Common-Source Stage with Degeneration

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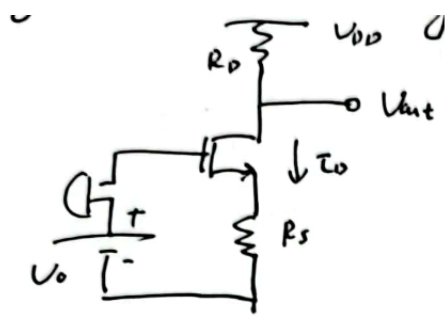
Degenerated CS Stage

We assume the $\lambda = 0$.

Step I: Bias Conditions



$$V_D = V_GS + I_DR_S$$

For saturation zone, $V_{DS} \geq V_{GS} - V_{TH}$.

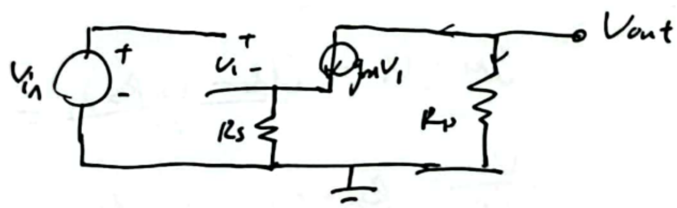
$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{TH})^2$$

Drain voltage=$V_{DD} - I_DR_D$

Step II: Gain, I/O Impedances

$$g_m v_1 = -\frac{v_{out}}{R_D}$$

$$v_{in} = V_1 + g_m v_1 * R_S$$

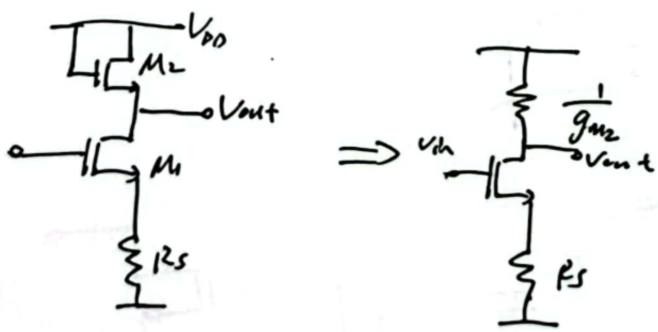


$$\implies \frac{v_{out}}{v_{in}} = -\frac{R_D}{\frac{1}{g_m} + R_s}$$

Therefore:

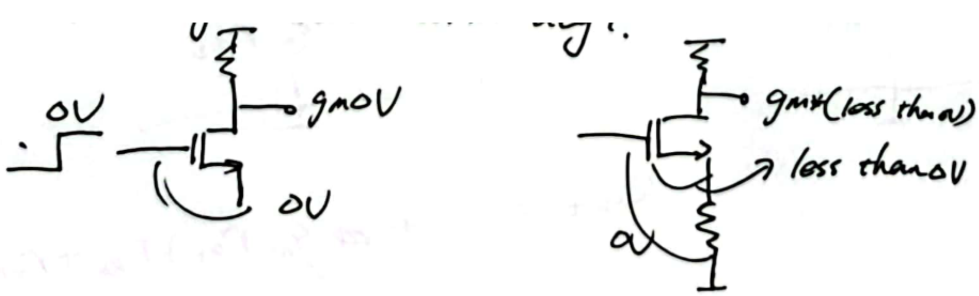
$$A_v = -\frac{Resistance\ tied\ between\ Drain\ and\ AC\ Ground}{\frac{1}{g_m} + Resistance\ tied\ between\ Source\ and\ AC\ Ground}$$

Example



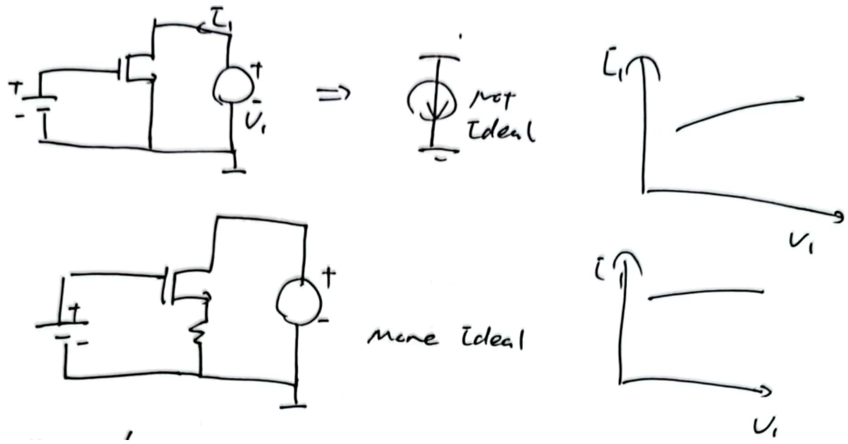
$$A_v = -\frac{\frac{1}{g_{m2}}}{\frac{1}{g_{m1}} + R_S}$$

So why is gain less with degenerated CS stage?



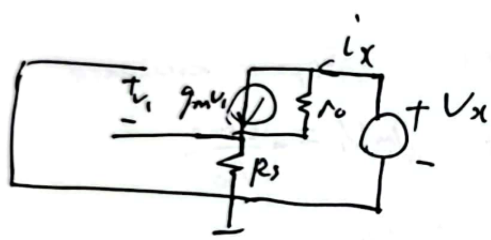
From the picture we can easily see the change of voltage between Gate and Source is less with deg. So the gain is less.

Let's build a current source



We draw the I/V relationship between Drain and Source, it's clear that the CS stage with degeneration is more smooth. Or we can call it more ideal, as a current source. That's the meaning of degeneration.

Small-Signal Imp



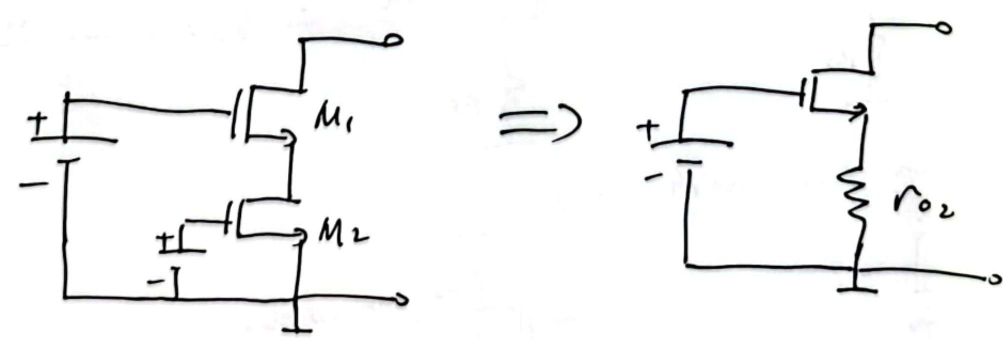
Calculate the output impedance.

$$i_x R_S = -v_1$$

$$g_m v_1 + \frac{v_x - i_x R_S}{r_o} = i_x$$

$$\implies \frac{v_x}{i_x} = R_S + r_o + g_m R_S r_o = (1 + g_m r_o) R_S + r_o$$

Example



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

This structure has a special name: Cascode. We will learn it after.

Link

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