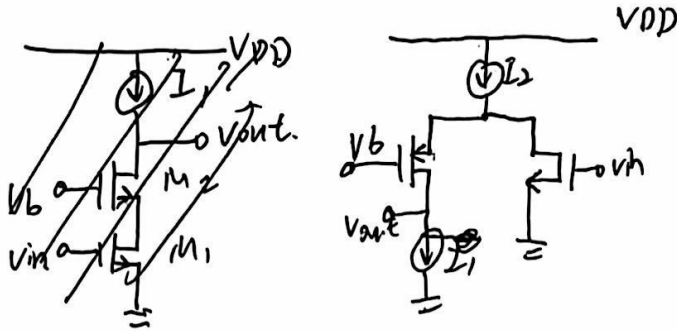


# Homework 8.

## Question 1.

(a).



(b) Cascode structure.

$$G_m = \frac{I_{out}}{V_{in}} = -g_{m1} \frac{r_{o1}}{r_{o1} + (r_{o2} \parallel \frac{1}{g_{m2} + g_{mb2}})}$$

$$R_{out} = r_{o1} + r_{o2} + (g_{m2} + g_{mb2}) r_{o1} r_{o2}$$

$$A_v = G_m R_{out} = -g_{m1} \frac{r_{o1} (r_{o1} + r_{o2} + (g_{m2} + g_{mb2}) r_{o1} r_{o2})}{r_{o1} + (r_{o2} \parallel \frac{1}{g_{m2} + g_{mb2}})} = -g_{m1} r_{o1} (1 + g_{m2} r_{o2} + g_{mb2} r_{o2})$$

2) Folded-cascode structure.

$$G_m = -g_{m1} \frac{r_{o1}}{r_{o1} \parallel r_{o2} \parallel \frac{1}{g_{m2} + g_{mb2}}}$$

$$R_{out} = r_{o1} + r_{o2} + (g_{m2} + g_{mb2}) r_{o1} r_{o2}$$

$$A_v = G_m R_{out} = -g_{m1} \frac{r_{o1} (r_{o1} + r_{o2} + (g_{m2} + g_{mb2}) r_{o1} r_{o2})}{r_{o1} + (r_{o2} \parallel \frac{1}{g_{m2} + g_{mb2}})} = -g_{m1} r_{o1} (1 + g_{m2} r_{o2} + g_{mb2} r_{o2})$$

## Question 2.

(a)  $I_C = \frac{(W/L)}{(W/L)_C} \cdot I_{ref} = I_{ref}$

since for the DC current,  $V_{in} = V_{out}$ ,

$$I_A = I_B = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} \cdot (\frac{V_{in}}{2} - V_{TH} - V_S)^2 \cdot (V_{DD} - V_{TH} - V_B)^2$$

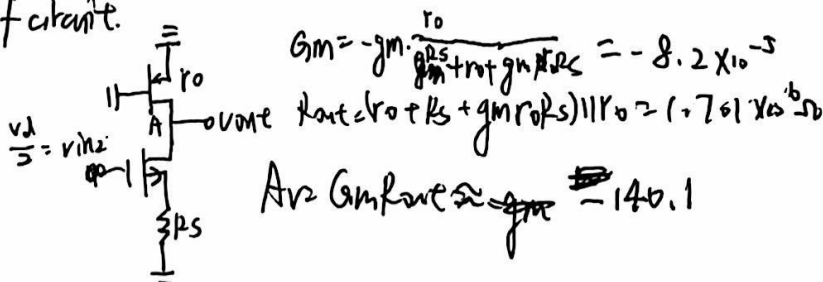
$$\Rightarrow V_A = V_B$$

$$\frac{1}{2} \mu_{p0} C_{ox} \frac{W}{L} (V_S - V_A - V_{TH})^2 = 5 \mu A$$

$$\text{so } V_A = V_B = 3.98V$$

(b)  $r_o = \frac{1}{I_D} = 2 \times 10^{-6} \Omega$  ( $I_D = \frac{I_{ref}}{2} = 5 \mu A = 5 \times 10^{-6} A$ )

Half circuit.



$$G_m = -g_{m1} \frac{r_{o1}}{r_{o1} + r_{o2} + (g_{m2} + g_{mb2}) r_{o1} r_{o2}} = -8.2 \times 10^{-5}$$

$$R_{out} = r_{o1} + r_{o2} + (g_{m2} + g_{mb2}) r_{o1} r_{o2} = 1.761 \times 10^{-6} \Omega$$

$$A_v = G_m R_{out} \approx -140.1$$



(C) for common mode  $G_m = \frac{2g_m}{2} \cdot \frac{r_o}{2} \cdot \left( \frac{1}{2} \parallel \frac{r_o}{2} \right)$

$R_{out} = \frac{r_o}{2} \parallel (2g_m \cdot \frac{r_o}{2}) \cdot \left( \frac{R_s}{2} + r_o \right) \parallel \frac{r_o}{2} = 1 \times 10^6 \Omega$

$\Rightarrow A_{cm} = -0.498$

$CMRR = 48.99 \text{ dB} \Rightarrow 49 \text{ dB}$

$= -4.98 \times 10^{-7}$

