26/2/20

Lec 18

$\overline{V_{od_n}^2}$ for noise cancelling LNA:

1) Noise from M_1 (CG stage) = 0

2) Noise from M_2 (CS stage) = $4kT\gamma g_{m_2} \cdot R_L^2$

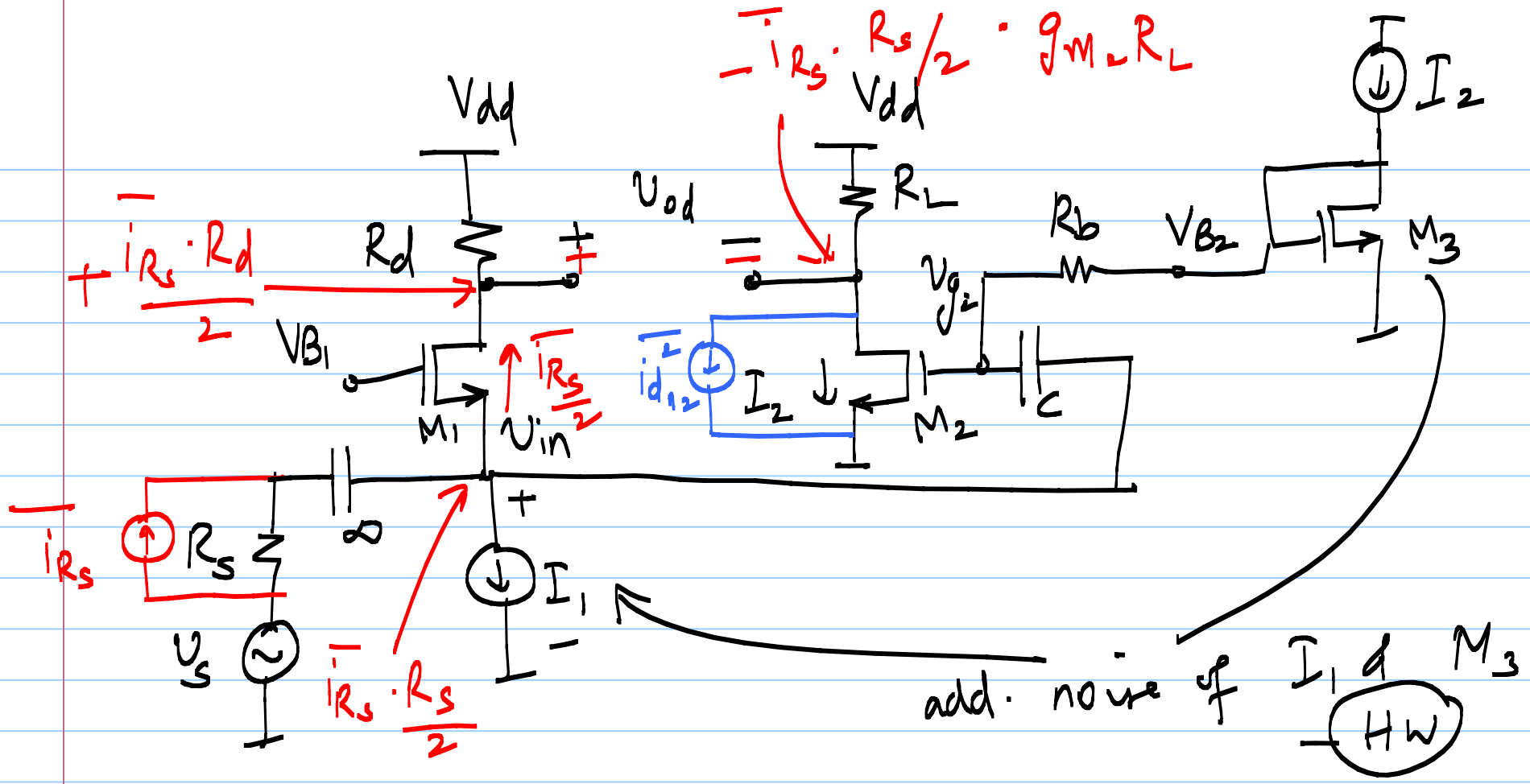
3) Noise from R_L = $4kTR_L$

4) Noise from R_d = $4kTR_d$

5) Noise from R_s = $\left| \frac{\overline{i_{R_s}}}{2} \left(R_d + R_s g_{m_2} R_L\right) \right|^2$

$= \left| \frac{\overline{i_{R_s}}}{2} \left(R_d + R_s \cdot \frac{R_d}{R_s}\right) \right|^2$

$= \left| \overline{i_{R_s}} \cdot R_d \right|^2 = \frac{4kTR_d^2}{R_s}$


Vdd
Rd
VB1
M1
Vin
Rs
Vs
I1
Vdd
RL
Vod
Rb
VB2
M3
I2
M2
C
add. noise of I1 & M3
HW

$$NF = 1 + \frac{4kT\gamma g_{m_2} R_L^2 + 4kTR_L + 4kTR_d}{4kT \cdot R_d^2/R_s}$$

$$= 1 + \gamma \cdot \frac{(g_{m_2} R_L)}{R_d/R_s} \cdot \left(\frac{R_L}{R_d}\right) + \frac{R_L R_s}{R_d^2} + \frac{R_s}{R_d}$$

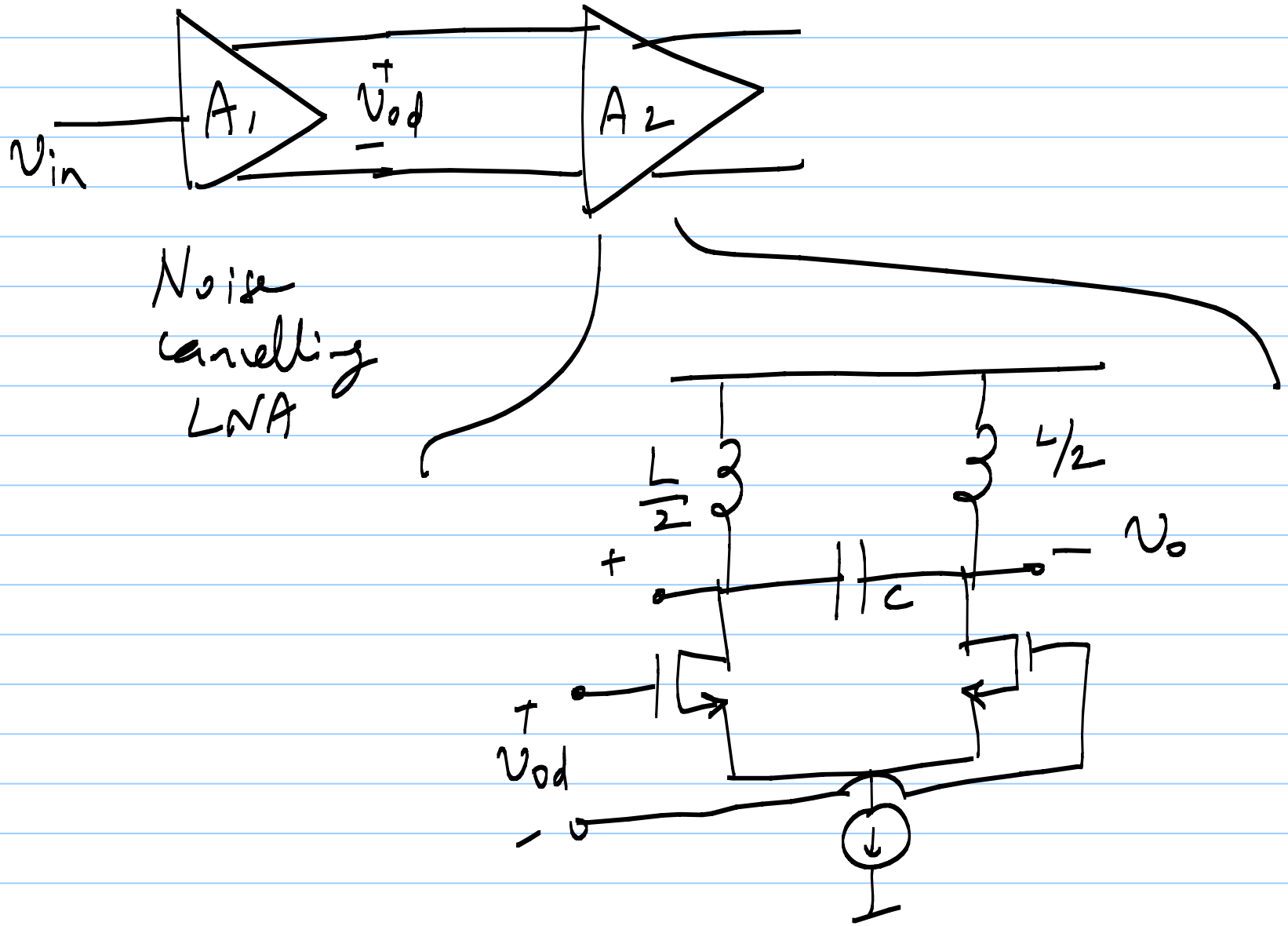
$$\boxed{NF = 1 + \gamma \cdot \frac{R_L}{R_d} + \frac{R_s}{R_d} + \frac{R_L R_s}{R_d^2}}$$

$$\frac{R_d}{R_s} = g_{m_2} \cdot R_L$$

$$\frac{R_L}{R_d} = \frac{1}{g_{m_2} R_s}$$

low NF $\Rightarrow$ maximise R_d, minimise R_L

$\Rightarrow$ maximise g_{m_2}


v_{in}
A_1
v_{od}
A_2
Noise cancelling LNA
$\frac{L}{2}$
$L/2$
+
v_o
−
C
+
v_{od}
−

IIP_3 :

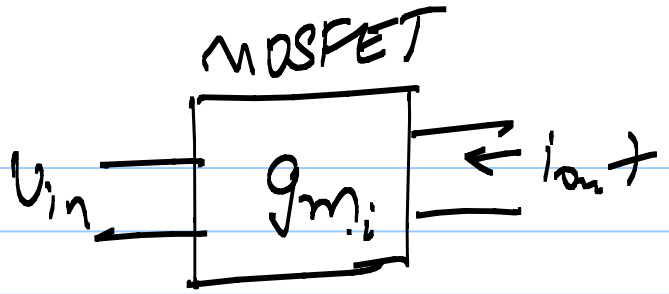
* MOSFET with purely square law behaviour $I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)^2$

$IIP_3 = \infty$

There is no 3rd order component $\alpha_3 = 0$

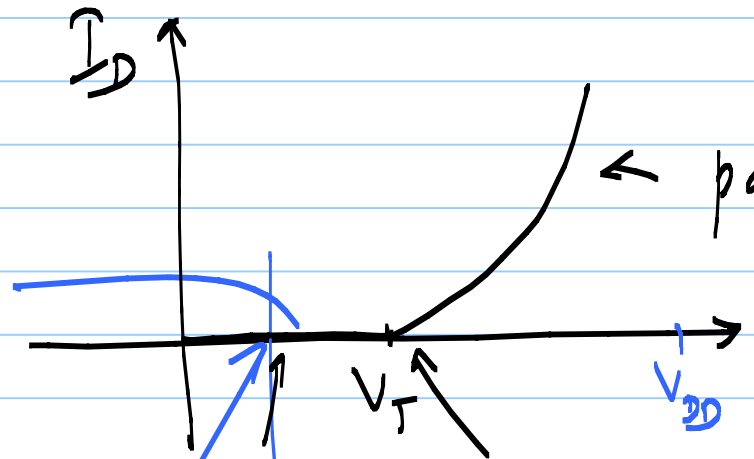
* Cannot design for IIP_3
* Design for all other specs
* Then "measure" IIP_3 (simulate)

$$g_{m_1} = \frac{\partial I_D}{\partial V_{GS}} = \alpha_1$$



$$g_{m_2} = \frac{1}{2!} \frac{\partial^2 I_D}{\partial V_{GS}^2} = \alpha_2$$

$$g_{m_3} = \frac{1}{3!} \frac{\partial^3 I_D}{\partial V_{GS}^3} = \alpha_3$$



← parabolic "strong inversion"

actual $I_D > 0$

$V_{depl.}$

@ $V_{GS} = V_T$, device inverts

↳ device goes from depletion → weak inversion → moderate inv. → strong inv.

I_D vs V_{GS} is exponential

* If $V_{GS} \sim V_T \Rightarrow$ moderate inv.

→ device transitions from exp. to $(\ )^2$

$$V_T - 0.1V < V_{GS} < V_T + 0.1V$$

$$\downarrow (V_{GS} - V_T) \propto \underbrace{\sqrt{\frac{I_D}{(W/L)}}} \Rightarrow \begin{cases} \uparrow (W/L) \\ \downarrow I_D \end{cases} \Big\} \text{ very low } f_T$$

In weak inv. $I_D = I_0 \exp\left(\frac{V_{GS} - V_T}{\eta V_t}\right)$ "sub-threshold" operation

* If $\beta \to \infty$ in subthreshold region