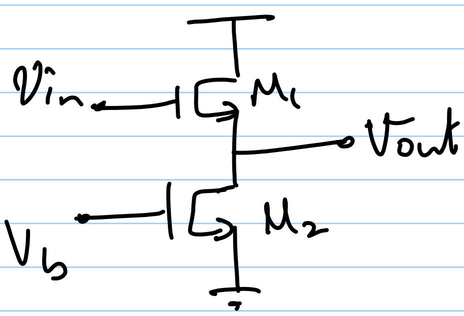
25/1/12

Lec 10

Source Follower



recall $g_{out} = g_{m_1} + g_{mbs_1} + g_{ds_1} + g_{ds_2}$

$$a_v = \frac{g_{m_1}}{g_{out}}$$

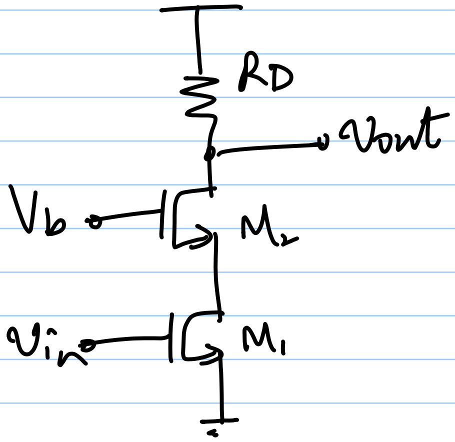
$$\frac{\overline{v^2_{n,out}}}{\Delta f} = \left(4KT\gamma_1 g_{m_1} + 4KT\gamma_2 g_{m_2}\right) \cdot \frac{1}{g^2_{out}}$$

$$\frac{\overline{v^2_{n,in}}}{\Delta f} = \frac{4KT\gamma_1}{g_{m_1}} + \frac{4KT\gamma_2 g_{m_2}}{g^2_{m_1}}$$

{ very similar to C.S. with PMOS current source }

* Source followers add noise & gain < 1 ⇒ not preferred in LNAs

Cascode



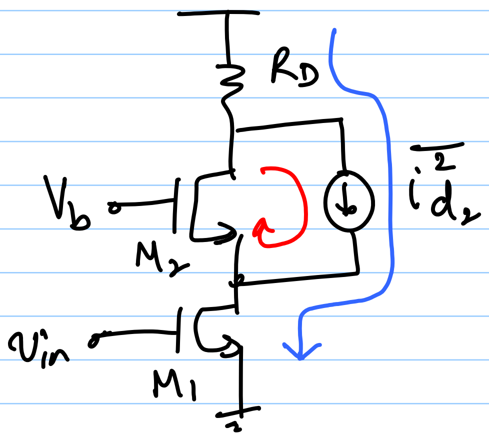
$$\frac{\overline{v^2_{n,out}}}{\Delta f}(M_1, R_D) = \left[4kT g_D + 4kT\gamma_1 g_{m_1}\right] R_D^2$$

(ignore 1/f noise)

$$a_v = -g_{m_1} R_D$$

$$\Rightarrow \frac{\overline{v^2_{n,in}}}{\Delta f}(M_1, R_D) = 4kT\left[\frac{\gamma_1}{g_{m_1}} + \frac{1}{g^2_{m_1} R_D}\right]$$

noise of M_2?

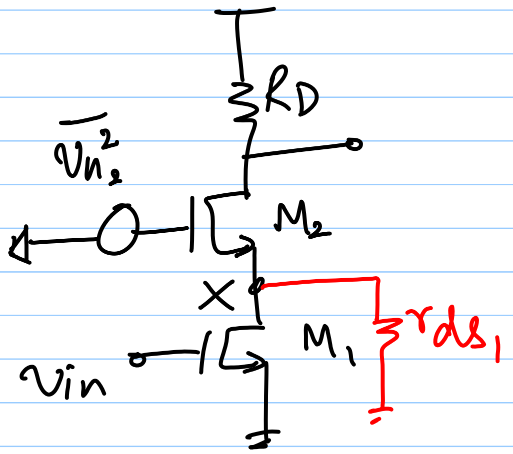


$Z_{in_1} \approx \frac{1}{g_{m_2}}$

$Z_{in_2} = r_{ds_1}$

Most of $\overline{i^2_{d_2}}$ flows through M_2

$\Rightarrow \overline{v^2_{n,out}}(M_2)$ [and therefore $v^2_{n,in}(M_1)$] are very very small another way to look at it:

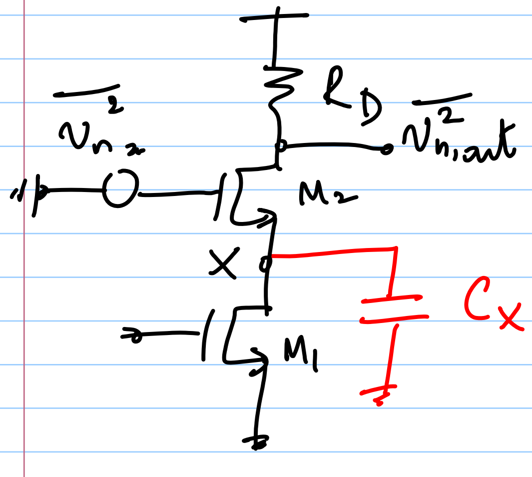


Effective transconductance of M_2

$$= \frac{g_{m_2}}{1 + g_{m_2} r_{ds_1}}$$

= very very small

(degenerated with large resistance)



@ high freq., C_X becomes prominent

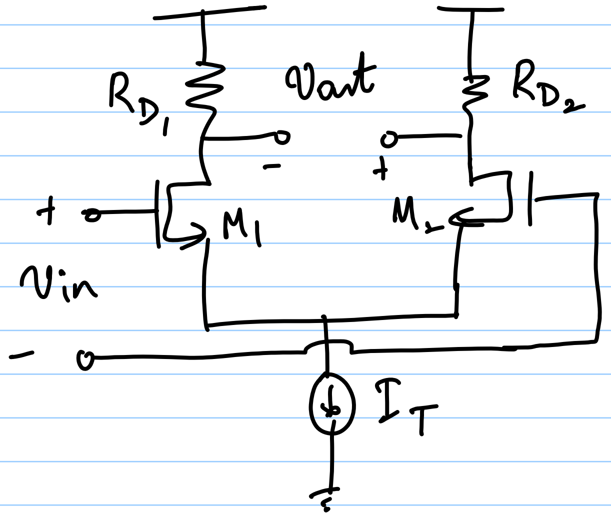
$$G_{m_2} = \frac{g_{m_2}}{1 + g_{m_2}\left(\frac{1}{j\omega C_X}\right)}$$

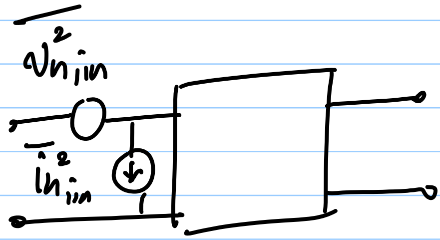
$$= \frac{1}{\frac{1}{g_{m_2}} + \frac{1}{j\omega C_X}}$$

$$\frac{\overline{v_{n,out}^2}}{\overline{v_{n_2}^2}} \approx \frac{R_D^2}{\left(\frac{1}{g_{m_2}}\right)^2 + \left(\frac{1}{\omega C_X}\right)^2}$$

i.e. $\overline{v_{n,out}^2} \uparrow$

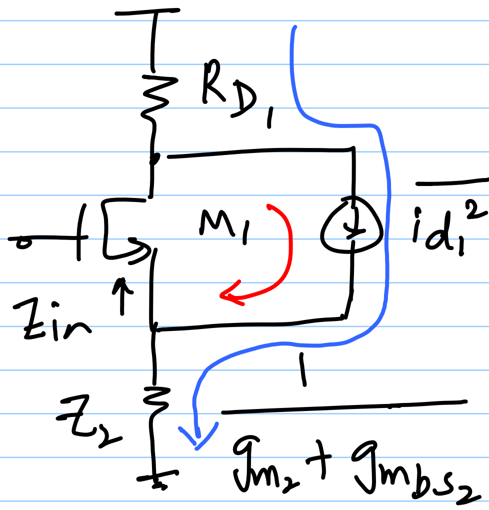
Differential Pairs





* $\overline{id_1^2}$ & $\overline{id_2^2}$ are uncorrelated

→ cannot use half-ckt concepts!



$$Z_{in} = \frac{1}{g_{m_1}+g_{mbs_1}}$$

⇒ $\frac{\overline{id_1}}{2}$ flows through M_1 & R_{D_1}

* $\frac{\overline{id_1}}{2}$ flowing into Z_2 flows into R_{D_2}

$$\frac{\overline{v_{n,out}}(M_1)}{\delta f} = \frac{\overline{id_1}}{2} \cdot R_{D_1} + \frac{\overline{id_1}}{2} R_{D_2}$$

(correlated, so currents add)

$$\therefore \overline{v_{n,out}^2}(M_1) = \overline{i_{d1}^2} \cdot R_D^2$$

$$\therefore \overline{v_{n,out}^2} = \left(\overline{i_{d1}^2} + \overline{i_{d2}^2}\right) R_D^2 + 2(4kTR_D)$$

$$= 8kT\left(\gamma g_{m_{1,2}} R_D^2 + R_D\right)$$

$$|a_{vd}|^2 = g_m^2 R_D^2$$

$$\Rightarrow \overline{v_{n,in}^2} = 8kT\left(\frac{\gamma}{g_{m_{1,2}}} + \frac{1}{g_{m_{1,2}}^2 R_D}\right)$$

$$= 2\,\overline{v_{n,in}^2}_{CS}$$

$$\therefore \overline{v_{n,in}} = \sqrt{2}\; v_{n,in_{CS}}$$ (2x devices, uncorrelated noise)

How about noise from I_T? (call it $\overline{i_n}$)

1) $v_{in} = 0$ (no diff. input)

$\overline{i_n}$ (noise) divides equally between diff paths ⇒ Common-mode noise only

2) Δv_{in}

$$\Delta I_{D1} - \Delta I_{D2} = g_m \Delta v_{in}$$

$$= \sqrt{2\mu C_{ox}\left(\frac{W}{L}\right)\left(\frac{I_T + \overline{i_n}}{2}\right)} \cdot \Delta v_{in}$$

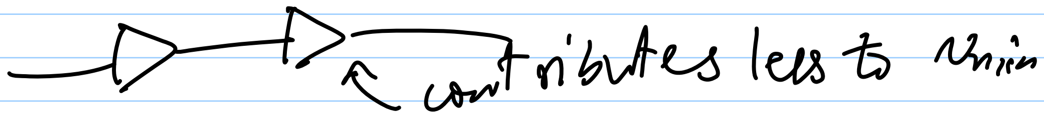
$$\approx \sqrt{2\mu C_{ox}\left(\frac{W}{L}\right)\left(\frac{I_T}{2}\right)}\left(1+\frac{\overline{i_n}}{2I_T}\right)\Delta v_{in}$$

$$= g_{m_0}\,\Delta v_{in}\left(1+\frac{\overline{i_n}}{2I_T}\right)$$

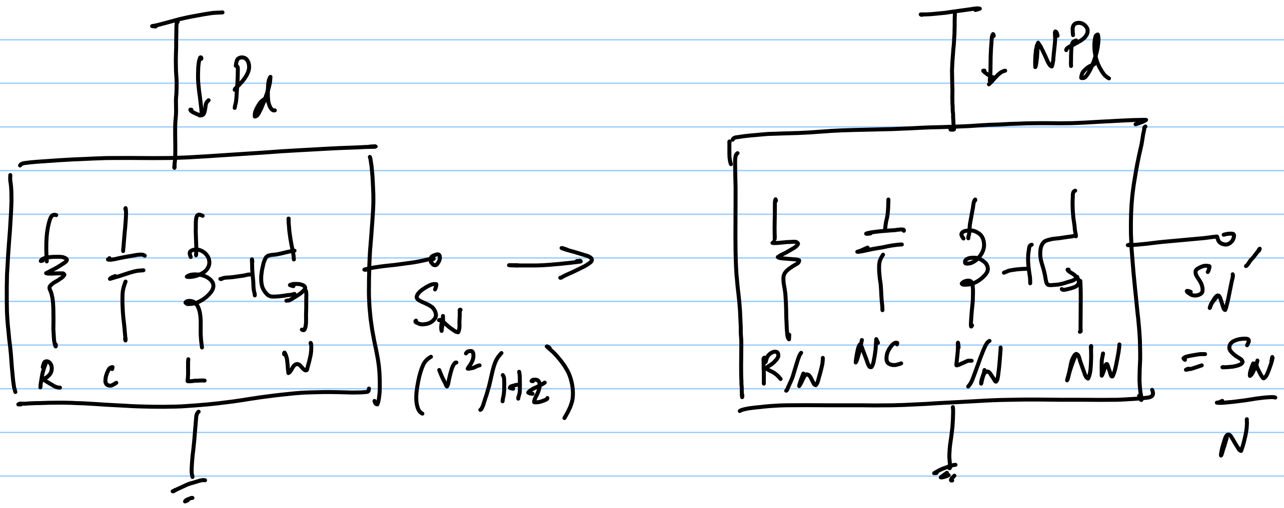
$\Rightarrow$ diff. noise @ output

$\rightarrow$ this effect is usually negligible (multiplied by Δv_{in})

Cascade



Noise scaling:



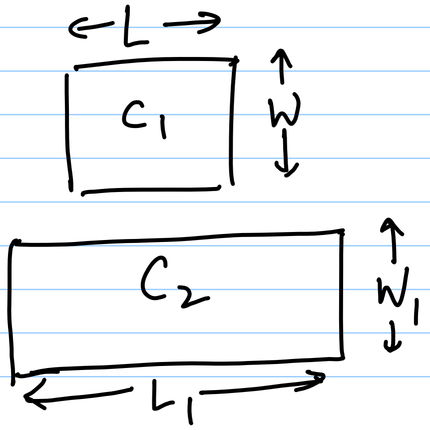
More on noise when we get to opamps!

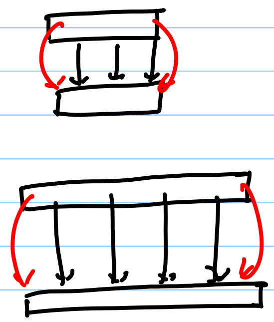
Mismatch

- Systematic
- Random

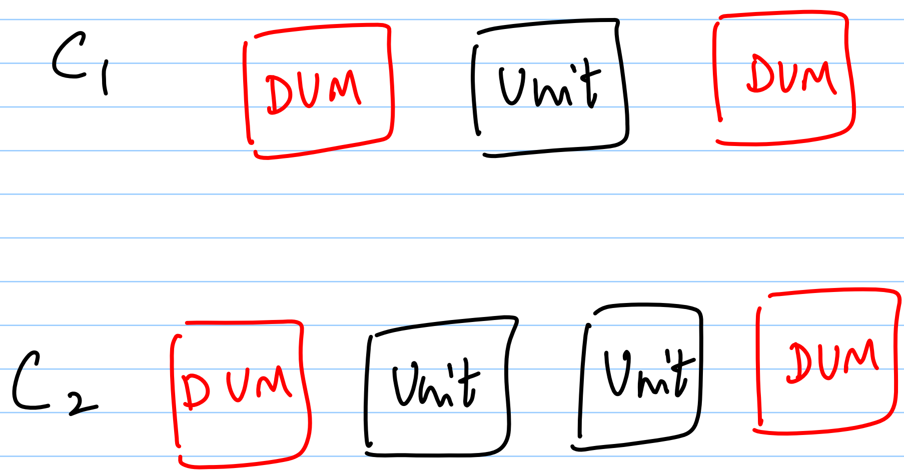
Systematic mismatch:

Say you want cap ratio $\frac{C_2}{C_1} = \frac{2}{1}$





$$C = C_{Area} \cdot WL + C_{Fringe}(2W + 2L)$$



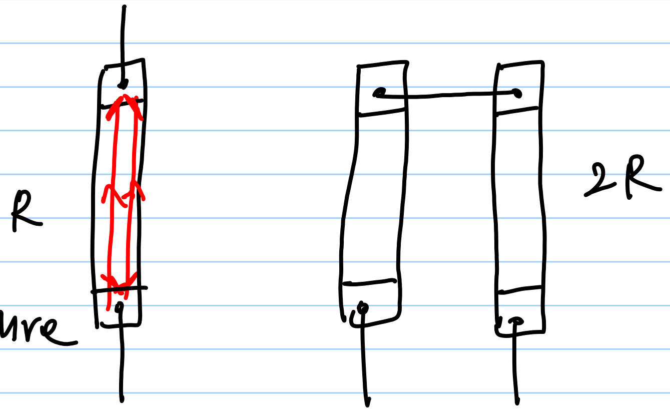
$C_2 = 2C_1$

You can achieve fractional ratios like 4/3 etc.

resistors:

$$\frac{R_2}{R_1} = \frac{2}{1}$$

$R = 2R_{end} + R_{intrinsic}$



* Process directionality due to temp, mask, pressure etc.

General idea: (to reduce systematic mism.)

* use identical units (different numbers)
* use dummy devices to create identical surroundings
* same orientation