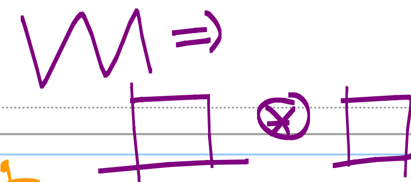
ECE 614 – Lecture 12

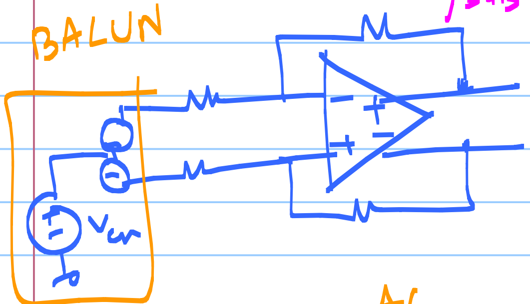
Note Title

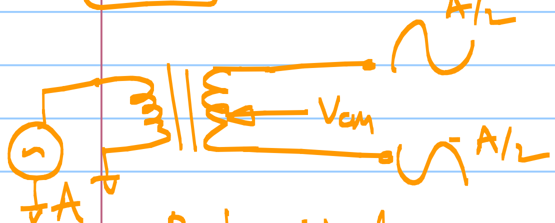
10/4/2012



$f_{3dB} = f_{un} \cdot \beta$

BALUN





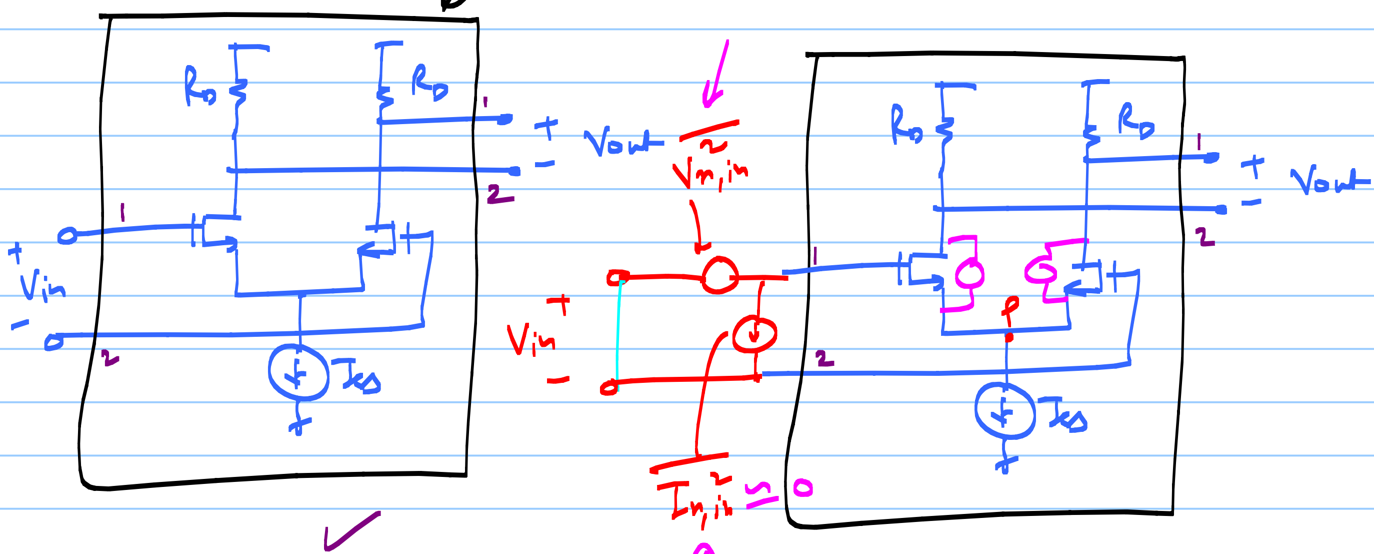
Balun_ideal

HD3, HD5

Distortion Analysis

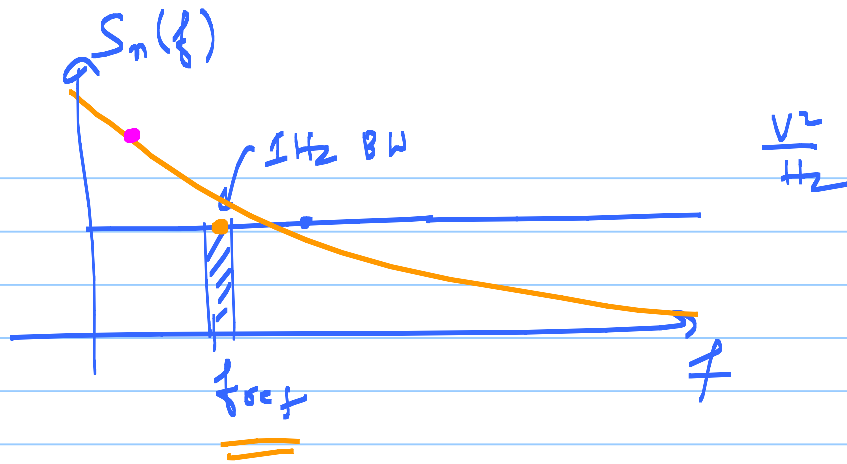
.disto

2-port circuit

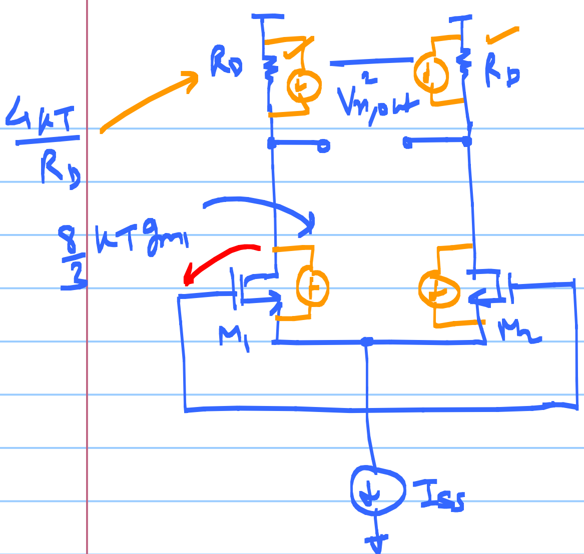


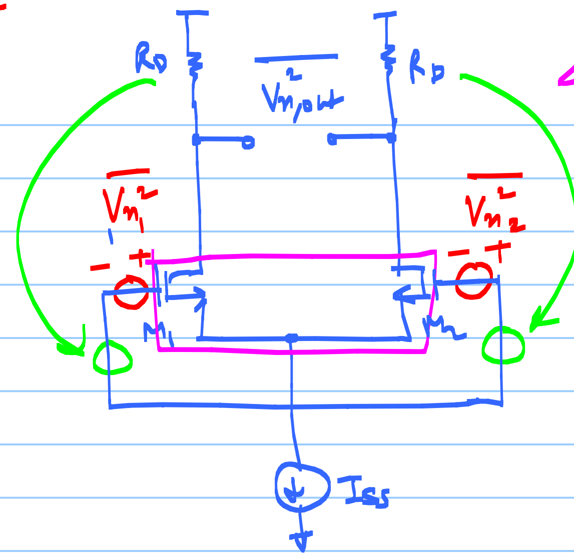
CMOS and @ low-f

Spot Noise.



* Transpose Noise sources to the input





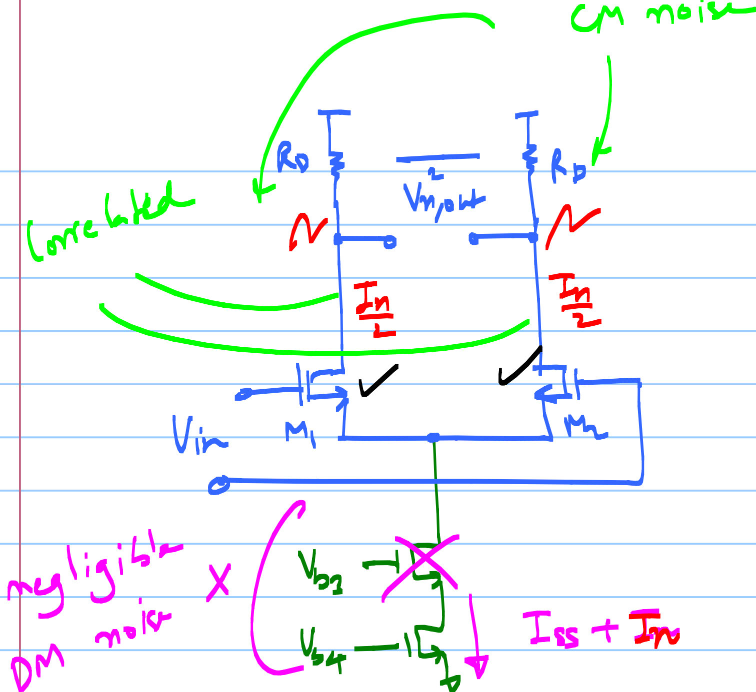
$$R_T = \frac{3}{2g_m}$$

$$\frac{4kT}{R_T} = \frac{8}{3}kTg_m$$

V_{n_1} & V_{n_2} are uncorrelated

$$\overline{V_{n,in}^2} = \overline{V_{n_1}^2} + \overline{V_{n_2}^2} + 2\times\frac{4kT}{g_{m_1}^2 R_D} + 1/f \text{ Noise}$$

$$\overline{V_{n,in}^2} = \boxed{8kT\Big(\frac{2}{3g_{m_{1,2}}}} + \frac{1}{g_{m_{1,2}}^2 R_D}\Big) + \frac{2K}{C_{ox}(WL)_{1,2}}\cdot\frac{1}{f}$$



$V_{in} = 0$

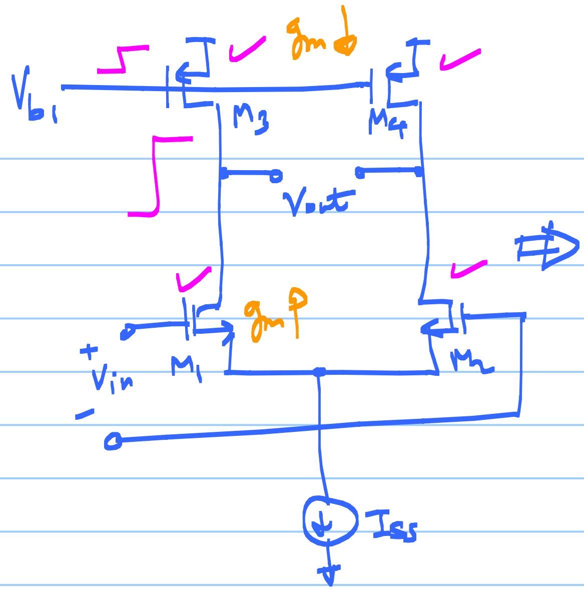
$V_{in} > 0$

$$\Delta I_{D_1} - \Delta I_{D_2} = g_m \Delta V_{in}$$

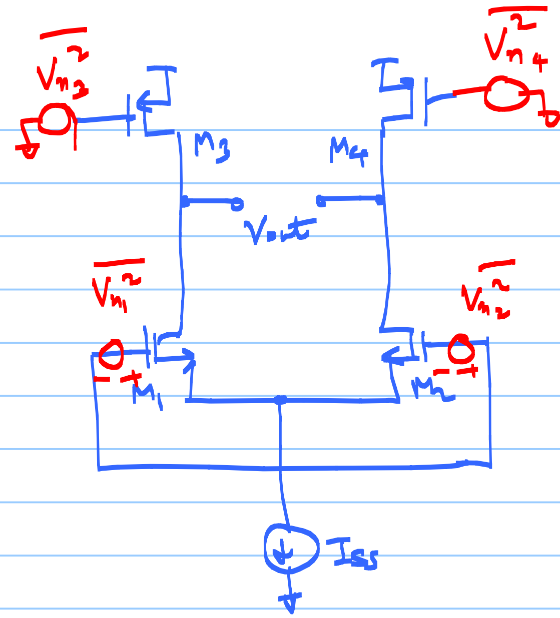
$$= g_{m0}\left(1 + \frac{I_n}{2 I_{ss}}\right) \cdot \Delta V_{in}$$

* for small inputs, the differential o/p noise is negligible

* Same goes for CMFB circuit noise

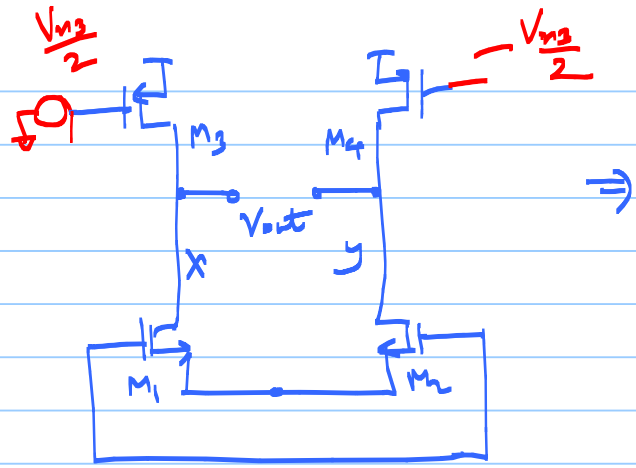


V_{b1}
g_m ↓
M_3
M_4
V_{out}
g_m ↑
M_1
M_2
V_{in}
I_{SS}

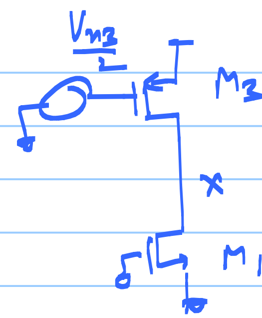


$\overline{V_{n3}^2}$
$\overline{V_{n4}^2}$
M_3
M_4
V_{out}
$\overline{V_{n1}^2}$
$\overline{V_{n2}^2}$
M_1
M_2
I_{SS}

Differential picture



$\Rightarrow$



$$\overline{V^2_{n,out}}\Big|_{M_3} = g_{m3}^2 (r_{o1}\|r_{o3})^2 \cdot \overline{V^2_{n3}}$$

$$\overline{V^2_{n,out}}\Big|_{M_4} = g_{m4}^2 (r_{o2}\|r_{o4})^2 \cdot \overline{V^2_{n4}}$$

$$\overline{V^2_{n,in}}\Big|_{M_3,M_4} = \frac{\overline{V^2_{n,out}}\big|_{M_3} + \overline{V^2_{n,out}}\big|_{M_4}}{A_v^2} \qquad \leftarrow g_{m1}^2 \cdot (r_{o1}\|r_{o3})^2$$

$$= 2 \times \frac{g_{m3}^2}{g_{m1}^2} \cdot \overline{V^2_{n3}}$$

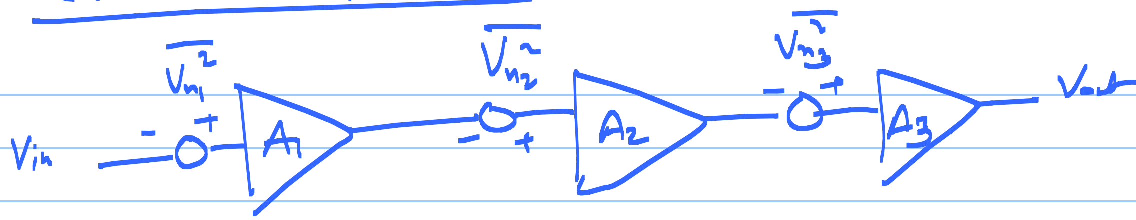
$$4kT\cdot\frac{2}{3}\frac{1}{g_{m3}}$$

$$\overline{V^2_{n,in}} = 2\overline{V^2_{n_1}} + 2\cdot\frac{g_{m3}^2}{g_{m1}^2}\cdot\overline{V^2_{n_3}}$$

$$= 8kT\left(\frac{2}{\underline{\underline{3g_{m1}}}} + \frac{2g_{m3}}{\underline{\underline{g_{m1}^2}}}\right) + \frac{2K_n}{C_{ox}(WL)_{1,2}\,f} + \frac{2K_p}{C_{ox}(WL)_{3,4}}\cdot\frac{1}{f}\cdot\frac{g_{m3}^2}{g_{m1}^2}$$

$g_{m1}\uparrow$, $g_{m3}\downarrow$

Cascaded Amplifiers

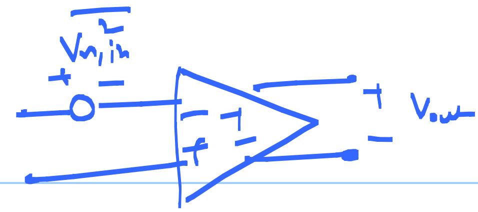


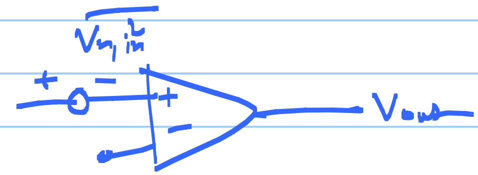
$$\overline{V_{n,out}^2} = \overline{V_{n_1}^2}\cdot(A_1A_2A_3)^2 + \overline{V_{n_2}^2}\cdot(A_2A_3)^2 + \overline{V_{n_3}^2}\cdot A_3^2$$

$$\overline{V_{n,in}^2} = \frac{\overline{V_{n,out}^2}}{(A_1A_2A_3)^2} = \underbrace{\overline{V_{n_1}^2}} + \frac{\overline{V_{n_2}^2}}{A_1^2} + \frac{\overline{V_{n_3}^2}}{A_1^2A_2^2}$$

first stage dominates

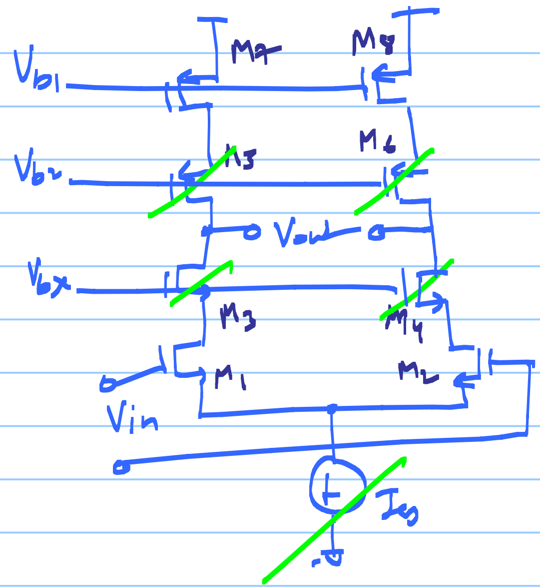
Noise in opamps



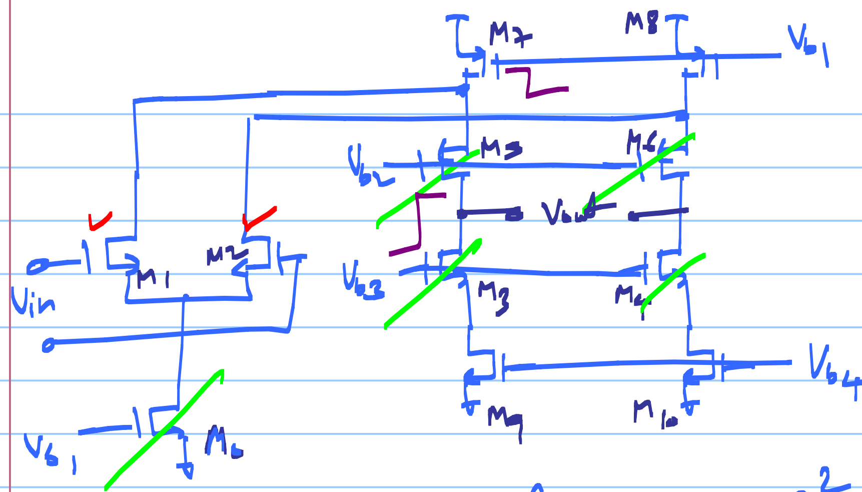


Telescopic

$M_{1,2}$ ← Primary Noise Contributors
$M_{7,8}$



$$\overline{V_n^2} = 4kT\left(2\cdot\frac{2}{3g_{m1,2}} + 2\cdot\frac{2}{3}\frac{g_{m7,8}}{g_{m1,2}^2}\right) + \frac{2K_N}{(WL)_{1,2}C_{ox}f} + \frac{2K_P}{(WL)_{7,8}C_{ox}f}\cdot\frac{g_{m7,8}^2}{g_{m1,2}^2}$$



$M_{1,2}$

$M_{7,8}$

$M_{9,10}$

$A_v = g_{m1} \cdot R_{out}$

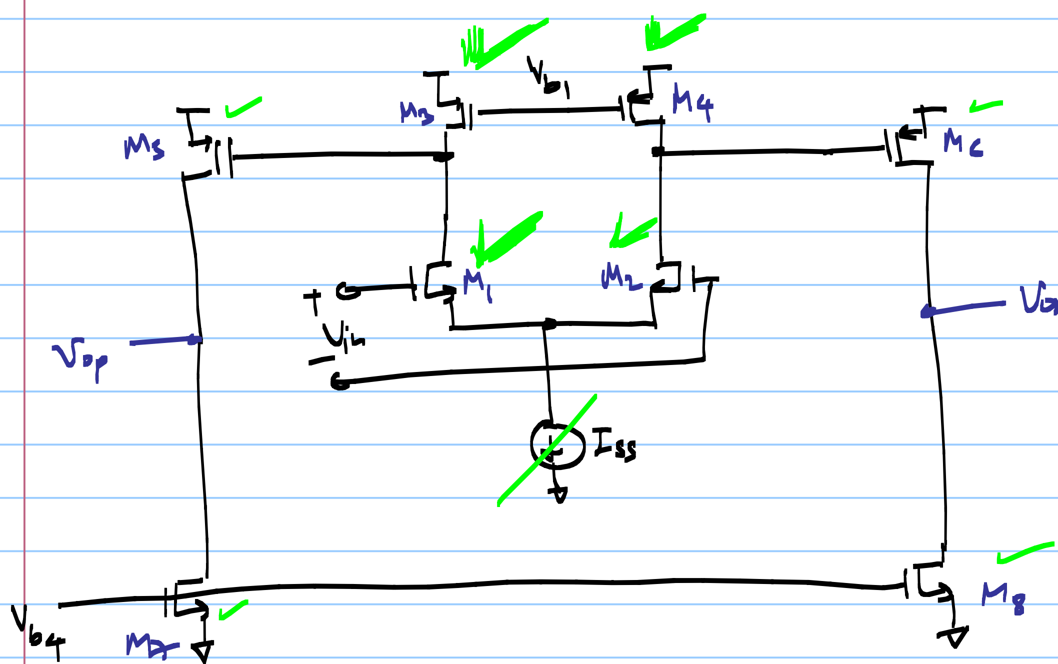
$$\overline{V_{n,out}^2}\Big|_{M_{7,8}} = 2\left(4kT\,\frac{2}{3g_{m7,8}} \cdot g_{m7,8}^2 \cdot R_{out}^2\right)$$

$$\overline{V_{n,out}^2}\Big|_{M_{9,10}} = 2\left(4kT \cdot \frac{2}{3g_{m9,10}} \cdot g_{m9,10}^2 R_{out}^2\right)$$

$$\overline{V_{n,in}^2} = 8kT\left(\frac{2}{3g_{m1,2}} + \frac{2}{3}\cdot\frac{g_{m7,8}}{g_{m1,2}^2} + \frac{2}{3}\,\frac{g_{m9,10}}{g_{m1,2}^2}\right) + \frac{1}{f} \text{ Noise terms.}$$

"Noise vs Output swing trade-off"

Two-stage opamp



* Second stage noise is divided by A_1^2

$$\overline{V_{n,in}^2}\Big|_{M_1-M_4} = 2\cdot 4kT\cdot\frac{2}{3}\cdot\frac{(g_{m1}+g_{m3})}{g_{m1}^2}$$

$$\overline{V_{n,in}^2}\Big|_{M_5-M_8} = \frac{2\cdot 4kT\cdot\frac{2}{3}\cdot(g_{m5}+g_{m7})\cancel{(r_{o5}||r_{o7})^2}}{g_{m1}^2\cdot(r_{o1}||r_{o3})^2\cdot g_{m5}^2\cdot\cancel{(r_{o5}||r_{o7})^2}}$$

$$= \frac{16kT}{3}\cdot\frac{(g_{m5}+g_{m7})}{g_{m1}^2\,g_{m5}^2\,(r_{o1}||r_{o3})^2}$$

$$\overline{V_{n,in}^2} = \frac{16kT}{3}\cdot\frac{1}{g_{m1}^2}\left[g_{m1}+g_{m3}+\frac{g_{m5}+g_{m7}}{g_{m5}^2(r_{o1}||r_{o3}^2)}\right].$$

small contribution from the 2nd stage