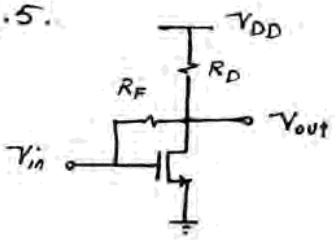
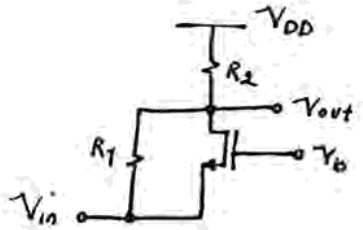
3.5.



(a)

$$\frac{V_o - V_{in}}{R_F} + g_{m1} V_{in} + \frac{V_o}{r_{o1}} + \frac{V_o}{R_D} = 0$$

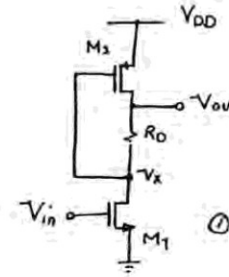
$$A_V = \frac{V_o}{V_{in}} = -\frac{g_{m1} - 1/R_F}{\frac{1}{R_F} + \frac{1}{r_{o1}} + \frac{1}{R_D}}$$



(b)

$$\frac{V_o}{R_2} + (V_o - V_{in})\left(\frac{1}{R_1} + \frac{1}{r_{o1}}\right) - g_{m1} V_{in} = 0$$

$$\frac{V_o}{V_{in}} = \frac{g_{m1} + \frac{1}{R_1} + \frac{1}{r_{o1}}}{\frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{r_{o1}}}$$



(d)

$$① \left(g_{m1}V_{in}+\frac{V_X}{r_{o1}}\right)R_D+V_X=V_{out}, \quad ② -\left(g_{m2}V_X+\frac{V_{out}}{r_{o2}}\right)=g_{m1}V_{in}+\frac{V_X}{r_{o1}},$$

$$② \rightarrow V_X\left(-g_{m2}-\frac{1}{r_{o1}}\right)=g_{m1}V_{in}+\frac{V_{out}}{r_{o2}} \quad ② \rightarrow V_X=-\frac{g_{m1}\cdot V_{in}+V_{out}/r_{o2}}{g_{m2}+\frac{1}{r_{o1}}} \quad ③$$

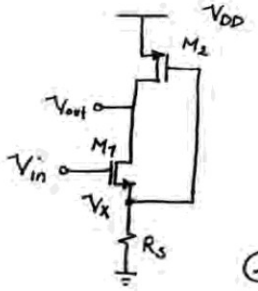
$$① \rightarrow g_{m1}R_D V_{in}+\left(1+\frac{R_D}{r_{o1}}\right)V_X=V_o \quad ④$$

$$③, ④ \rightarrow g_m R_D V_{in}-\frac{\left(1+\frac{R_D}{r_{o1}}\right)\left(g_{m1}V_{in}+\frac{V_{out}}{r_{o2}}\right)}{g_{m2}+\frac{1}{r_{o1}}}=V_{out}$$

$$\left[g_{m1}\cdot R_D-\frac{g_{m1}\left(1+R_D/r_{o1}\right)}{g_{m2}+\frac{1}{r_{o1}}}\right]V_{in}=\left[1+\frac{\frac{1}{r_{o2}}\left(1+R_D/r_{o1}\right)}{g_{m2}+\frac{1}{r_{o1}}}\right]V_{out}$$

$$\left[g_{m1}\cdot R_D\left(g_{m2}+\frac{1}{r_{o1}}\right)-g_{m1}\left(1+\frac{R_D}{r_{o1}}\right)\right]V_{in}=\left[g_{m2}+\frac{1}{r_{o1}}+\frac{1}{r_{o2}}\left(1+\frac{R_D}{r_{o1}}\right)\right]V_{out}$$

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



(e)

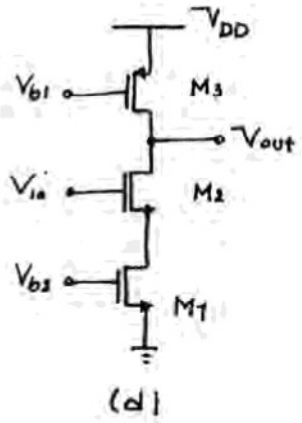
$$-\Big(\underbrace{\frac{V_{out}}{r_{o2}}+g_{m2}V_X}_{①}\Big)=\underbrace{\frac{V_{out}-V_X}{r_{o1}}+g_{m1}\left(V_{in}-V_X\right)}_{②}=\underbrace{\frac{V_X}{R_S}}_{③}$$

$$①, ③ \rightarrow V_X=-\frac{V_{out}}{r_{o2}\left(g_{m2}+\frac{1}{R_S}\right)}$$

$$②, ③ \quad \frac{V_{out}}{r_{o1}}+g_{m1}V_{in}=-\frac{V_{out}}{r_{o2}\left(g_{m2}+\frac{1}{R_S}\right)}\left(\frac{1}{R_S}+g_{m1}+\frac{1}{r_{o1}}\right)$$

$$\frac{V_{out}}{r_{o1}}\cdot r_{o2}\left(g_{m2}+\frac{1}{R_S}\right)+g_{m1}\cdot V_{in}\cdot r_{o2}\left(g_{m2}+\frac{1}{R_S}\right)=-V_{out}\left(\frac{1}{R_S}+g_{m1}+\frac{1}{r_{o1}}\right)$$

$$\frac{V_{out}}{V_{in}}=-\frac{g_{m1}\left(g_{m2}+1/R_S\right)r_{o2}}{g_{m1}+\frac{1}{R_S}+\frac{1}{r_{o1}}\left[1+r_{o2}\left(g_{m2}+\frac{1}{R_S}\right)\right]}$$



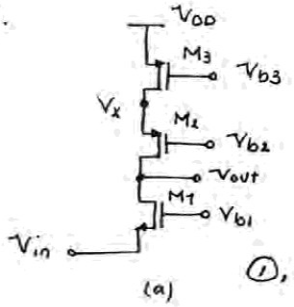
(d)

$$G_m = \frac{g_{m2} \cdot r_{o2}}{r_{o1} + \left[1 + g_{m2} \cdot r_{o1}\right] r_{o2}}$$

$$R_{out} = r_{o3} \,||\, \left[(1 + g_{m2} \cdot r_{o1}) \, r_{o2} + r_{o1} \right]$$

$$\frac{V_{out}}{V_{in}} = - \frac{g_{m2} \cdot r_{o2} \cdot r_{o3}}{r_{o3} + (1 + g_{m2} \cdot r_{o1}) \, r_{o2} + r_{o1}}$$

3.6.



(a)

$$-\frac{V_X}{r_{o3}} = g_{m2} V_X + \frac{V_X - V_{out}}{r_{o2}} = \frac{V_{out} - V_{in}}{r_{o1}} - g_{m1} V_{in}$$

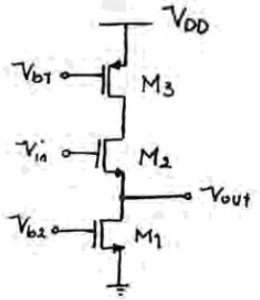
(1) (2) (3)

(1), (2) $\rightarrow$ $$V_X = \frac{V_{out}}{1 + r_{o2}\left(g_{m2} + \frac{1}{r_{o3}}\right)}$$

(1), (3) $\rightarrow$ $$\frac{V_{out} - V_{in}}{r_{o1}} - g_{m1} V_{in} = - \frac{V_{out}}{r_{o3} + r_{o2}(1 + g_{m2} \cdot r_{o3})}$$

$$V_{out}\left[\frac{1}{r_{o1}} + \frac{1}{r_{o3} + r_{o2}(1 + g_{m2} \cdot r_{o3})} \right] = \left(g_{m1} + \frac{1}{r_{o1}} \right) V_{in}$$

$$\frac{V_{out}}{V_{in}} = \frac{(1 + g_{m1} \cdot r_{o1}) \left[r_{o3} + r_{o2}(1 + g_{m2} \cdot r_{o3}) \right]}{r_{o1} + r_{o3} + r_{o2}(1 + g_{m2} r_{o3})}$$

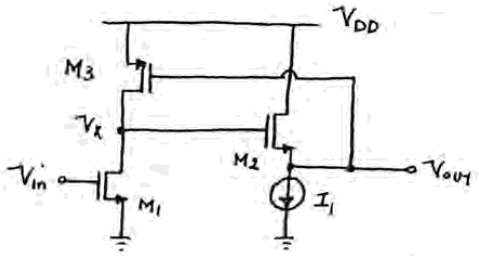


(e)

resistance seen looking up at the source of M_2

$$R_{in} = \frac{r_{o3} + r_{o2}}{1 + g_{m2} \cdot r_{o2}}$$

$$\frac{V_{out}}{V_{in}} = \frac{r_{o1}}{r_{o1} + \dfrac{r_{o3} + r_{o1}}{1 + g_{m2} r_{o2}}} = \frac{r_{o1}(1 + g_{m2} \cdot r_{o2})}{r_{o1}(1 + g_{m2} \cdot r_{o2}) + r_{o2} + r_{o3}}$$



(h)

$$-\left(\frac{V_X}{r_{o3}} + g_{m3} V_{out}\right) = g_{m1} V_{in} + \frac{V_X}{r_{o1}} \quad (1), (2)$$

$$-\frac{V_{out}}{r_{o2}} + g_{m2}(V_X - V_{out}) = 0 \quad @ \text{ output node} \quad (3)$$

$$(3) \rightarrow V_X = \frac{\frac{1}{r_{o2}} + g_{m2}}{g_{m2}} \cdot V_{out} = \frac{1 + g_{m2} r_{o2}}{g_{m2} r_{o2}} V_{out}$$

$$(1), (2) \rightarrow -\left[\left(\frac{1}{r_{o3}} + \frac{1}{r_{o1}}\right)\frac{1 + g_{m2} \cdot r_{o2}}{g_{m2} \cdot r_{o2}} + g_{m3}\right] V_{out} = g_{m1} \cdot V_{in}$$

$$\frac{V_{out}}{V_{in}} = -\frac{g_{m1} \cdot g_{m2} r_{o1} r_{o2} r_{o3}}{(r_{o1} + r_{o3})(1 + g_{m2} \cdot r_{o2}) + g_{m2} g_{m3} r_{o1} r_{o2} r_{o3}}$$