summary sheet

$$g_m = \sqrt{2k'\frac{W}{L} I_{DS}}$$

$$V_{DSAT} = \left(\frac{2 I_{DS}}{k'\frac{W}{L}}\right)^{\frac{1}{2}}$$

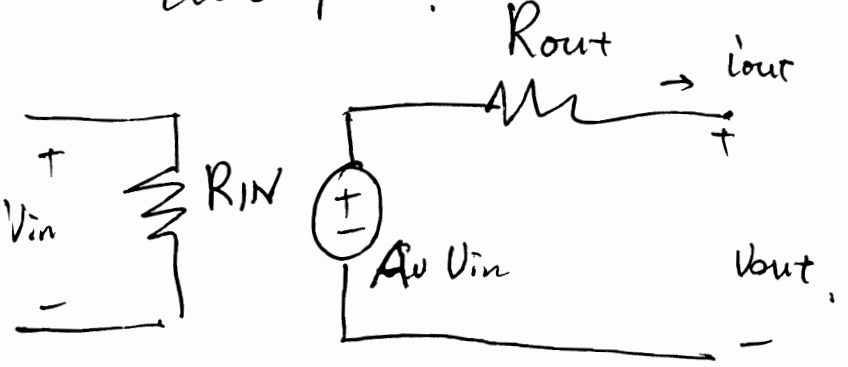
$$r_o = \frac{1}{\lambda I_{DS}}$$

$$\chi = \frac{\gamma}{\sqrt{2(2\phi_f + V_{SB})}}$$

$$g_{mb} = \chi g_m$$

$$V_T = V_{T0} + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$$

Summary sheet (small signal) two port.



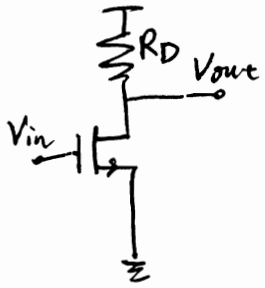
$$R_{in} = \left.\frac{V_{in}}{i_{in}}\right|_{i_{out}=0} \quad \text{(open at output)}$$

$$R_{out} = \left.\frac{V_{out}}{(-i_{out})}\right|_{V_{in}=0} \quad \text{(short at input)}$$

$$G_m = \left.\frac{i_{out}}{V_{in}}\right|_{V_{out}=0} \quad \text{(short at output)}$$

$$A_V = G_m R_{out}$$

Summary Sheet (small signal)



CS config.

$G_m = -g_m$

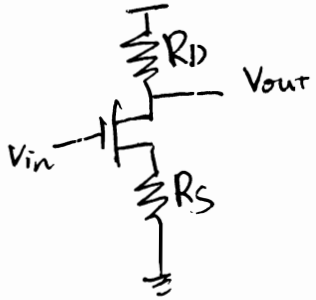
$R_{out} = R_D // r_o$

$R_{IN} = \infty$

$A_V = R_m R_{out} = -g_m(R_D // r_o)$

High gain: $A_V = 100 \sim 1000$

Moderate R_{out}: 10s of KΩ or KΩ



CS config with source degeneration.

$$R_{out} = \{R_S + r_o[1+g_m(1+\chi)R_S]\} // R_D$$
$$\doteq g_m(1+\chi) r_o R_S // R_D$$

$$R_{out}' = g_m(1+\chi) r_o R_S$$

χ small: $R_{out}' = g_m r_o R_S$

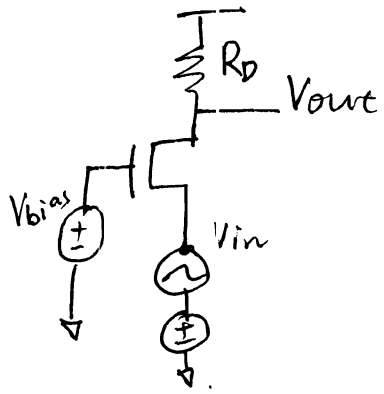
$R_{IN} = \infty$

$$G_m = \frac{-g_m}{1+g_m(1+\chi)R_S} \doteq \frac{-g_m}{1+g_m R_S}$$

(if body effect small)

$$A_V = G_m R_{out} \doteq -\frac{R_D}{R_S}$$

CG config.



DC analysis the same as CS.

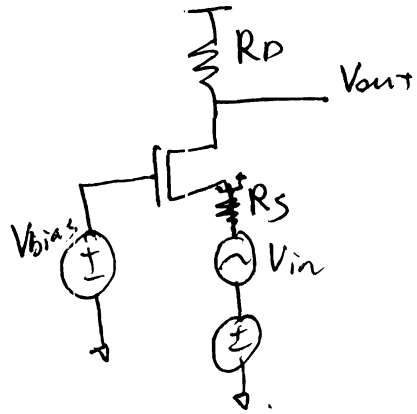
$$R_{out} = r_o \,//\, R_D$$

$$R_{in} \doteq \begin{cases} \frac{1}{g_m} & R_D < r_o \\ \frac{2}{g_m} & R_D = r_o \\ \frac{R_D + r_o}{(1+\chi) g_m r_o + 1} & R_D > r_o \end{cases}$$

$$G_m = g_m (1+\chi)$$

$$A_v = g_m (1+\chi)(r_o \,//\, R_D)$$

CG with R_S



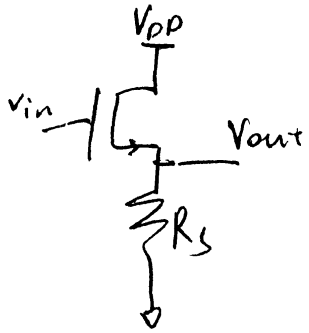
$$R_{out} \doteq g_m r_o (1+\chi) R_S \,//\, R_D$$

$$G_m = \frac{(1+\chi) g_m}{1 + (1+\chi) g_m R_S}$$

$$R_{in} = R_S + \begin{cases} \frac{1}{g_m} & R_D < r_o \\ \frac{2}{g_m} & R_D = r_o \\ \frac{R_D + r_o}{(1+\chi) g_m r_o + 1} & R_D > r_o \end{cases}$$

$$A_v = G_m R_{out}$$

CD (source follower)



$$R_{out} = \frac{1}{(1+X)g_m} \,//\, R_S \quad \rightarrow \text{low } 10\sim 1K\Omega$$

$$R_{IN} = \infty$$

$$G_m = \text{very long}.$$

$$A_V = \frac{g_m R_S}{(1+X)g_m R_S + 1} \approx 1 \quad \text{unit gain}.$$

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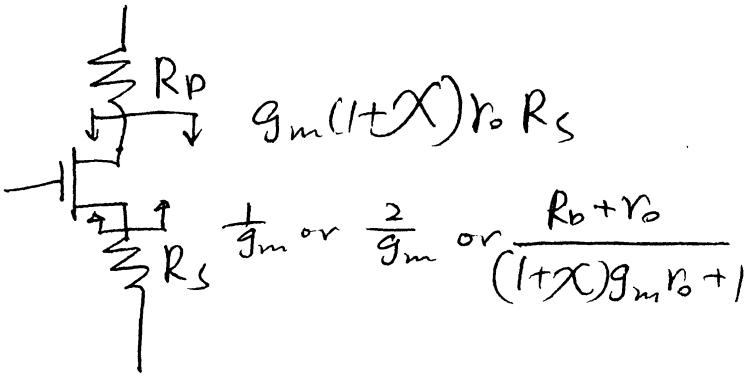
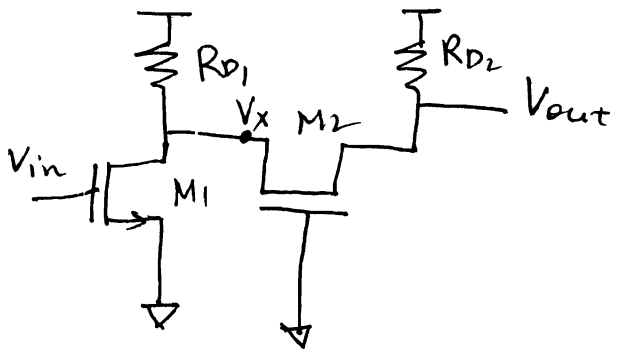
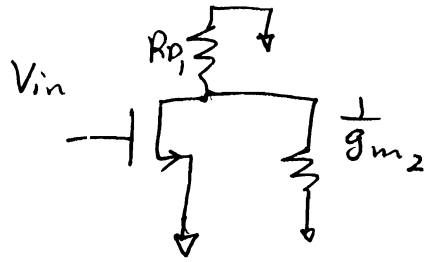
resistor equivalent.



Problem 1.



$\Rightarrow$



$$\frac{V_x}{V_{in}} = A_{V1} = -g_{m1}\left(\frac{1}{g_{m2}} // R_{D1} // r_{o1}\right)$$

$$R_{D1}, r_{o1} >> \frac{1}{g_{m2}}$$

$$\Rightarrow A_{V1} = -g_{m1}\cdot\frac{1}{g_{m2}}$$

if $g_{m1} = g_{m2}$ $\quad A_{V1} = -1$

$A_{V2} = ?$

$$A_{V2} = g_{m2}(1+\chi)(r_{o2} // R_{D2})$$

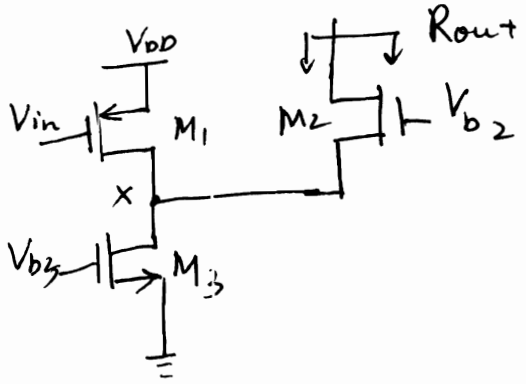
if $R_{D2} >> r_{o2}$ $\quad \chi \to 0$

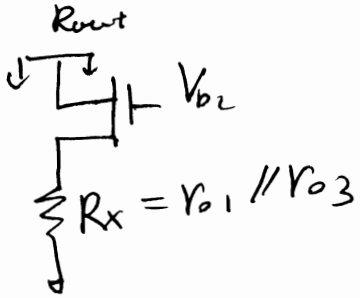
$$\Rightarrow A_{V2} = g_{m2} r_{o2}$$

$$\Rightarrow A_V = A_{V1}\cdot A_{V2} = -g_{m2} r_{o2}$$

if $R_{D2} << r_{o2}$, $\chi \to 0$ $\quad A_V = -g_{m2} R_{D2} = -g_m R_{D2}$

problem 2.

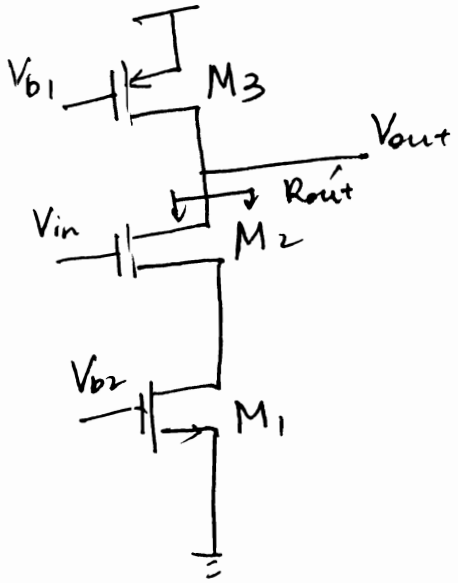




$$R_x = r_{o1} \,/\!/\, r_{o3}$$

$$R_{out} = g_{m2}(1+\chi)\, r_{o2}\, R_x$$

$$= g_{m2}(1+\chi)\, r_{o2}\,(r_{o1} \,/\!/\, r_{o3})$$



$$R_{out} = R_{out}' \,/\!/\, r_{o3}$$

$$R_{out}' = g_{m2}(1+\chi)\, r_{o2}\, r_{o1}$$