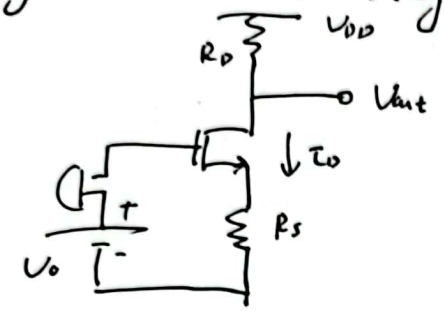
Degenerated CS Stage. ($\lambda = 0$)



Step I: Bias Conditions

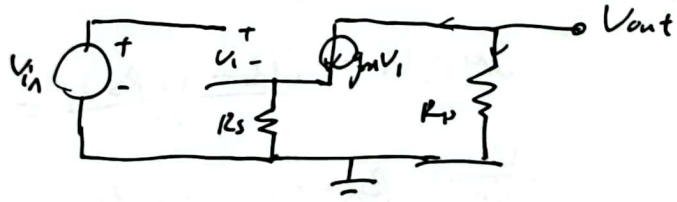
$$V_G = V_{GS} + I_D R_S$$

Sat. $\quad I_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{TH})^2$

Drain Voltage $= V_{DD} - I_D R_D$

For Sat. $\quad V_{DS} \geq V_{GS} - V_{TH}$

Step II: Gain, I/O Impedances ~~Input Resistance~~

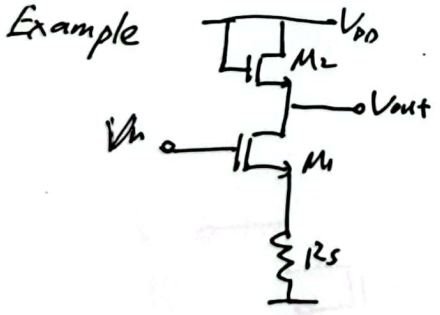


$$\begin{cases} g_m V_1 = -\dfrac{V_{out}}{R_D} \\ V_{in} = V_1 + g_m V_1 \cdot R_S. \end{cases}$$

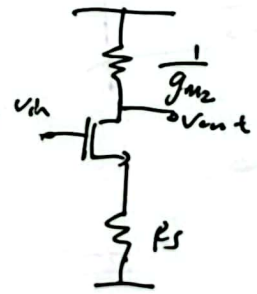
$$\Rightarrow \frac{V_{out}}{V_{in}} = -\frac{R_D}{\frac{1}{g_m} + R_S}$$

$$\therefore A_V = -\frac{\text{Resistance tied between Drain and AC Ground}}{\frac{1}{g_m} + \text{Resistance tied between Sauce and AC Ground}}$$

Example

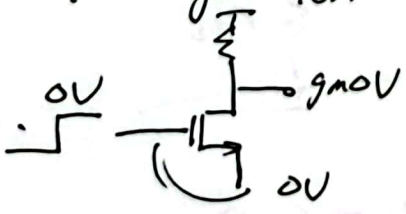


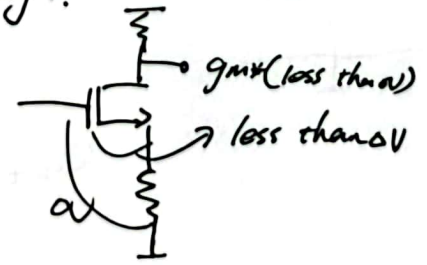
$\Rightarrow$



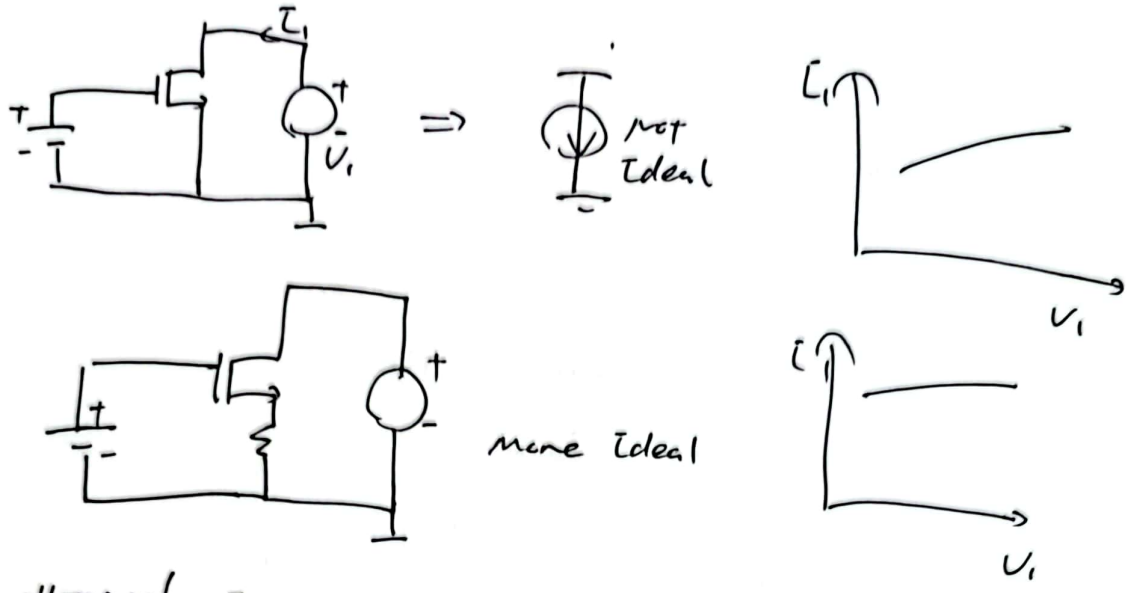
$$\therefore A_V = -\frac{\frac{1}{g_{m2}}}{\frac{1}{g_{m1}} + R_S}$$

Why is gain less with deg?.

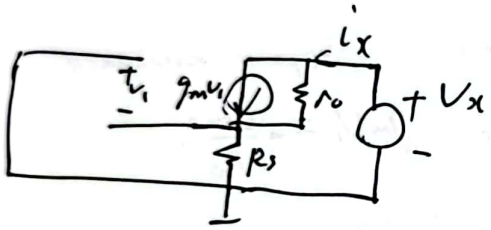




Let's build a current source.



Small-signal Imp:

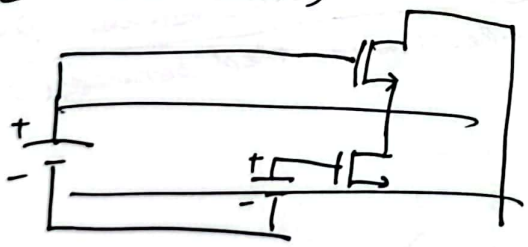


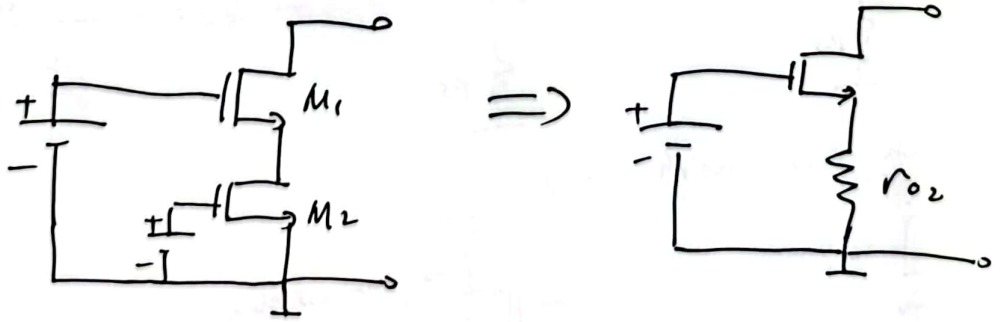
$$\begin{cases} i_x \cdot R_S = -V_1 \\ g_m \cdot V_1 + \dfrac{(V_x - i_x R_S)}{r_o} = i_x \end{cases}$$

$$\Rightarrow \frac{V_x}{i_x} = R_S + r_o + g_m R_S r_o$$

$$= (1 + g_m r_o) R_S + r_o$$

Example (cascode)





$$R_{out} = (1 + g_m r_{o1}) r_{o2} + r_{o1}$$