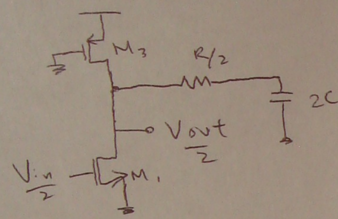
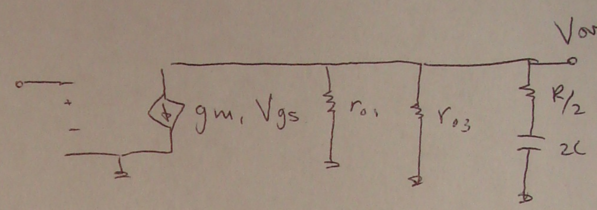
Year 2011 EECE 488 Assignment 3 Solution.

Q1.

i). Half circuit:

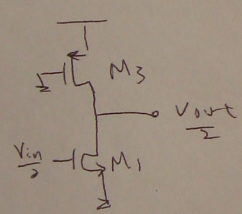




$$Av = -g_{m1}\left(r_{o1} \,||\, r_{o3} \,||\left(\frac{R}{2} + \frac{1}{s2C} \right) \right)$$

ii) Very low frequency means capacitor acts as open circuit.

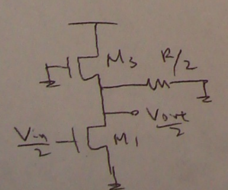
Half circuit:



$$Av = -g_{m1}\,(r_{o1} \,||\, r_{o3})$$

iii) Very high frequency means capacitor acts as short circuit.

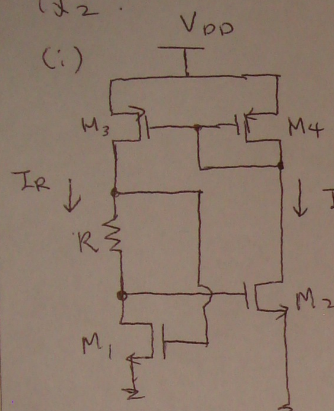
Half circuit



$$Av = -g_{m1}\left(r_{o1} \,||\, r_{o3} \,||\, \frac{R}{2} \right)$$

Q2.

(i)



$$\left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 \qquad \lambda = \gamma = 0.$$

All transistors in saturation..

$$I_{D3} = \frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)_3\left(|V_{gs3}| - |V_{thp}|\right)^2$$

$$I_{D4} = \frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)_4\left(|V_{gs4}| - |V_{thp}|\right)^2$$

$$|V_{gs3}| = |V_{gs4}|$$

$$\Rightarrow I_{D3} = I_{D4}.$$

$$\therefore I_R = I_{out} \qquad \therefore I_{D1} = I_{D2}$$

$$I_R = \frac{V_{gs1} - V_{gs2}}{R}$$

$$I_{D1} = I_{D2} = I_{out} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2\left(V_{gs2} - V_t\right)^2$$

$$\Rightarrow V_{gs2} = \sqrt{\frac{2 I_{out}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_2}} + V_t$$

$$V_{gs1} = \sqrt{\frac{2 I_{out}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_1}} + V_t$$

substitute

$$\Rightarrow R \cdot I_{out} = \sqrt{\frac{2 I_{out}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_1}} - \sqrt{\frac{2 I_{out}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_2}}$$

Assume $\left(\frac{W}{L}\right)_2 = K\left(\frac{W}{L}\right)_1$ where K is a constant.

$$= \sqrt{\frac{2 I_{out}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_1}}\left(1 - \frac{1}{\sqrt{K}}\right)$$

(ii) No change because I_{out} doesn't depend on V_{DD}.

$$I_{out} = \frac{2}{\mu_n C_{ox}\left(\frac{W}{L}\right)_1} \cdot \frac{1}{R^2} \cdot \left(1 - \frac{1}{\sqrt{K}}\right)^2$$

(iii) No change since no body effect, because bulks are connected to S.

Q3. Total power consumed $P = 3mW = I \cdot V_{DD}$. $V_{DD} = 3V$

$\Rightarrow I_{total} = \frac{3mW}{3V} = 1mA$. $V_t = 0.5V$

It's given that bias current for stage 1 and 2 are equal,

so $I_{D0} = 0.5mA$ and $I_{D6} = 0.5mA = I_{D5}$

Swing = 2.6V and allocate equal overdrive voltage to M5 & M6, means $V_{ov5} = V_{ov6} = 0.2V$. $\Rightarrow V_{bias1} - V_t = 0.2V$

$\Rightarrow \boxed{V_{bias1} = 0.7V.}$

$I_{D5} = 0.5mA = \frac{1}{2}\mu_p C_{ox} \frac{W_{p5}}{L}(V_{ov5})^2$ $\mu_p C_{ox} = 0.5 mA/V^2$

$L = 0.4\mu m$ $\Rightarrow \boxed{W_{p5} = 20\mu m}$ $\mu_n C_{ox} = 1mA/V^2$

$I_{D6} = \frac{1}{2}\mu_n C_{ox}\frac{W_{n5}}{L}(V_{ov6})^2 \Rightarrow \boxed{W_{n6}} = \frac{2I_{D6} \cdot L}{\mu_n C_{ox}(V_{ov6})^2} = 10\mu m$

Assume all transistors in stage 1 (differential amplifier) are perfectly matched, $\Rightarrow I_{D3} = I_{D4} = 0.25mA = I_{D1} = I_{D2}$

$$\boxed{W_{p3} = \frac{2I_{D3} \cdot L}{\mu_p C_{ox}(V_{ov3})^2} = 10\mu m = W_{p4}}$$

since $\underbrace{V_{sg3} = V_{sg5}}_{\uparrow \text{given.}} \Rightarrow V_{ov3} = V_{ov5} = 0.2V$

$$\boxed{W_{n0} = \frac{2I_{D0} \cdot L}{\mu_n C_{ox}(V_{ov0})^2} = 10\mu m}$$

$V_{ov0} = V_{ov6}$ because same V_{gs}.

Total gain $A_v = 1000$

$A_v \approx g_{m2}(r_{o2} \| r_{o4}) \cdot g_{m5}(r_{o5} \| r_{o6})$

$r_o = \frac{1}{\lambda I_D} \Rightarrow r_{o2} = 40k\Omega$

$r_{o4} = 40k\Omega$ $r_{o5} = 20k\Omega$

$r_{o6} = 20k\Omega$

$g_{m5} = \mu_p C_{ox}\frac{W_{p5}}{L}(V_{ov5}) = 5mS$

plug in A_v equation $\Rightarrow g_{m2} = 1mS$

$g_{m2} = \frac{2I_{D2}}{V_{gs2} - V_t}$ $V_{gs2} - V_t = V_{ov2} = \frac{2I_{D2}}{g_{m2}} = 0.5V$

$$\boxed{W_{n2} = W_{n1} = \frac{2I_{D2} \cdot L}{\mu_n C_{ox}(V_{gs2} - V_t)^2} = 0.8\mu m.}$$