1. (a) Source terminal is common to both input and output.

(b) $I_{DS} = \frac{K_n'}{2}(V_{GS}-V_T)^2 = 5(5-1)^2 = 80\,mA$

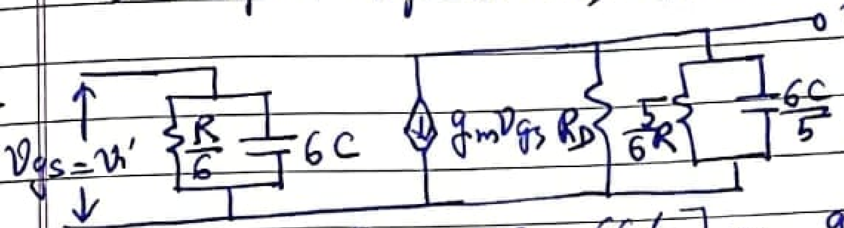
$V_{DS} = V_{DD} - I_{DS}R_D = 15 - 80\times0.125 = 5\,V$

$V_{DS} > V_{GS} - V_T$, Transistor in satn.

$g_m = K'(V_{GS}-V_T) = 10(5-1) = 40\,mS$.

$v_o = -g_m R_D v_i = -40\times0.125\times10^{-3}\angle\pi/3 = -5\times10^{-3}\angle\pi/3$

(c) Output impedance, $Z_o = R_D = 125\,\Omega$

2. 

$K = -5$ in Miller's theorem [From previous problem]

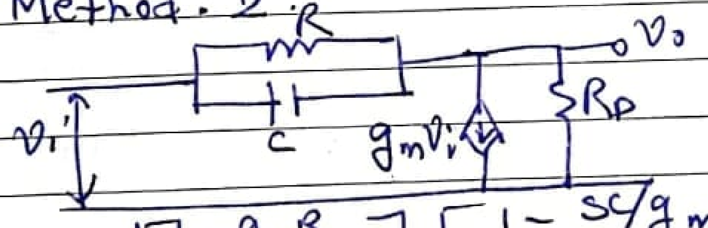
$$\frac{v_o}{v_i} = -g_m\left[R_D \| \frac{5R}{6} \| 6C/5\right] \simeq -g_m\left[R_D \| 6C/5\right] \quad \left[\because \frac{5R}{6} \gg R_D\right]$$

~~Corner~~ Corner 3dB frequency

$$\omega_o = \frac{1}{R_D\cdot 6C/5} = \frac{5}{6}\frac{1}{CR_D} = \frac{5}{6}\frac{\times10^9}{125} = 6.67\times10^6\ rad/s.$$

Actually, the gain can not come down to 28 dB. with the given parameters.

Method: 2



$$\frac{(v_o - v_i)(1+sCR)}{R} + g_m v_i + \frac{v_o}{R_D} = 0$$

$$v_o = \left[\frac{1-g_mR}{1+R/R_D}\right]\left[\frac{1-sC/g_m}{1+\frac{sRC}{1+R/R_D}}\right] \simeq -g_mR_D\left[\frac{1-sC/g_m}{1+sCR_D}\right]$$

$g_m = 40\,mS$, $g_mR \gg 1$. Pole freq (3dB) $= \frac{1}{CR_D} = \frac{10^9}{125} = 8\times10^6\ rad/s$.

$R = 1\,M\Omega$,

$R_D = 125\,\Omega$, $R \gg R_D$.

Zero freq $= \frac{g_m}{C} = \frac{40\times10^{-3}}{10^{-9}} = 40\times10^6\ rad/s$.

The minimum gain = 0 dB.

Maximum gain = 14 dB.

The zero is near enough that the gain does not go to ~~0~~ $14 - 28 = -14\,dB$

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3. $|I_{DS}| = 5mA.\ g_m = \sqrt{2k'I_{DS}} = \sqrt{2\times10\times5} = 10ms$

$\mu = g_m r_o = g_m \frac{1}{\lambda I_{DS}} = \frac{10}{0.01\times5} = 200 \gg 1.$

$v_{o2} = \frac{\mu}{1+\mu} v_i \simeq v_i$

$v_{o1} = \frac{-\mu v_i r_o}{r_o + r_o + (1+\mu) r_o} \simeq -v_i$

$\frac{v_{o1} - v_{o2}}{v_i} \simeq -2$

4.(b) $v_o = \frac{(1+\mu)(iR_s) r_o}{r_o + r_o + (1+\mu) R_s}, Z = \frac{v_o}{i} = \frac{(1+\mu) r_o R_s}{2r_o + (1+\mu) R_s}$

$\Rightarrow Z \simeq \frac{\mu r_o R_s}{2r_o + \mu R_s} = \frac{g_m r_o^2 R_s}{2r_o + g_m r_o R_s} = \frac{g_m r_o R_s}{2 + g_m R_s}.$

$g_m = 10ms$ $\qquad \simeq r_o$

$R_s = 1\,k\Omega$ $\qquad = \frac{1}{\lambda I_{DS}} = 20\,k\Omega$

$g_m R_s = 10 \gg 2$

~~(a). $I_{DS} = 5mA$. $\frac{k'}{2}(V_{GS}-V_T)^2 = 5 \Rightarrow V_{GS} = V_{GG2} = V_T + 1$~~ ~~$= 2V$~~

~~$V_{DS} = V_{GS} - V_T$ [For minimum V_{DD}]~~

~~$= 1.$~~

~~$V_{o2}(DC) = 1V.$~~

(a) $I_{DS} = 5mA$, $\frac{k'}{2}(V_{GS}-V_T)^2 = 5$, $V_{GS} - V_T = 1$

$\Rightarrow V_{GS} = 2V.$

$V_{DS} = V_{GS} - V_T$ [For minimum V_{DD}]

$= 1V.$

$V_D = V_{DS} + I_D R_S = 1 + 5\times1 = 6V. = 6V$

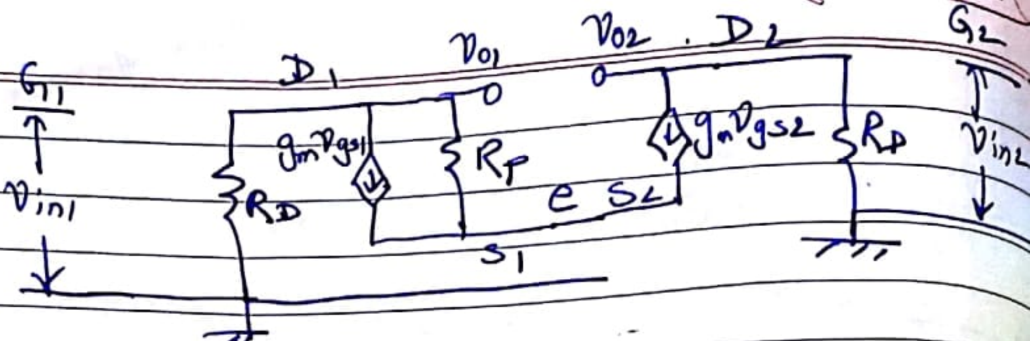
$V_{GG2} = V_{GS} + I_D R_S = 2 + 5 = 7V.$

By similar analysis for top pMOS, $V_{DS} = -1$,

$V_{DD} = V_S = V_D + 1 = 6 + 1 = 7V$

and $V_{GG1} = 5V$

5.



$$\frac{v_{o1}}{R_D} + g_m v_{gs1} + \frac{v_{o1} - e}{R_P} = 0$$

$$\frac{v_{o2}}{R_D} + g_m v_{gs2} = 0$$

$$\frac{v_{o1} - e}{R_P} + g_m v_{gs1} + g_m v_{gs2} = 0 \quad \left| \begin{array}{l} v_{gs1} = v_{i1} - e \\ v_{gs2} = v_{i2} - e. \end{array} \right.$$

$$\Rightarrow e = \frac{v_{o1} + g_m R_P (v_{i1} + v_{i2})}{1 + 2 g_m R_P}$$

$$= \frac{v_{o1}}{1 + 2g_m R_P} + \frac{v_{i1} + v_{i2}}{2}. \quad [g_m R_P >> 1].$$

$$= \frac{v_{o1}}{1 + 2g_m R_P} + v_{cm}. \quad \left[\begin{array}{l} v_{i1} - v_{i2} = v_{dm}. \\ \frac{v_{i1} + v_{i2}}{2} = v_{cm} \end{array} \right]$$

$$v_{gs1} = v_{i1} - e$$

$$= v_{i1} - \frac{v_{o1} + g_m R_P (v_{i1} + v_{i2})}{1 + 2 g_m R_P}.$$

$$= \frac{v_{i1}(1 + g_m R_P) - g_m R_P v_{i2} - v_{o1}}{1 + 2 g_m R_P}$$

$$\simeq \frac{v_{i1}}{2} - \frac{v_{i2}}{2} - \frac{v_{o1}}{1 + 2 g_m R_P} \simeq \frac{v_d}{2} - \frac{v_{o1}}{2 g_m R_P}.$$

$$v_{gs2} \simeq -\frac{v_d}{2} - \frac{v_{o1}}{2 g_m R_P}.$$

$$v_{o2} = -g_m R_D v_{gs2}$$

$$\Rightarrow v_{o1} \frac{R_D}{2R_P} - v_{o2} = -g_m R_D v_d/2$$

$$v_{o2} = -g_m R_D\left[a v_{i2} - b v_{i1} - \frac{v_{o1}}{1+2g_m R_P}\right]$$

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$$a+b=1 \qquad a = \frac{1+g_m R_P}{1+2g_m R_P}$$

$$a-b = \frac{1}{1+2g_m R_P} \qquad b = \frac{g_m R_P}{1+2g_m R_P}$$

$$v_{o2}\left[1+\frac{g_m R_P}{1+2g_m R_P}\right] = -g_m R_D\left[-b v_{i1} + a v_{i2}\right].$$

$$v_{o1} = -v_{o2}.$$

$$\frac{v_{o1}-v_{o2}}{\cancel{v_D}} = -2v_{o2}.$$

$$= +\frac{2g_m R_D}{1+\frac{g_m R_D}{1+2g_m R_P}}\left[-b v_{i1} + a v_{i2}\right]$$

$$= \alpha\cdot\left[-b\left(\frac{v_d}{2}+v_{cm}\right)+a\left(-\frac{v_d}{2}+v_{cm}\right)\right]$$

$$= \alpha\left[-\frac{v_d}{2}(b+a)+v_{cm}\cdot(a-b)\right]$$

$$= -\frac{\alpha}{2}v_d(a+b)+\alpha(a-b)v_{cm}.$$

$$A_{DM} = -\alpha/_2\,(a+b) = -\frac{\alpha}{2} = -\frac{g_m R_D}{1+\frac{g_m R_D}{1+2g_m R_P}}$$

$$A_{CM-DM} = \alpha(a-b) = \frac{2g_m R_D}{1+\frac{g_m R_D}{1+2g_m R_P}}\cdot\frac{1}{1+2g_m R_P}.$$

$$= \frac{2g_m R_D}{1+2g_m R_P+g_m R_D}$$

$$\simeq \frac{2R_D}{2R_P+R_D} = \frac{R_D/R_P}{1+R_D/2R_P}$$

$\cancel{2 R_D/R_P}$ $\cancel{2R_P+}$

$$|CMRR| = \frac{a-b}{a+b}\,\frac{1}{2}\left(\frac{a+b}{a-b}\right) = \frac{1}{2(1+2g_m R_P)}.$$