} + r_{o4} + g_{m4} r_{o3} r_{o4} = 100k + 100k + 2m \cdot 100k \cdot 100k = 20.2\ M\Omega$$

13.

(a)

$$V_{in\_dc,min} = V_{DS,M5} + V_{GS,M1} = V_{ov} + V_{ov} + V_{th,M1} = 2 \cdot 0.2 + 0.5 = 0.9\ V$$

(b)

$V_{out,min} = V_{DS,M5} + V_{DS,M2} = V_{ov} + V_{ov} = 2 \cdot 0.2 = 0.4\ V$

$V_{out,max} = V_{DD} - V_{DS,M4} = V_{DD} - V_{ov} = 1.8 - 0.2 = 1.6\ V$

Maximum output swing: 0.4~1.6V=1.2V

(c)

$A_v = g_{m1}(r_{o2} \parallel r_{o4}) = 2m \cdot (100k \parallel 100k) = 100$

(d)

$$\mathrm{CMRR} = \frac{A_v}{A_{v\_CM}} = \frac{\frac{1}{2} g_m r_o}{1/2 g_m r_o} = {g_m}^2 {r_o}^2 = 2m^2 \cdot 100k^2 = 40000$$

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