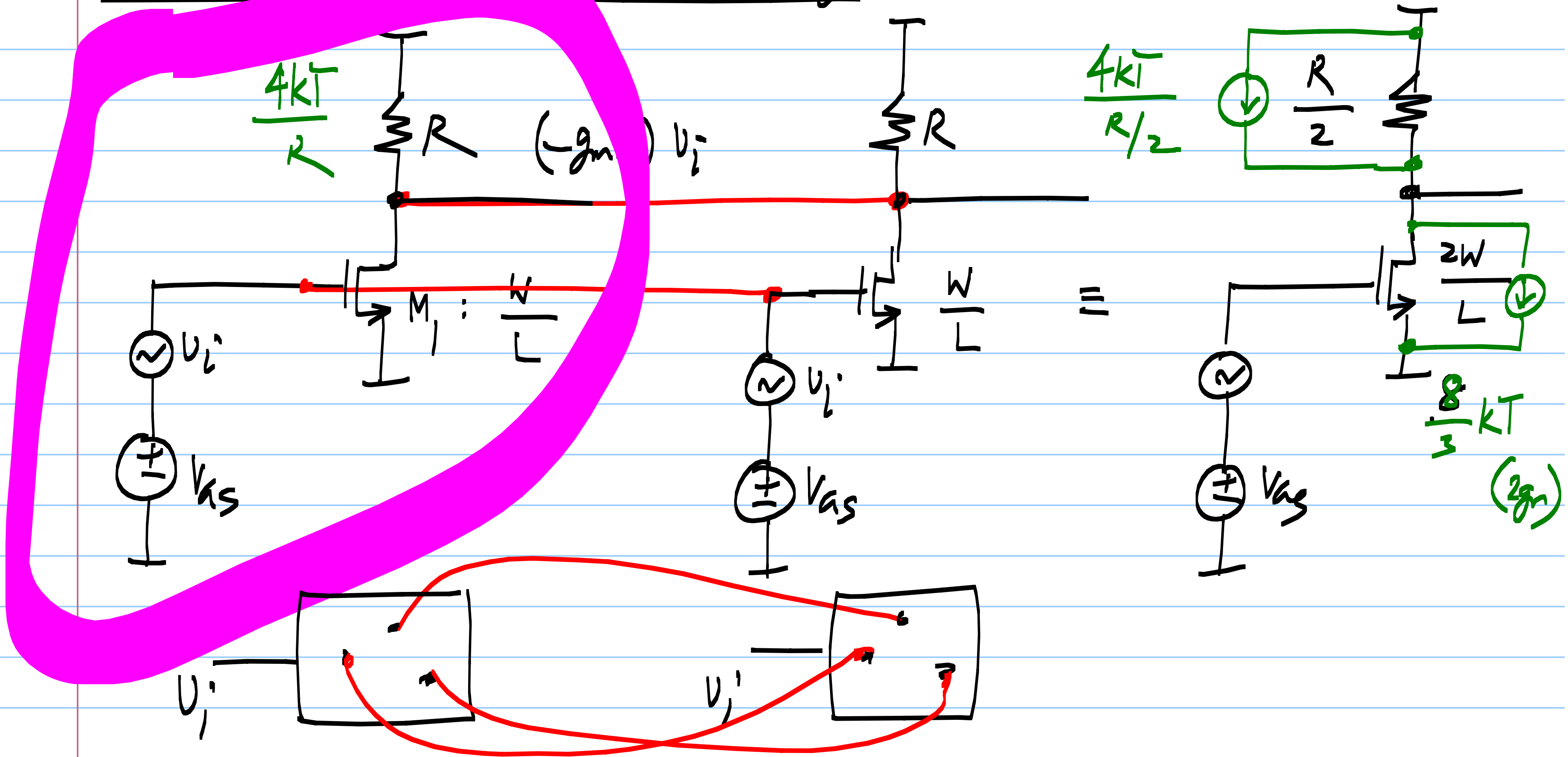
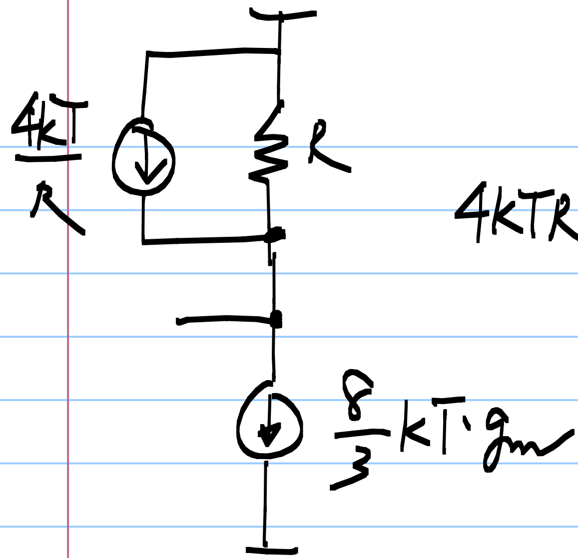
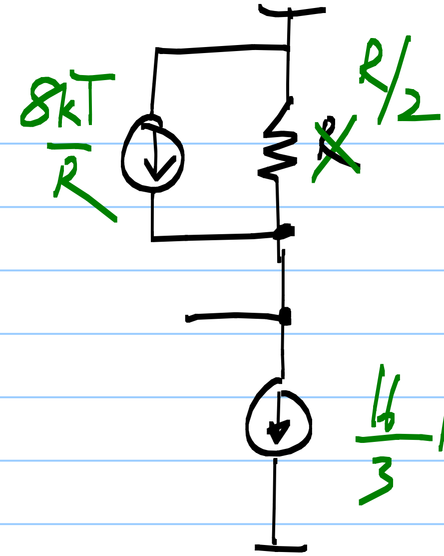
Lecture 26 Noise scaling

gain: $(-g_m R)$





$$4kTR + \frac{8}{3}kT\cdot g_m R^2$$

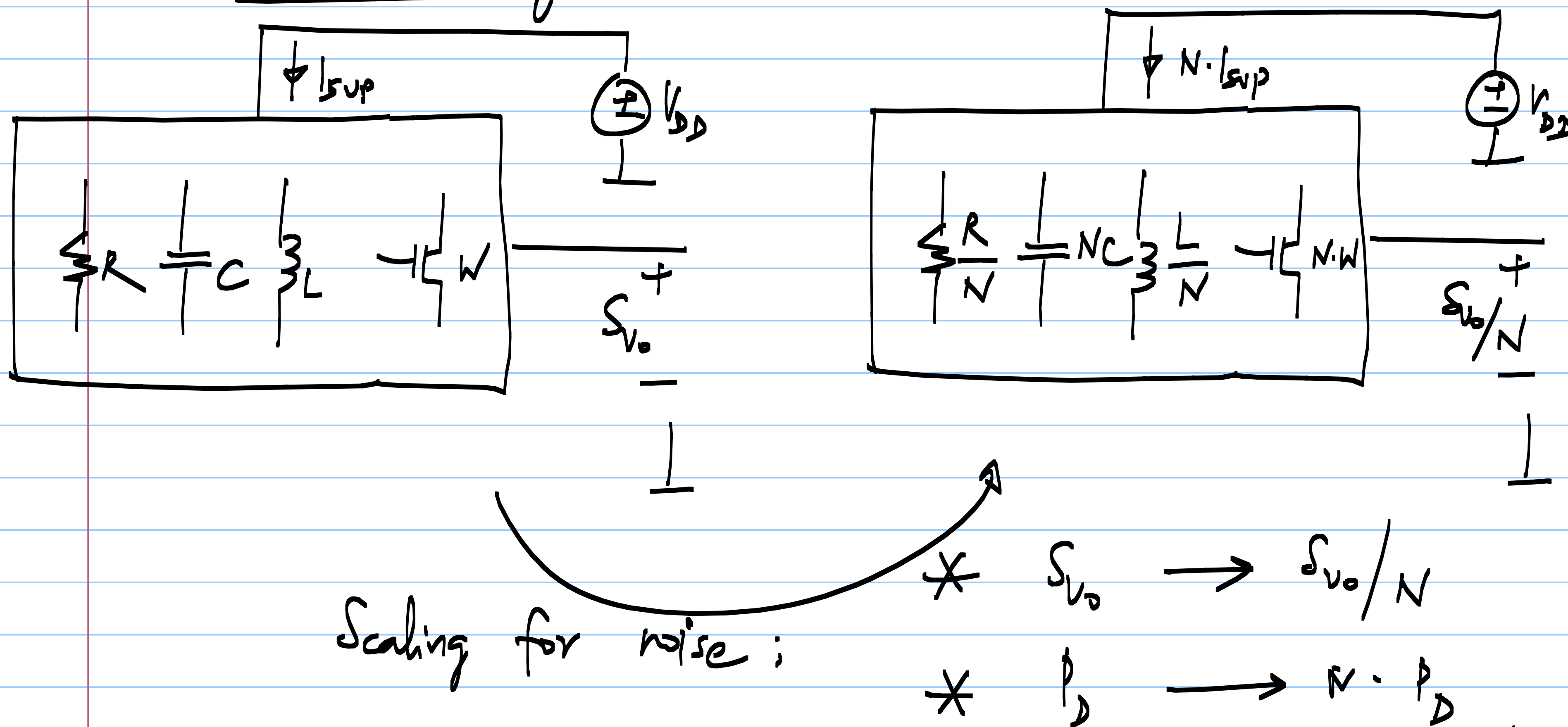


$$\frac{16}{3}kT\cdot g_m$$

$$\frac{4kTR}{2} + \frac{8}{3}kT\cdot g_m \frac{R^2}{2}$$

$$S_{v_o} \longrightarrow \frac{S_{v_o}}{2}$$

Noise scaling:



Scaling for noise:

* $S_{V_o} \longrightarrow S_{V_o}/N$
* $P_D \longrightarrow N \cdot P_D$
* Voltages $\longrightarrow$ Identical

Thermal noise : $\frac{4kT}{R}$; $\frac{8}{3}kTg_m$

$\propto T$

$S_{V_o} \longrightarrow \frac{S_{V_o}}{N}$

$P_D \quad \frac{T}{N}$ $\quad T_2 = T$

Carnot ~~engine~~ refrigerator

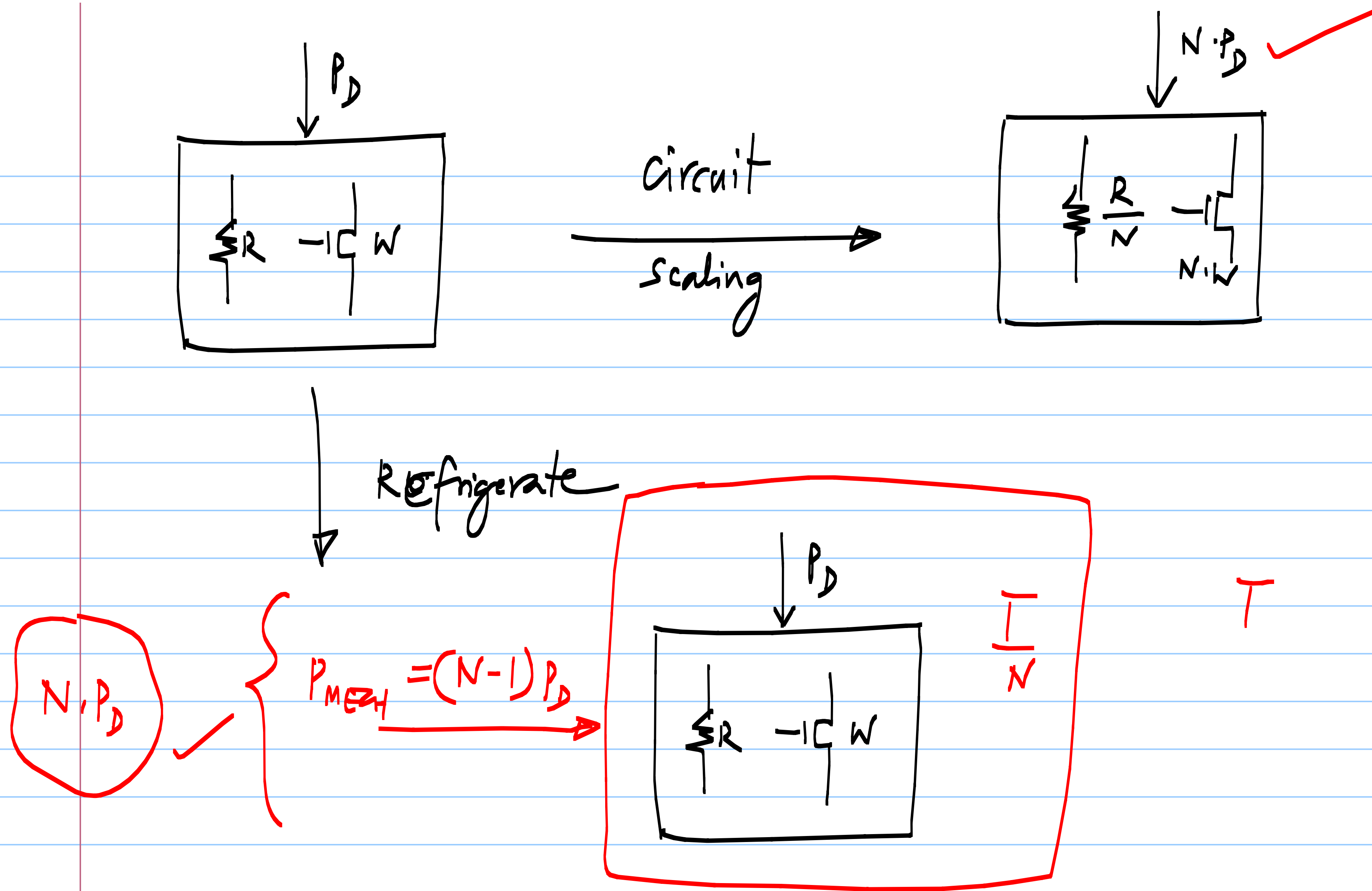
$P_{HEAT} = P_D$

$T_2 > T_1$

* input P_{MECH}
* transfers P_{HEAT} $T_1 \rightarrow T_2$

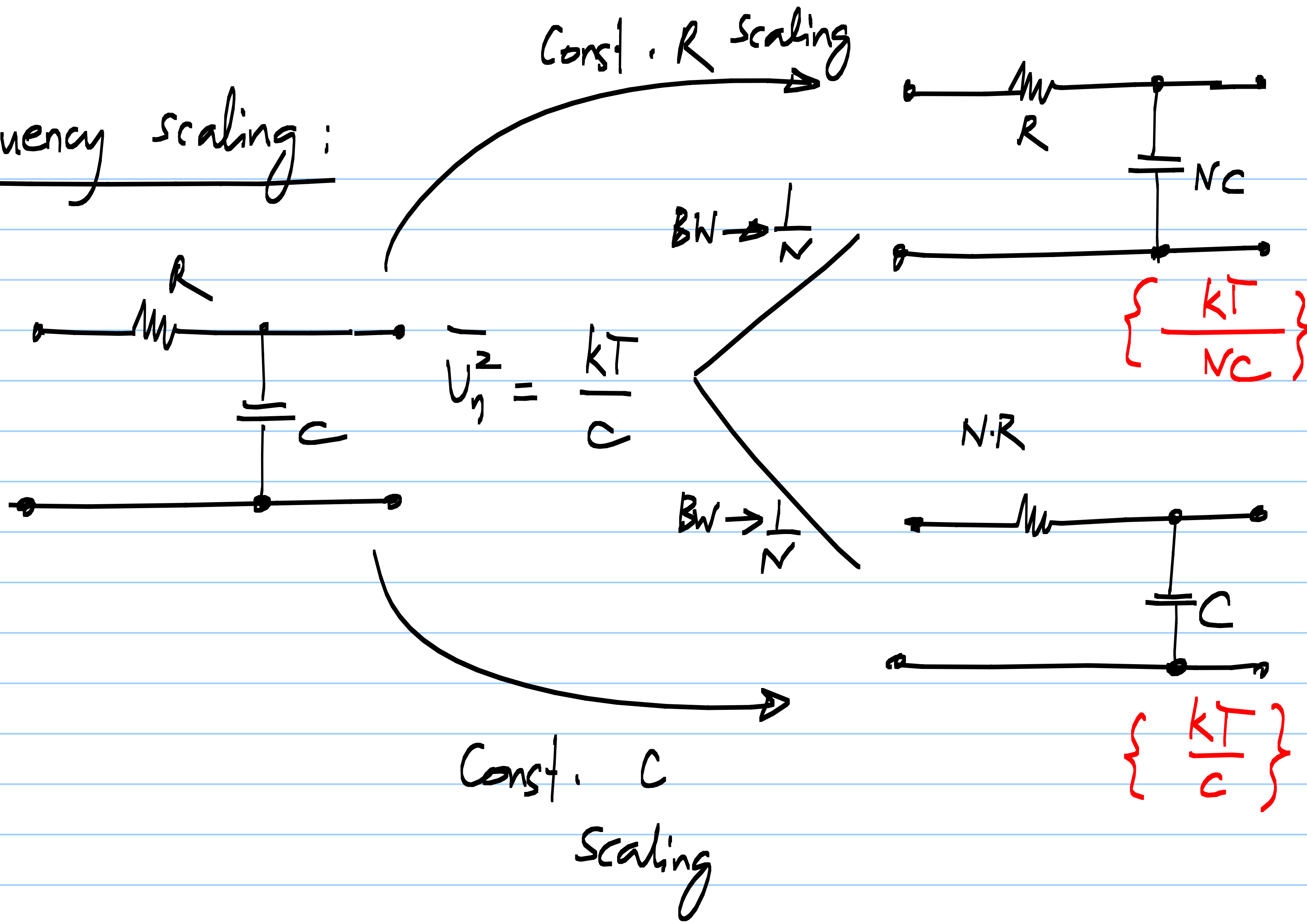
$$\frac{P_{MECH}}{P_{MECH} + P_D} = \frac{T - T/N}{T}$$

$$P_{MECH} = (N-1)\, P_D$$

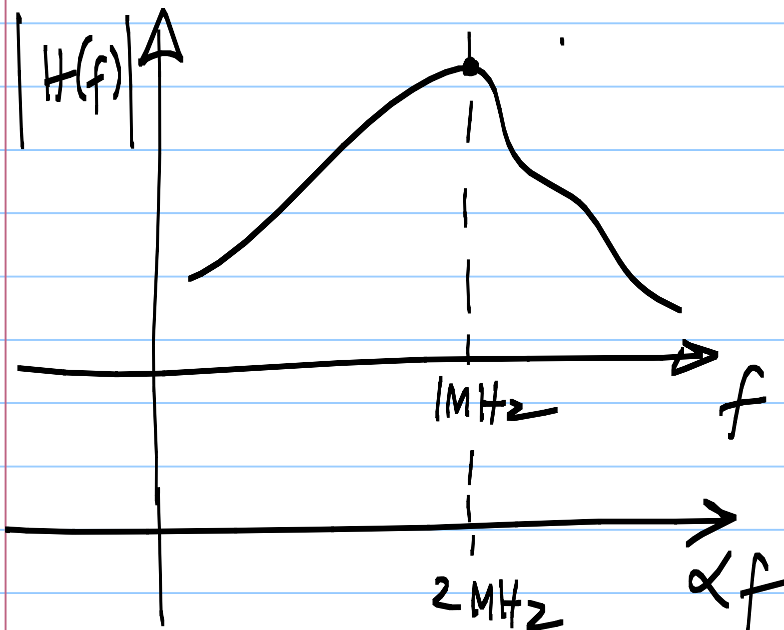


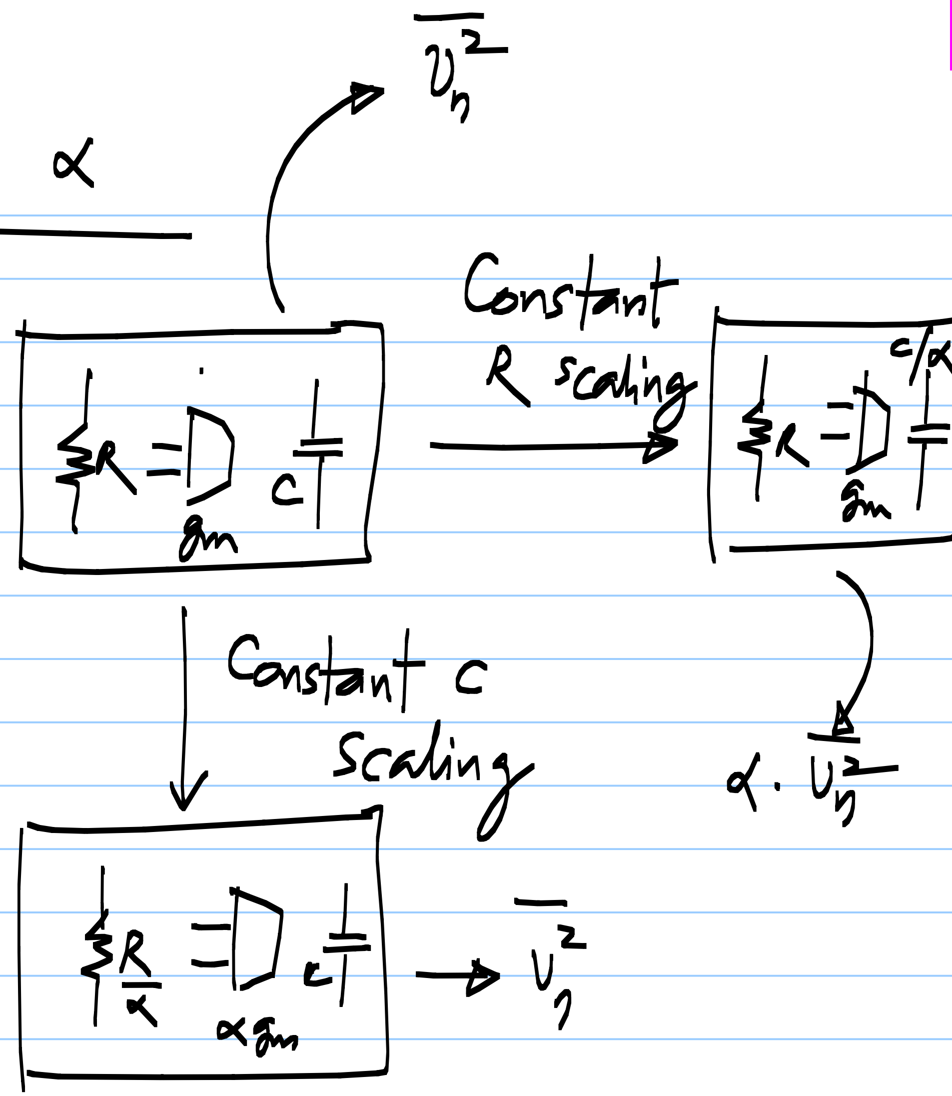
P_D
R
W
Circuit
Scaling
$N \cdot P_D$
$\frac{R}{N}$
$N \cdot W$
Refrigerate
N, P_D
$P_{MECH} = (N-1) P_D$
P_D
R
W
$\frac{T}{N}$
T

Frequency scaling:



Scale the bandwidth by α





(Impedance) All branch impedances $Z_k \rightarrow Z_k/N$

Noise scaling: { without changing the transfer functions }

* Scale all elements by N

$$\left\{\begin{array}{l} G \rightarrow N \cdot G;\quad g_m \rightarrow N \cdot G;\quad L \rightarrow \frac{L}{N};\quad C \rightarrow N \cdot C \\ R \rightarrow R/N \\ W \rightarrow N \cdot W \end{array}\right.$$

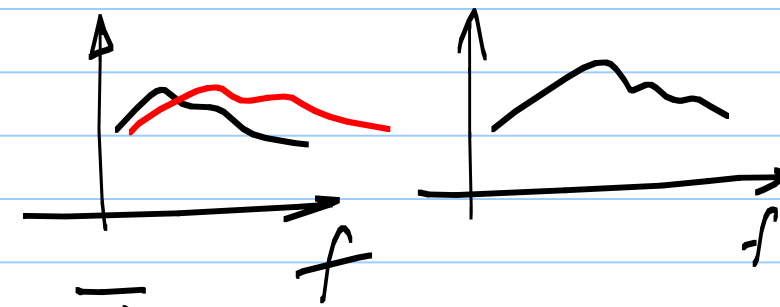
* $S_{v_o} \longrightarrow S_{v_o}/N$

* Currents in the circuit $i_k \longrightarrow N \cdot i_k$

$P_D \rightarrow N \cdot P_D$

Bandwidth scaling:

$H(f) \rightarrow H(f/\alpha)$



Constant C scaling

* $C \rightarrow C$
* $G \rightarrow \alpha \cdot G$
* $g_m \rightarrow \alpha \cdot g_m$

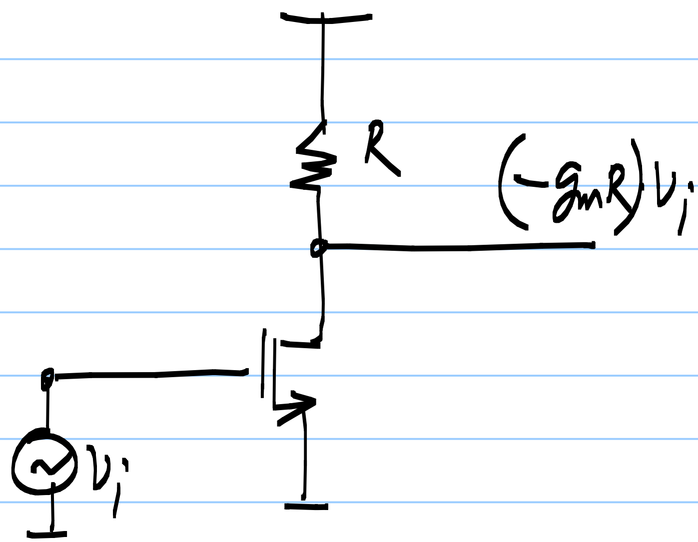
$\overline{v_n^2} \rightarrow \overline{v_n^2}$

Constant conductance scaling

* $C \rightarrow C/\alpha$
* $G, g_m \rightarrow G, g_m$

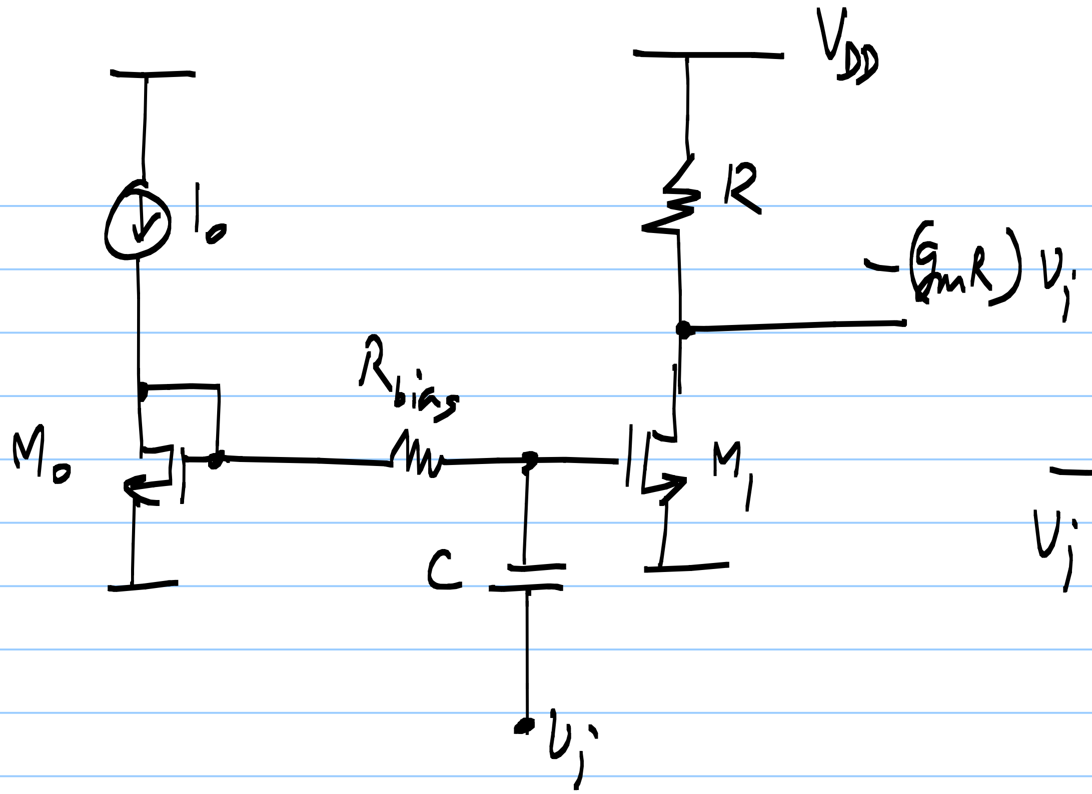
$\overline{v_n^2} \rightarrow \alpha \cdot \overline{v_n^2}$

Basic amplifier stages: CS, CG, CD (Source follower)

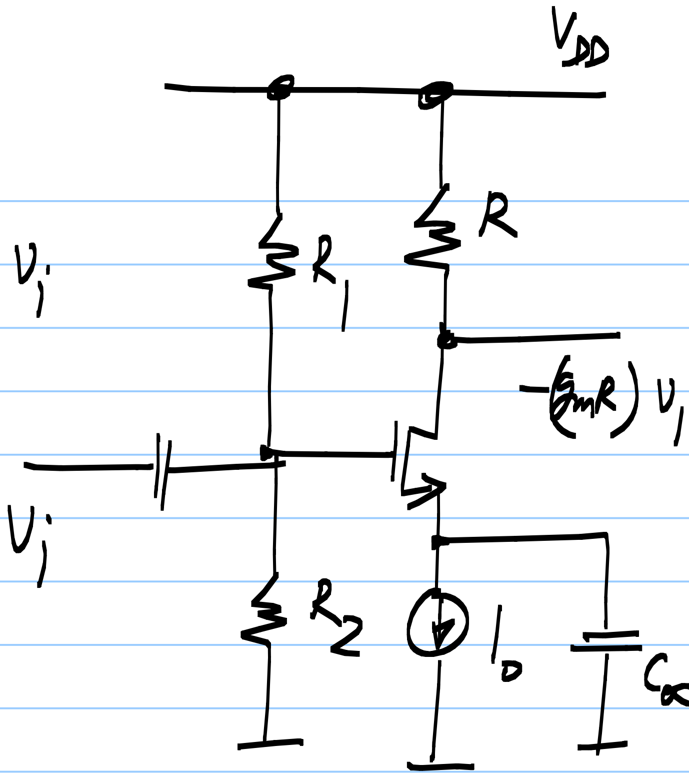


$(-g_m R)$

* Constant current biasing preferred to constant V_{GS} biasing → lower sensitivity of g_m

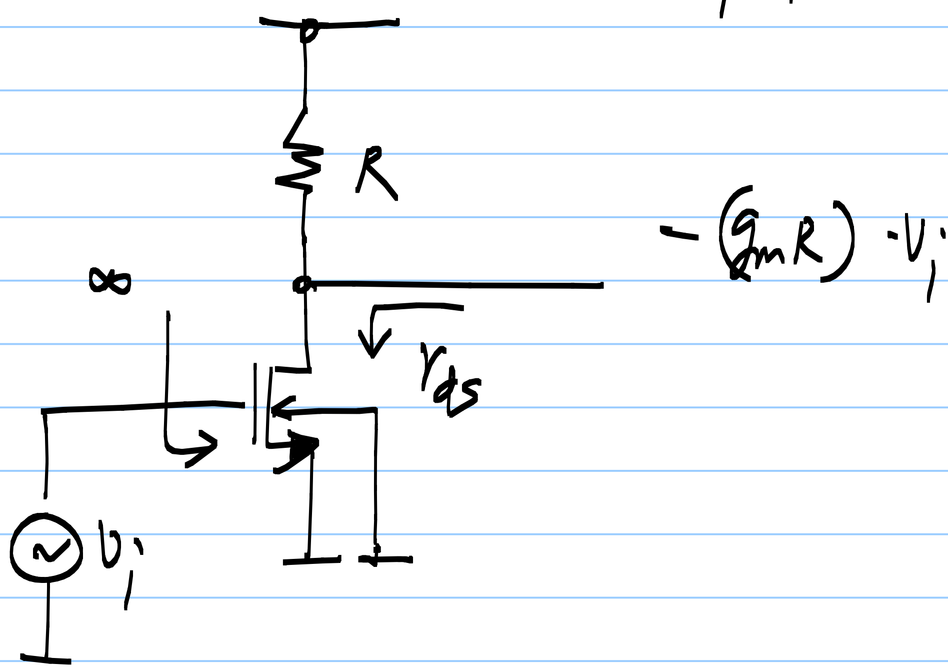


I_o
V_{DD}
R
$-(g_m R)\, v_i$
R_{bias}
M_o
M_1
C
v_i



V_{DD}
R_1
R
$-(g_m R)\, v_i$
v_i
R_2
I_o
C_∞

CS (common source amplifier)



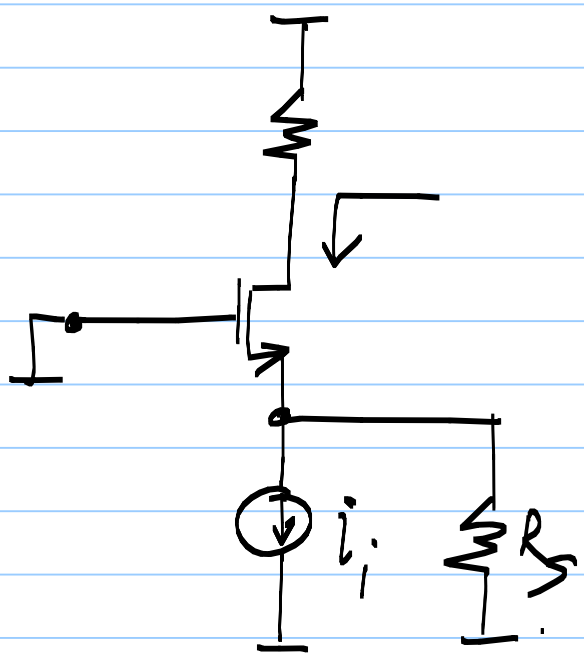
* Gain $\simeq -g_m R$
* Gain $= -g_m(R \| r_{ds})$

$$= \frac{-g_m}{G + g_{ds}}$$

* $v_{bs} = 0 \Rightarrow g_{mb} \cdot v_{bs} = 0$

Body effect doesn't influence the CS amp.

Common gate amplifier: Current buffer



* $i_o = i_i$
* $r_{ds} = \infty$; $(g_{ds} = 0)$

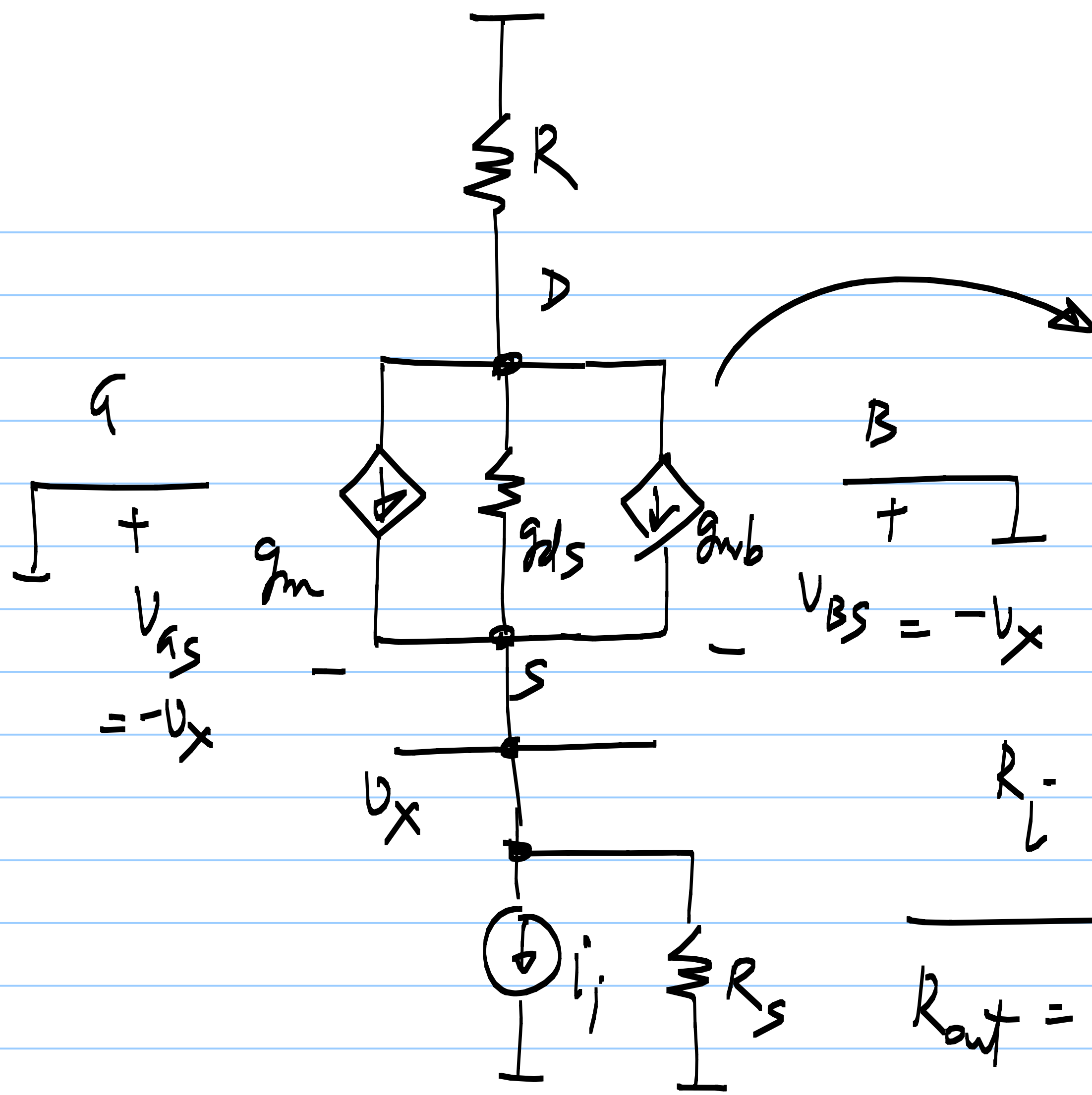
  $R_{in} = 1/g_m$

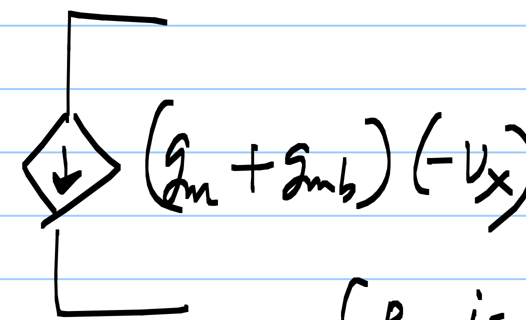
  $R_{out} = \infty$
* $r_{ds} \neq \infty$;

  $R_{out} = g_m r_{ds} \cdot R_s + r_{ds} + R_s$

  $R_{in} \simeq 1/g_m$ $\quad R \sim r_{ds}$

Not true if $R \gg r_{ds}$





$$R_i = \frac{1}{g_m + g_{mb}}$$

{ R is n-t $\gg r_{ds}$ }

$$R_{out} = (g_m + g_{mb}) r_{ds} \cdot R_s + r_{ds} + R_s$$