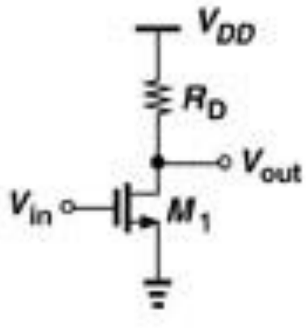
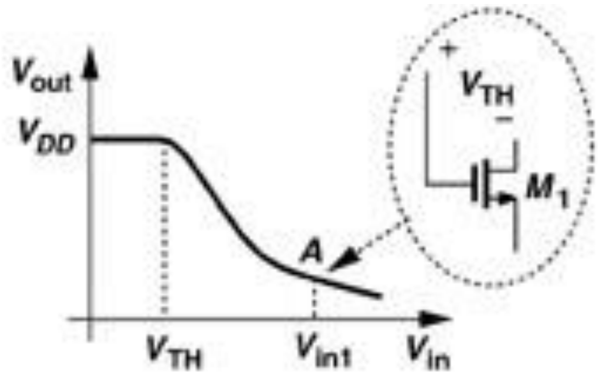
Lecture 2
IL2218 Analog electronics, advanced course

- Chapter 3 Single stage amplifiers
- CS-stage
  - different loadings
  - source degeneration
- CD-stage, source follower
- CG-stage
- Example 3.20a

CS-stage, common source



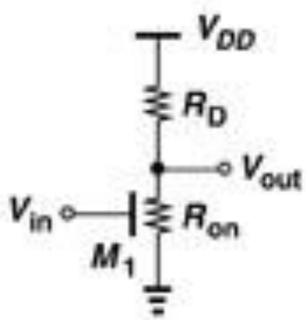
(a)



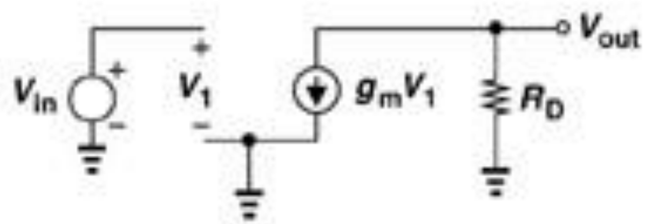
(b)

Saturation if

$$V_{DS} > V_{GS} - V_{TH}$$



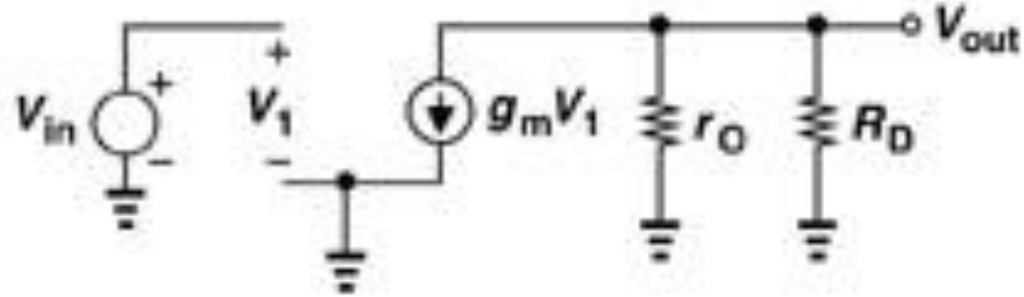
(c)

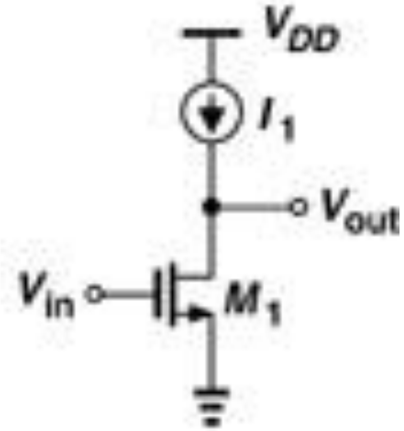


(d)

$$A_v = -g_m R_D$$

CS - Intrinsic gain



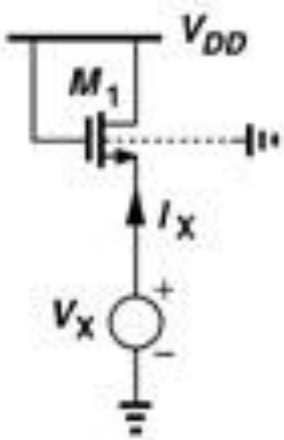


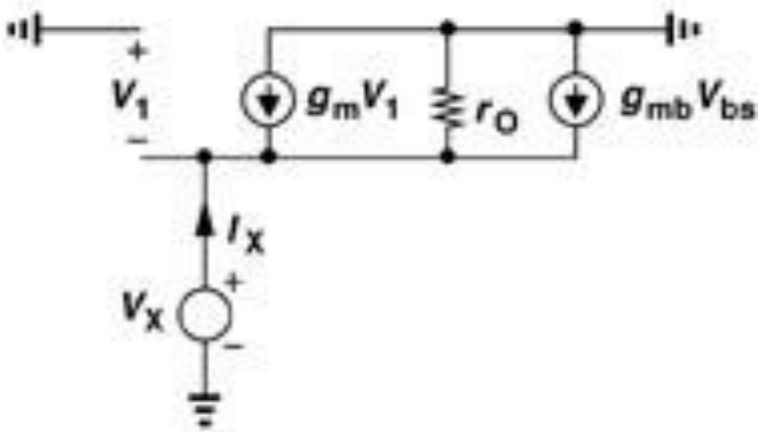
$$A_v = -g_m \left(r_o \,//\, R_D \right)$$

$$A_v = -g_m r_o$$

Intrinsic gain, max gain from one transistor

CS – diode connected load

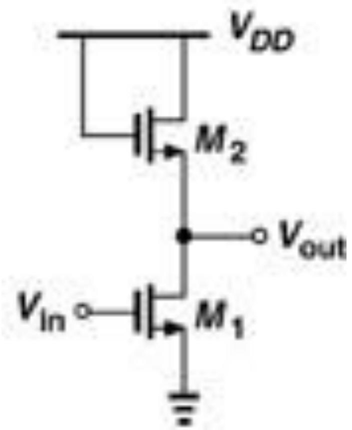




$$(g_m + g_{mb})V_x + \frac{V_x}{r_o} = I_x$$

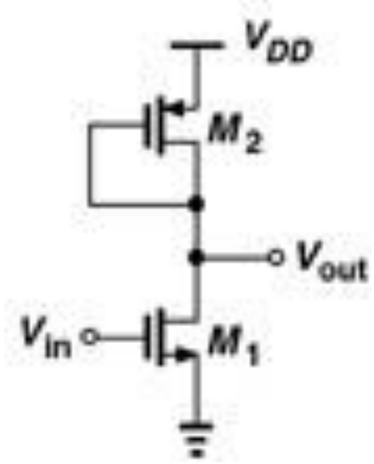
$$\frac{V_x}{I_x} = \frac{1}{g_m + g_{mb}} // r_o \approx \frac{1}{g_m + g_{mb}}$$

CS – diode connected load



$$A_v = -g_{m1}\frac{1}{g_{m2}+g_{mb2}} = -\frac{g_{m1}}{g_{m2}}\frac{1}{1+\eta}$$

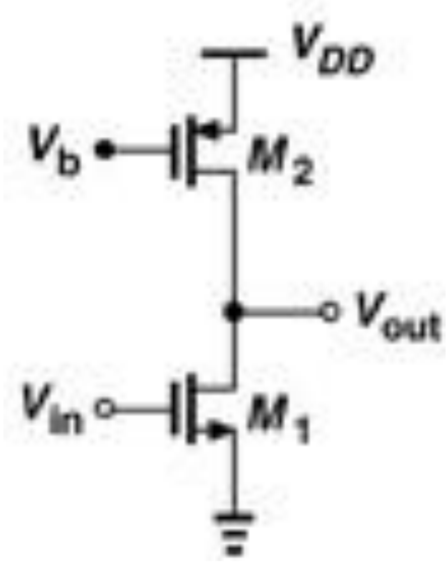
$$A_v = -\sqrt{\frac{(W/L)_1}{(W/L)_2}}\frac{1}{1+\eta}$$



$$A_v = -\sqrt{\frac{\mu_n (W/L)_1}{\mu_p (W/L)_2}} = -\frac{|V_{GS2}-V_{TH2}|}{V_{GS1}-V_{TH1}}$$

Gain is independent of bias current!
High gain $\Rightarrow$ Wide load transistor, limited output swing

CS – current source load



$$A_v = -g_{m1}\left(r_{o1} // r_{o2}\right)$$

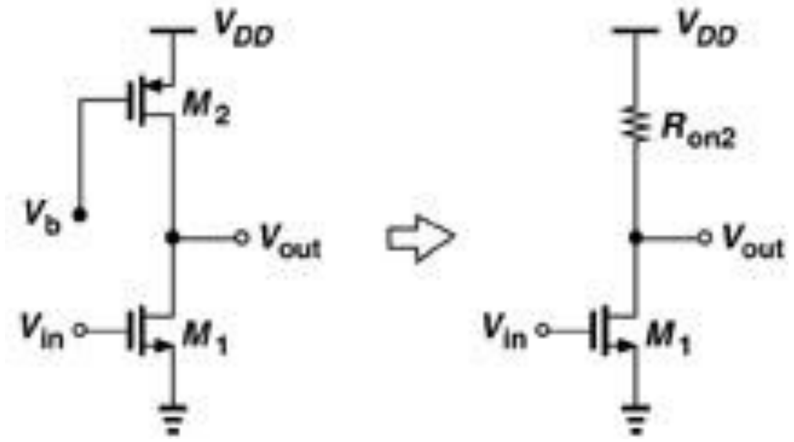
Assuming r_{o2} large, intrinsic gain

$$A_v = -g_{m1} r_{o1} = \sqrt{2\left(\frac{W}{L}\right)_1 \mu_n C_{ox} I_D} \cdot \frac{1}{\lambda I_D}$$

What happens with gain if

- L_1 increases?
- L_2 increases?
- I_D increases?

CS – triode load

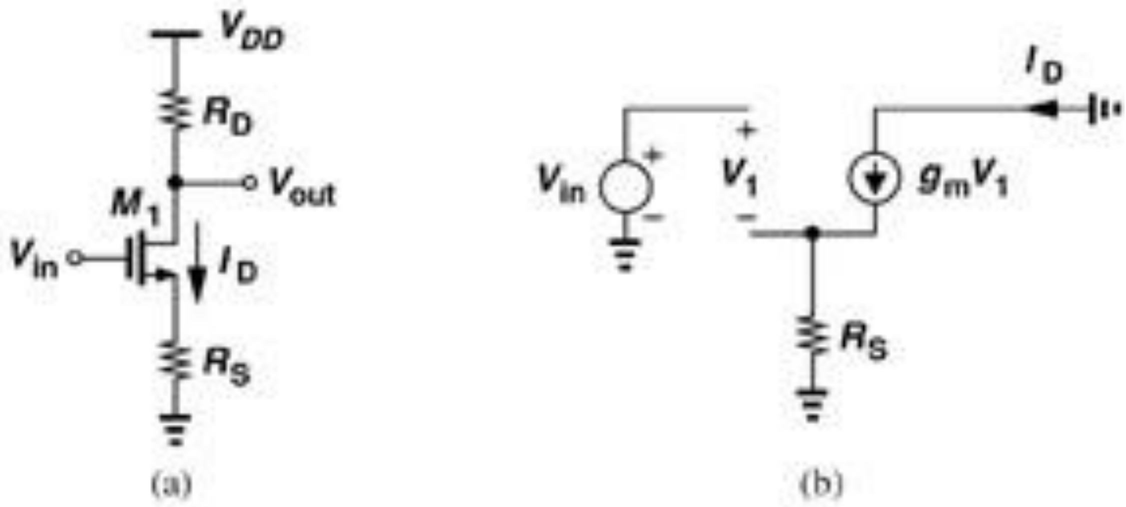


$$A_v = -g_m R_{ON2}$$

$$R_{ON2} = \frac{1}{\mu_n C_{ox} \left(\frac{W}{L}\right)_2 \left(V_{DD} - V_b - \left|V_{THP}\right|\right)}$$

Gain dependent on process parameters

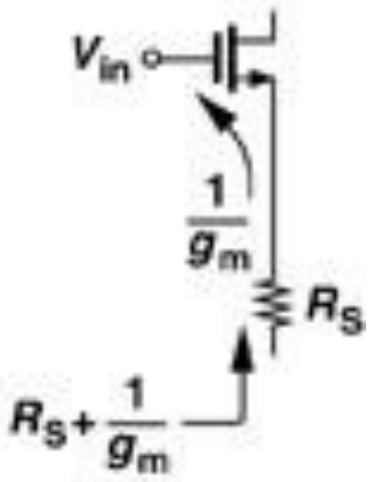
CS – source degeneration



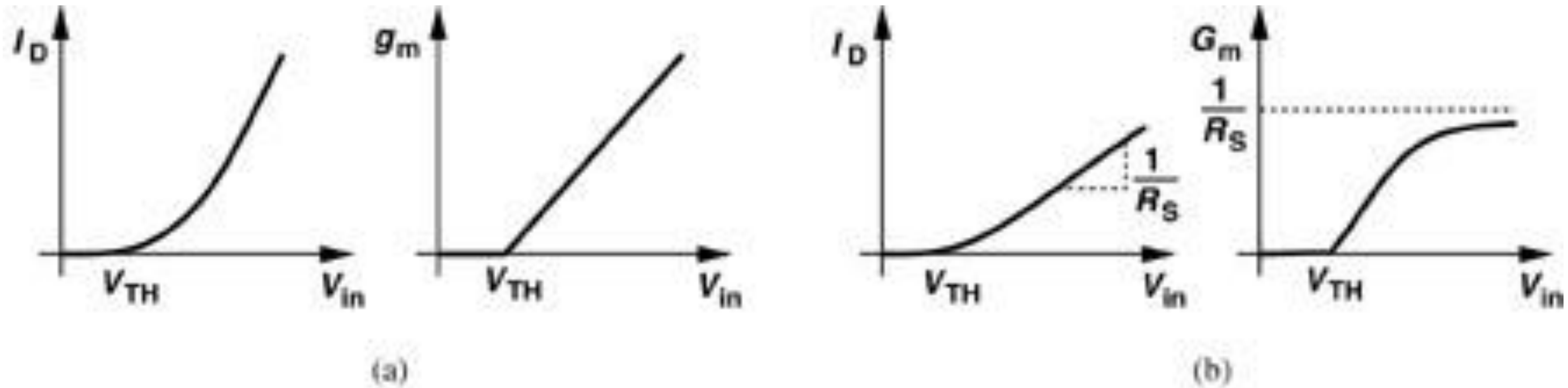
$$G_m = \frac{g_m}{1 + g_m R_S} \qquad A_v = -G_m R_D \qquad A_v = \frac{-g_m R_D}{1 + g_m R_S}$$

Feedback, increases linearity

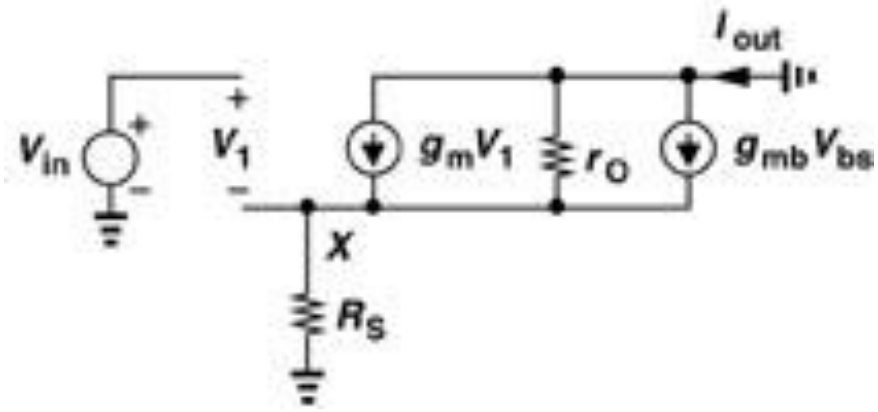
CS – source degeneration



$$A_v = \frac{-g_m R_D}{1 + g_m R_S} = -\frac{R_D}{1/g_m + R_S}$$



CS – source degeneration including output resistance and body effect



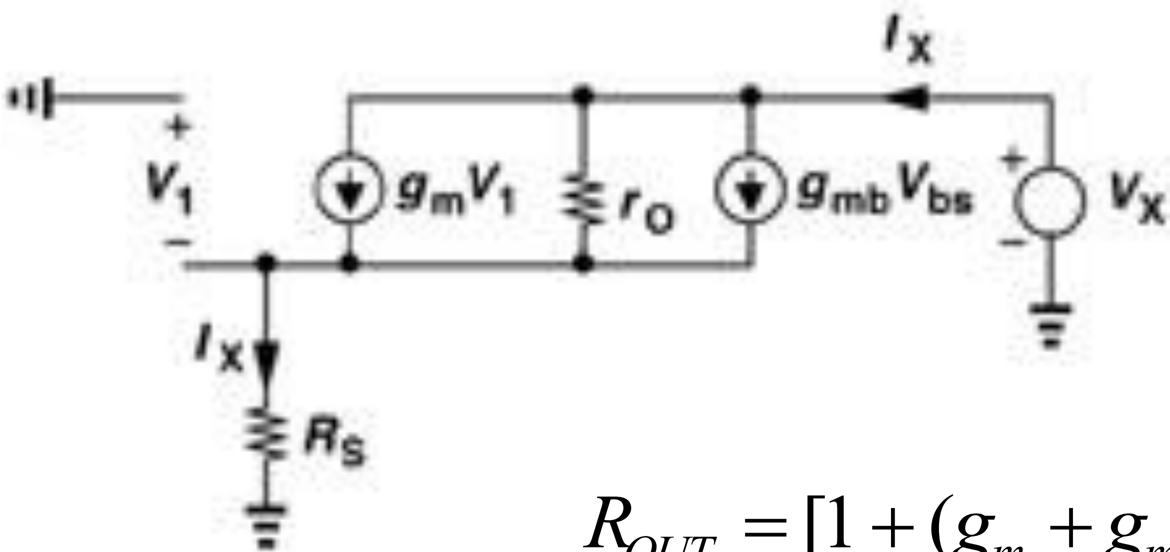
$$G_m = \frac{g_m r_o}{R_S + [1 + (g_m + g_{mb}) R_S] r_o}$$

$$G_m = \frac{g_m}{\frac{R_S}{r_o} + [1 + (g_m + g_{mb}) R_S]}$$

$$A_v = -G_m \left(R_D \,//\, R_{OUT} \right)$$

R_{OUT} ??

CS –output resistance

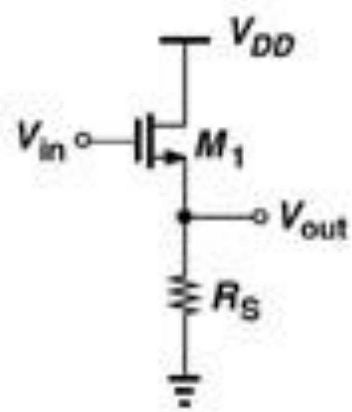


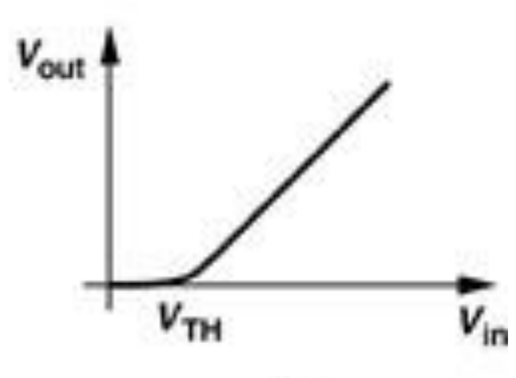
$$R_{OUT} = [1 + (g_m + g_{mb}) r_o] R_S + r_o$$

$$R_{OUT} = r_o' \approx r_o [1 + (g_m + g_{mb}) R_S]$$

$$A_v = -G_m (R_D \| r_o')$$

CD – source follower, common drain

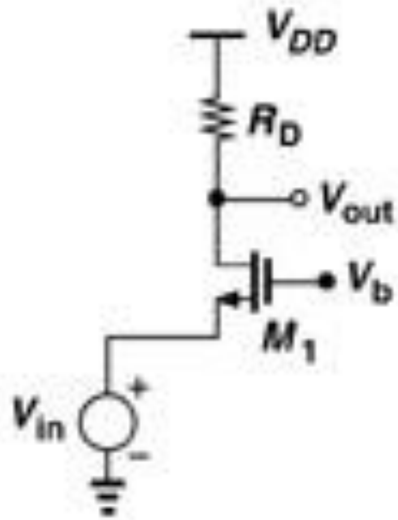




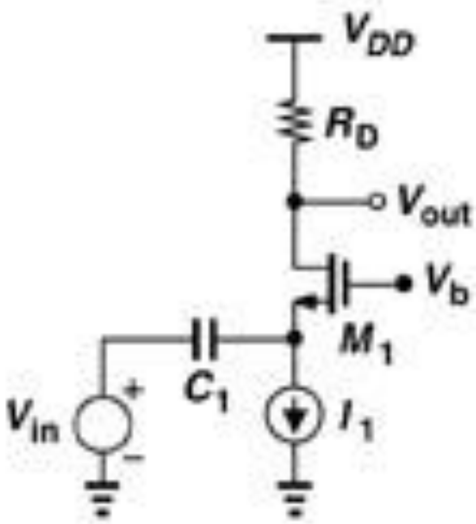
$$A_v = \frac{g_m R_S}{1 + (g_m + g_{mb}) R_S} = \frac{R_S}{1/g_m + (\frac{g_m + g_{mb}}{g_m}) R_S} \approx \frac{R_S}{1/g_m + R_S}$$

$$Rout = \frac{1}{g_m} // \frac{1}{g_{mb}} = \frac{1}{g_m + g_{mb}}$$

CG – common gate



(a)

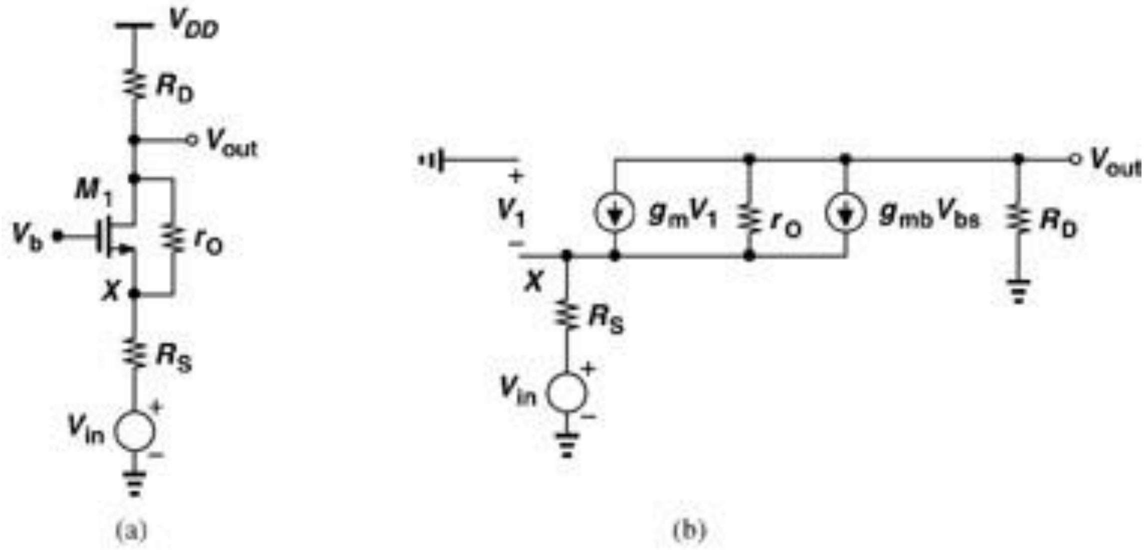


(b)

$$A_v = (g_m + g_{mb})R_D = g_m(1+\eta)R_D$$

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

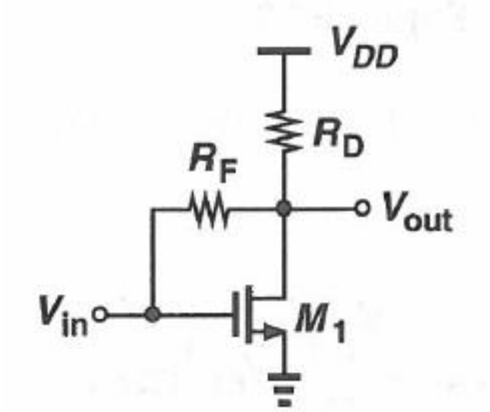
CG – common gate



$$A_v = \frac{(g_m + g_{mb})r_o + 1}{r_o + (g_m + g_{mb})r_o R_S + R_S + R_D} R_D$$

$$R_{in} = \frac{R_D + r_o}{1 + (g_m + g_{mb})r_o} \approx \frac{R_D}{(g_m + g_{mb})r_o} + \frac{1}{g_m + g_{mb}}$$

Problem 3.20 a



(a)

Assuming MOSFET is in saturation, calculate the small signal gain.

$$\lambda \neq 0, \quad \gamma = 0$$

Solution handed out is an example how to do the documentation from your simulations in labs.