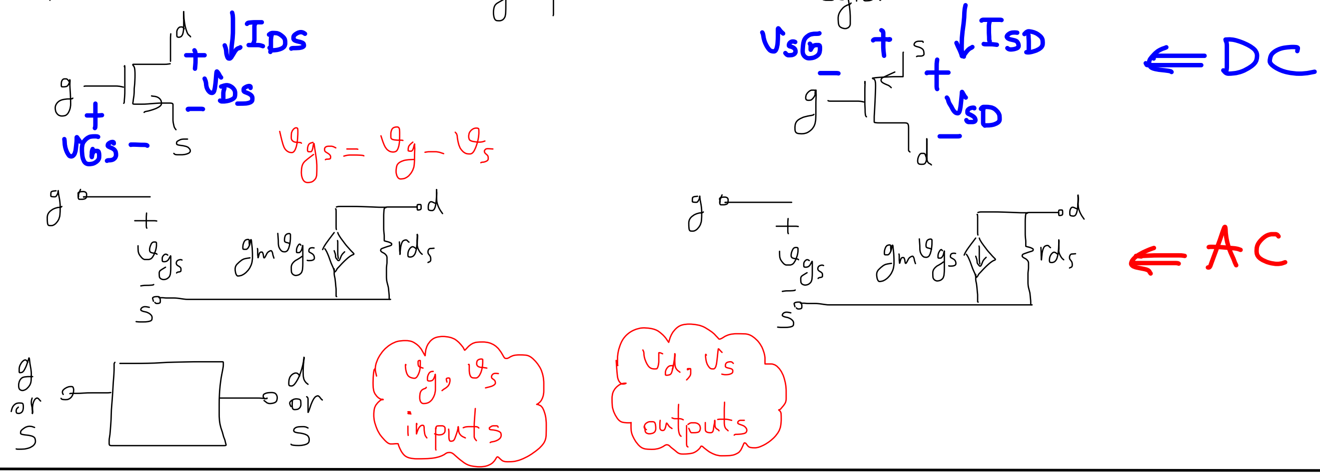
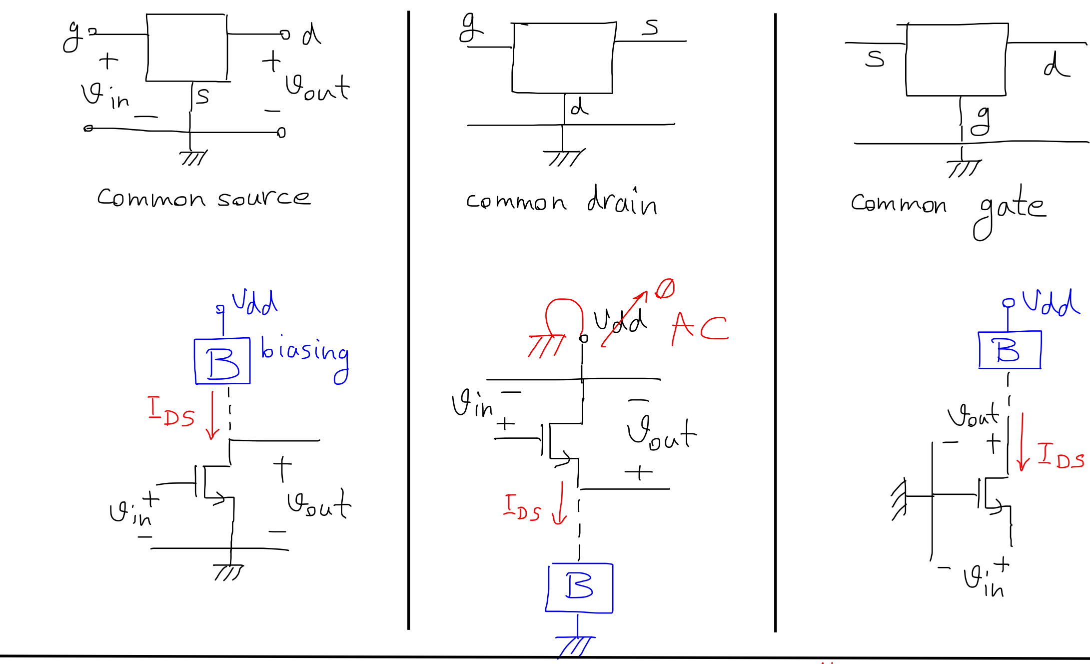
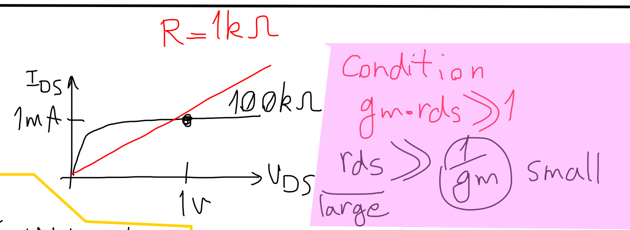
* Assume that transistors always operate in active region

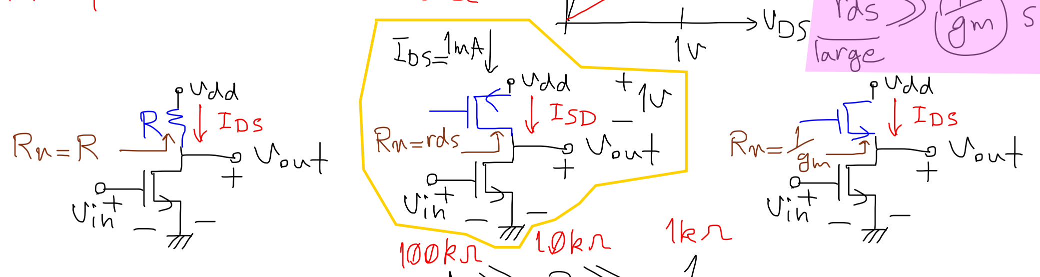




* How to build bias network ?

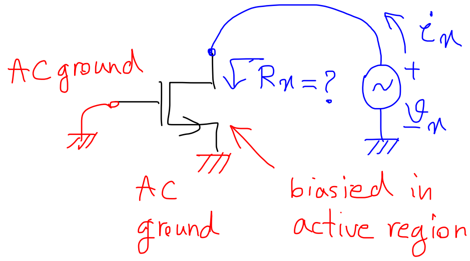
Example for Common Source





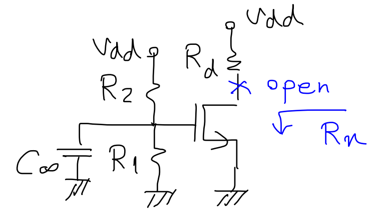
$$r_{ds} \gg R \gg \frac{1}{g_m}$$

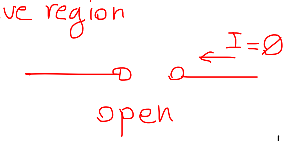
* Question: What is resistance seen at drain?

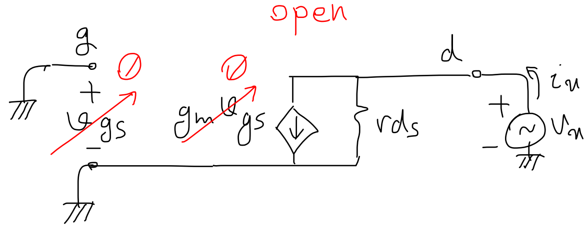


$$R_x = \frac{v_x}{i_x}$$

AC model



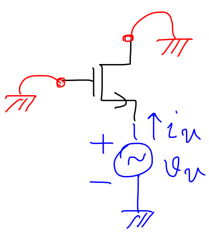




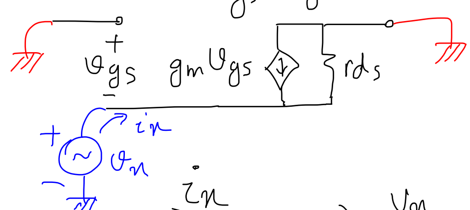
$$R_x = r_{ds}$$

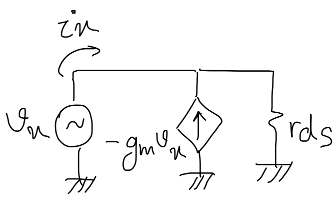
---

* Question: What is resistance seen @ source? (AC)

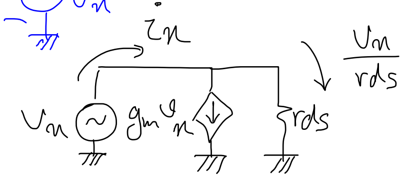


$$v_{gs} = v_g - v_s = -v_x$$



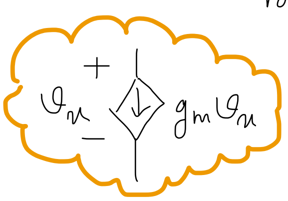


$\equiv$

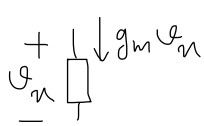


$$i_x = g_m v_x + \frac{v_x}{r_{ds}}$$

$$\frac{v_x}{i_x} = \frac{v_x}{g_m v_x + \frac{v_x}{r_{ds}}} = \frac{1}{g_m + \frac{1}{r_{ds}}}$$



$\equiv$

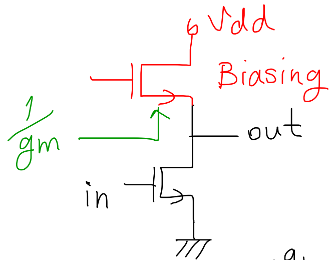


$$\frac{\text{voltage}}{\text{current}} = \frac{v_x}{g_m v_x} = \frac{1}{g_m}$$

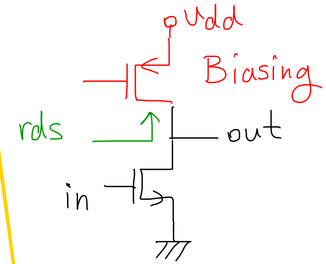
$$R_x = \frac{1}{g_m} \| r_{ds} = \frac{\frac{1}{g_m} \cdot r_{ds}}{\frac{1}{g_m} + r_{ds}} = \frac{1}{g_m + \cancel{\frac{1}{r_{ds}}}} \approx \frac{1}{g_m}$$

ignore

intrinsic gain $g_m \cdot r_{ds} \gg 1$



$-g_m(r_{ds}\|\frac{1}{g_m})$



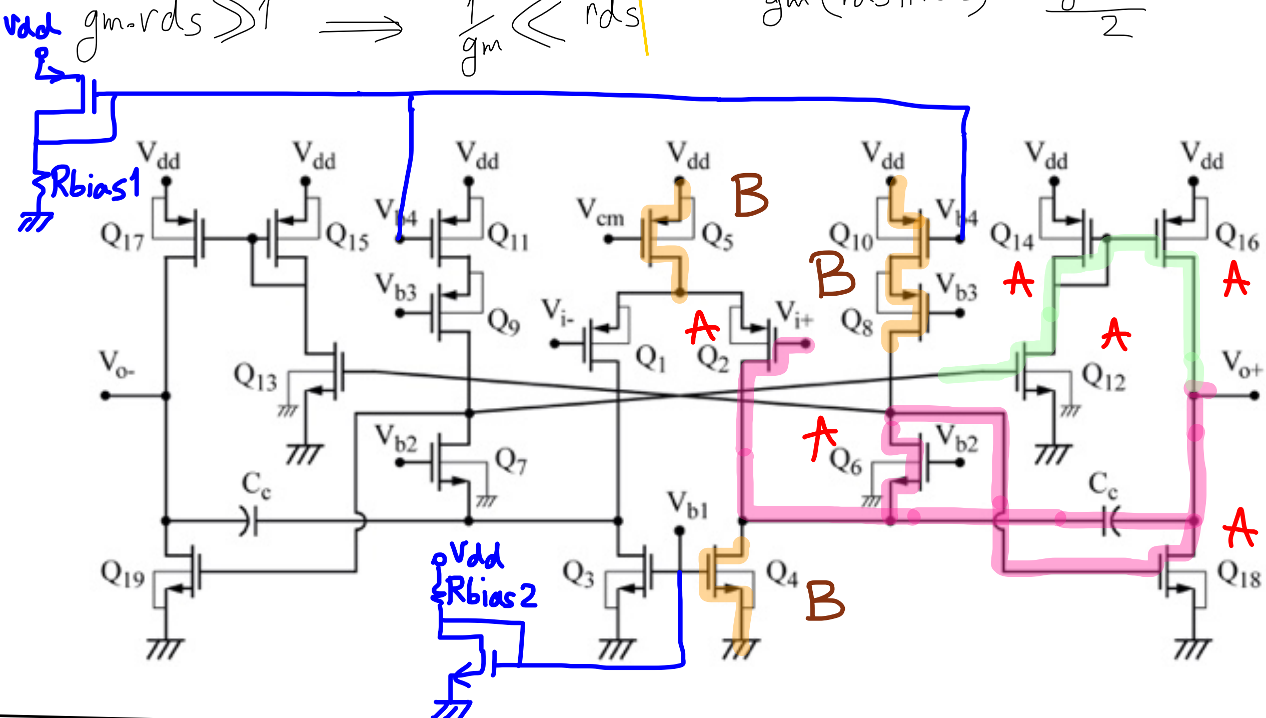
Better choice

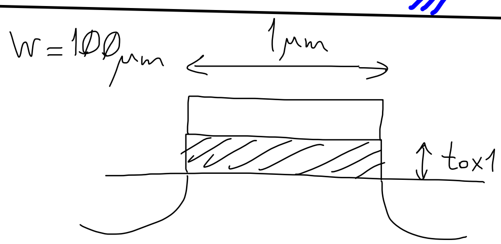
$-g_m(r_{ds}\|r_{ds}) = \frac{-g_m r_{ds}}{2}$

Note:
Always drain of biasing transistor must connect to output

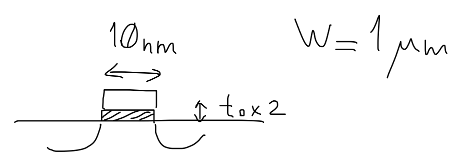
$\underbrace{\text{intrinsic gain}}$

$g_m \cdot r_{ds} \gg 1 \Longrightarrow \frac{1}{g_m} \ll r_{ds}$





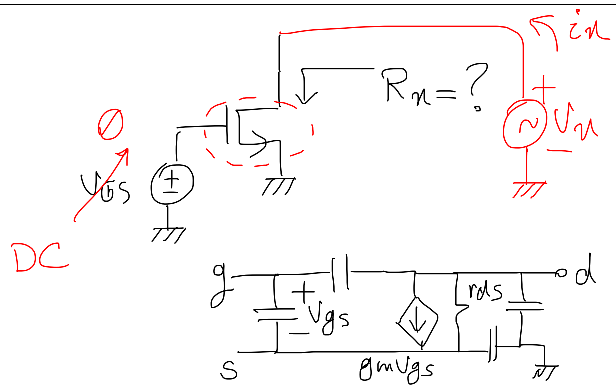
long-channel



short-channel

$g_m = \mu_n C_{ox} \frac{W}{L}(V_{GS}-V_{th})$

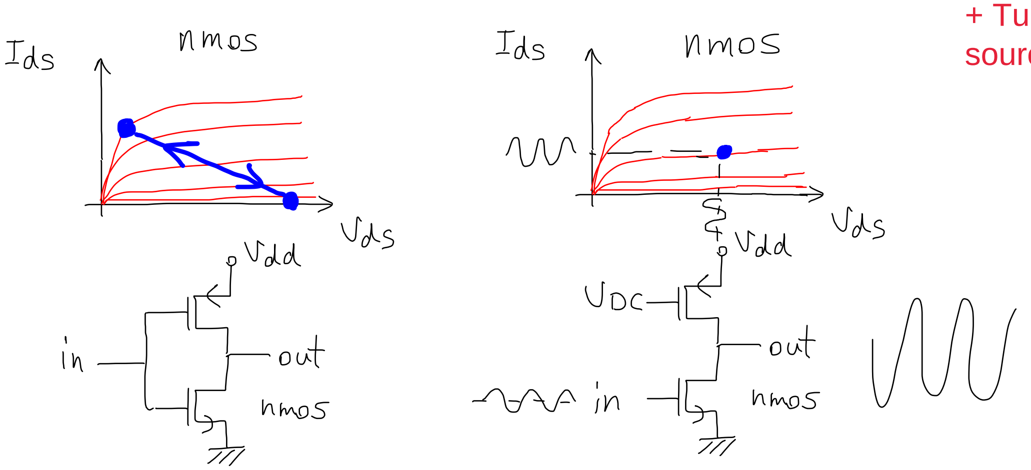
$\uparrow C_{ox} = \frac{\varepsilon_0 \varepsilon_r}{t_{ox}\downarrow}$

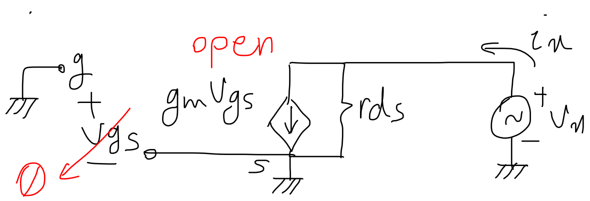


* finding resistance at a node

1. connect a V_x test source to that node
2. create AC model
3. find $R_x = \frac{V_x}{i_x}$

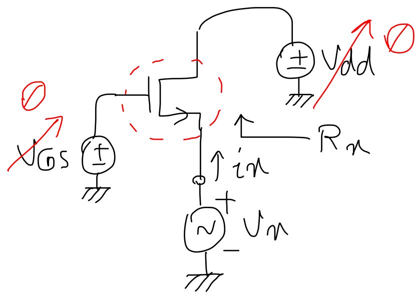
+ Turn off any other independent source

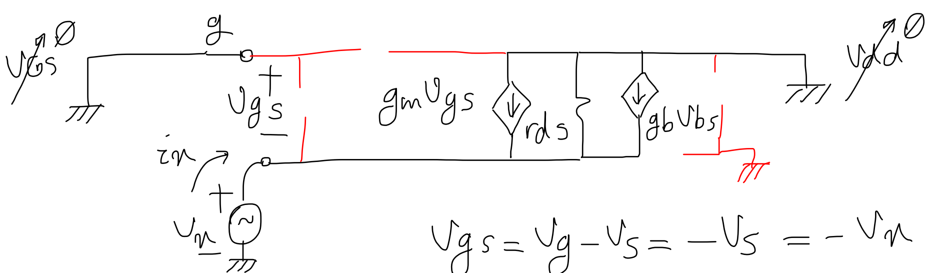




$$R_x = \frac{V_x}{i_x} = r_{ds}$$

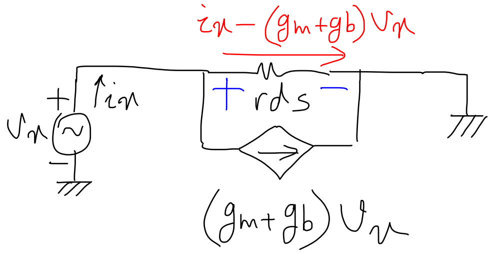
->> How to get the resistance from the source terminal (while including Body Effect) ?





$$V_{gs} = V_g - V_s = -V_s = -V_n$$

$$V_{bs} = V_b - V_s = -V_s = -V_n$$



$$V_n = r_{ds}\left[i_n - (g_m+g_b)V_n\right]$$

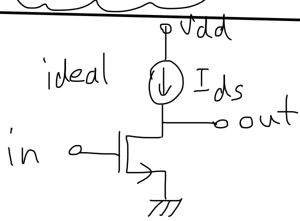
$$\boxed{R_n = \frac{V_n}{i_n} = \frac{r_{ds}}{\cancel{1} + (g_m+g_b)r_{ds}} = \frac{1}{g_m+g_b}}$$

ignore

$g_m \gg g_b$

$g_m \cdot r_{ds} \gg 1$

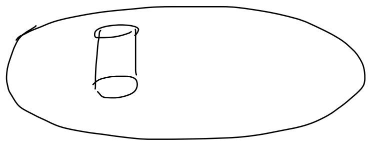
$$R_n \approx \frac{1}{g_m}$$

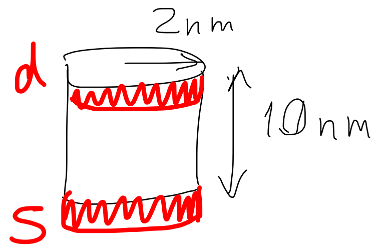


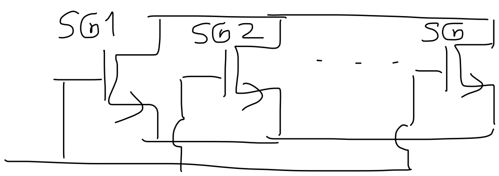
ideal current source resistance

$$-g_m(r_{ds}\,||\,\infty) \approx -g_m r_{ds}$$; this is the maximum gain of a single trasistors

->> The Nanowire SGFET Technology







Transistors have to be connected like this to increase the W in this technology ..
(We can't just modify the L or W of an individual transistor in this technology)