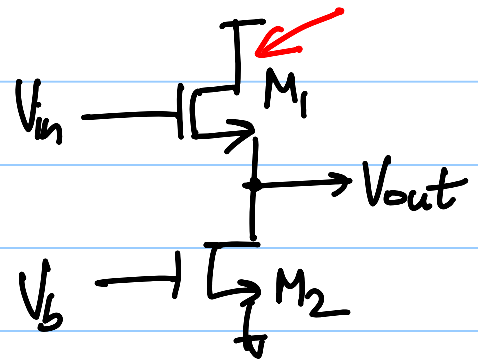
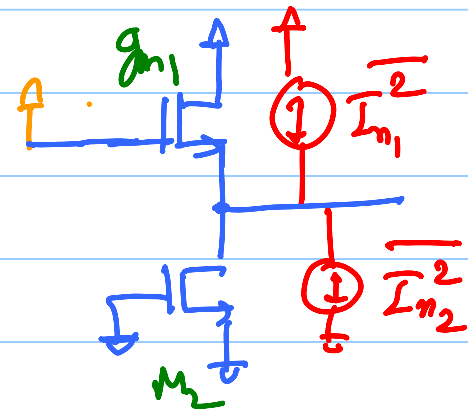
ECE 614 – Lecture 12

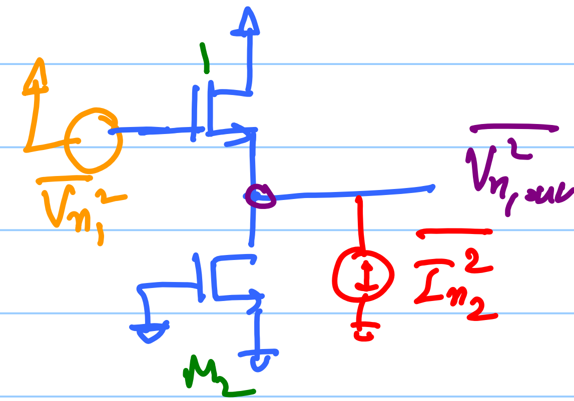
Note Title 10/2/2014



Noise circuit

$$\overline{V_{n_1}^2} = \frac{\overline{I_{n_1}^2}}{g_{m_1}^2}$$





$$A_v = \frac{\frac{1}{g_{mb_1}} \| r_{o_1} \| r_{o_2}}{\frac{1}{g_{mb_1}} \| r_{o_1} \| r_{o_2} + \frac{1}{g_{m_1}}} < 1$$

$$\left.\overline{V_{n,out}^2}\right|_{M_2} = \overline{I_{n_2}^2} \cdot \left(\frac{1}{g_{m_1}} \Big\| \frac{1}{g_{mb_1}} \Big\| r_{o_1} \Big\| r_{o_2} \right)$$

$$\overline{V_{n,in}^2} = \overline{V_{n_1}^2} + \frac{\overline{V_{n,out}^2}\Big|_{M_2}}{A_v^2}$$

$$\overline{V_{n,in}^2} \simeq \frac{8}{3}kT \cdot \left(\frac{1}{g_{m_1}} + \frac{g_{m_2}}{g_{m_1}^2} \right)$$

$g_{m_1} \uparrow$

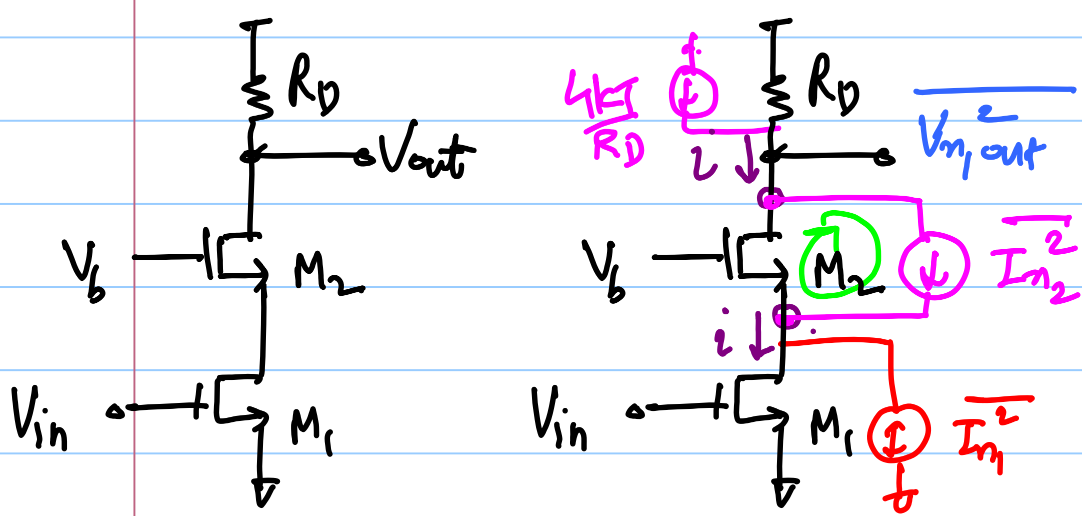
$g_{m_2} \downarrow$

$|A_v| < 1$

$\Rightarrow$

Cascode.

$$A_v = -g_{m_1}\left(\underbrace{g_{m_2} r_{o_2} r_{o_1}}_{g_m r_o^2} \,\|\, R_D\right)$$



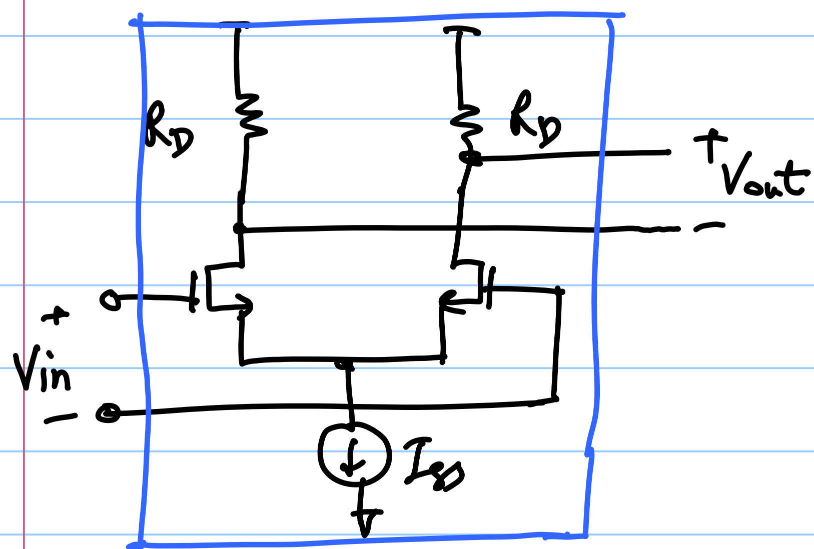
$I_{D_2} + I_{n_2} = 0$

@ low-frequencies & $r_{o_2} \to \infty$ $\Rightarrow$ I_{n_2} doesn't affect $V_{n,out}$

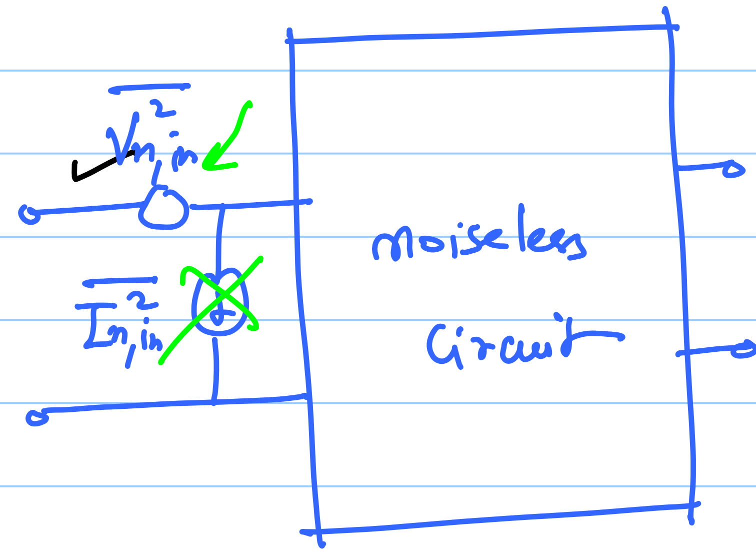
Noise behavior same as CS amplifier formed by M_1

$$\overline{V_{n,in}^2} = \frac{\overline{I_{n_1}^2}}{g_{m_1}^2} = \frac{8}{3}\frac{kT}{g_{m_1}} + \frac{4kT}{R_D} \times \frac{R_D^2}{(g_{m_1} \cdot R_D)^2} \Rightarrow \frac{4kT}{R_D\, g_m^2}$$

Differential Pair:

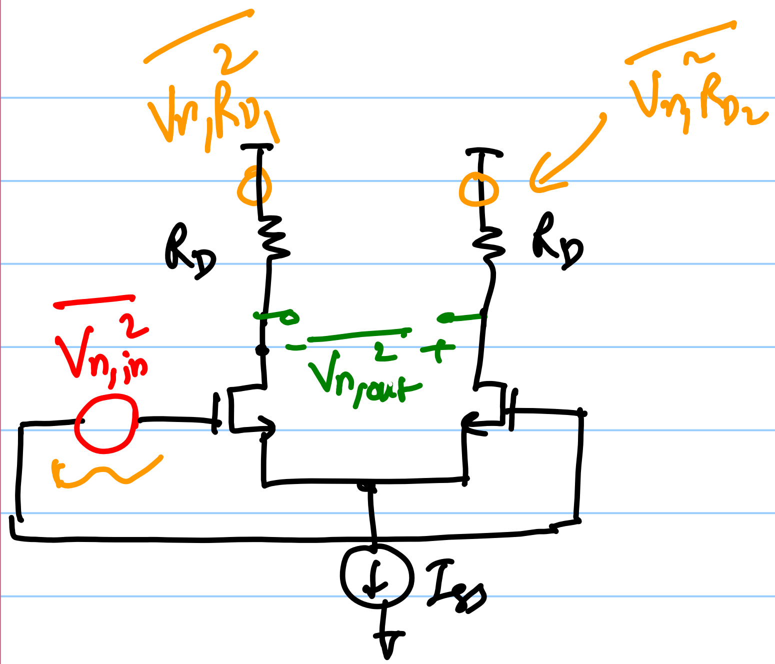


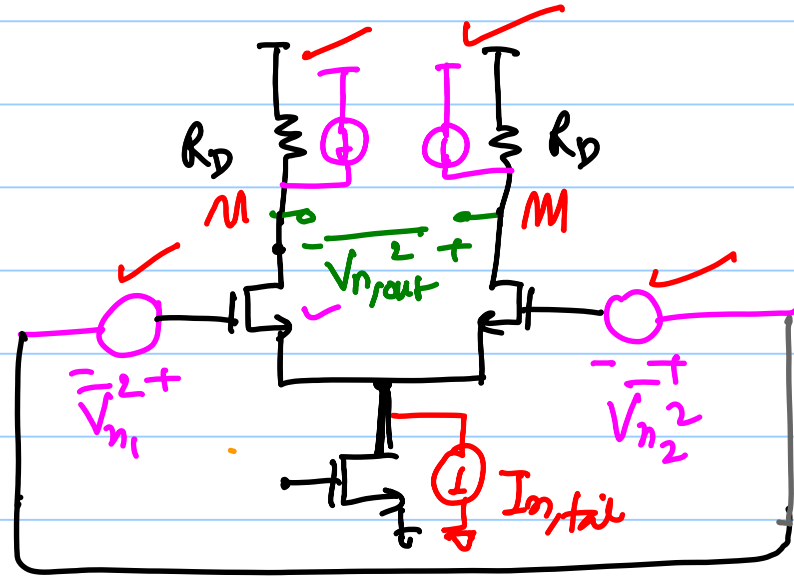
2-port circuit



@ low-f $Z_{in} \to \infty$

$\Rightarrow \overline{I^2_{n,in}}$ is negligible





$V_d \simeq 0$

$V_a > 0$

$$\overline{V_{n,in}^2} = \overline{V_{n_1}^2} + \overline{V_{n_2}^2} + 2\times\frac{4KT}{g_m^2 R_D}$$

$$\Rightarrow \overline{V_{n,in}^2} = 8KT\left[\frac{2}{3}g_m + \frac{1}{g_m^2 R_D}\right] + \frac{2K}{C_{ox}WL}\cdot\frac{1}{f}$$

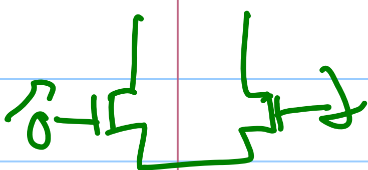
2X compared to a CS amplifier

$V_d = 0 \Rightarrow$ I_{ss} produces CM noise at the output

$\Rightarrow$ no contribution to the differential $\overline{V^2_{n,in}}$

↳ Correlated noise in the two halves gets cancelled out in differential output.

$V_d \simeq V_{in} \Rightarrow$



$$\Delta I_{D_1} - \Delta I_{D_2} = g_m \Delta V_{in} = g_{m_0}\left(1+\frac{I_n}{2I_{ss}}\right)\Delta V_{in}$$

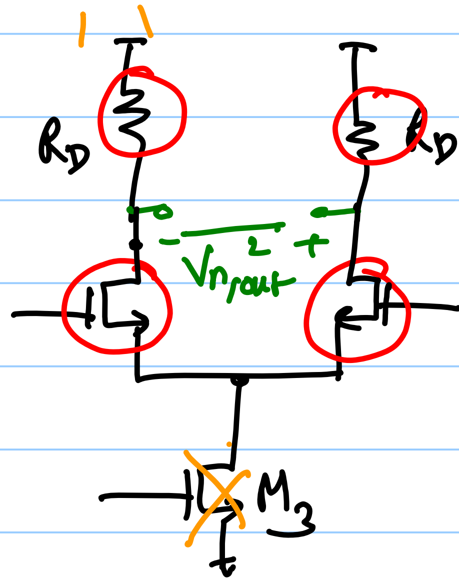
for $I_n << I_{ss}$

$\Rightarrow$ negligible effect

$$\frac{I_n^2}{I_{ss}^2} = \frac{\frac{8}{3}KT g_{m,tail}\cdot\Delta f}{I_{ss}^2} << 1$$

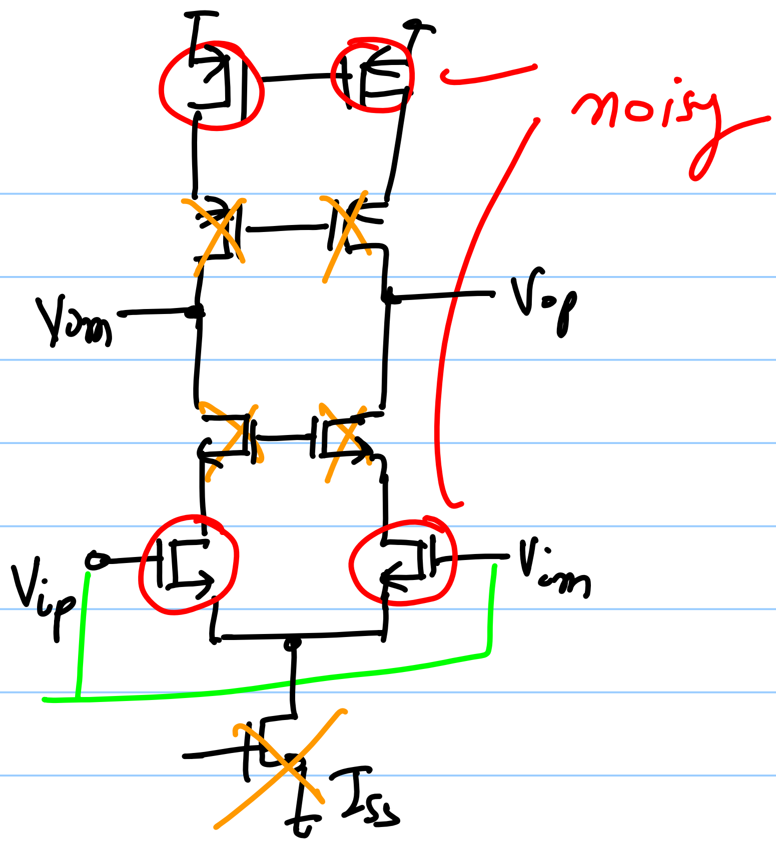
Contribution to $\overline{V_{n,in}^2}$

To minimize $\overline{V_{n,in}^2}$



$g_m \uparrow$

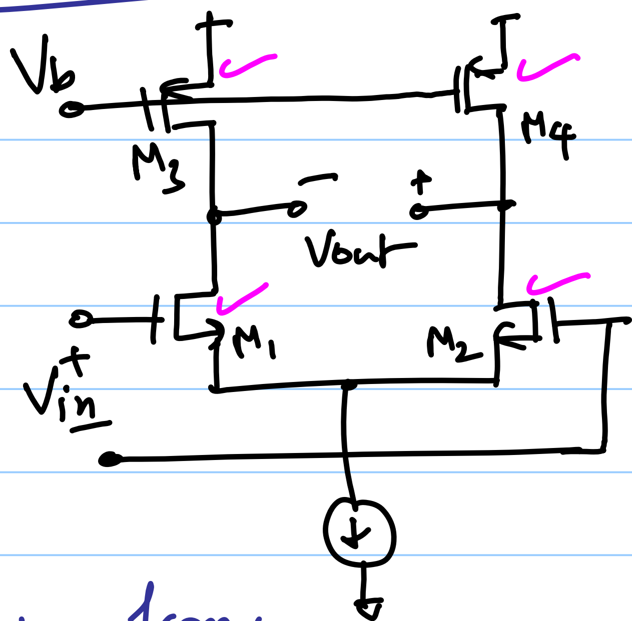
g_{m3} doesn't matter

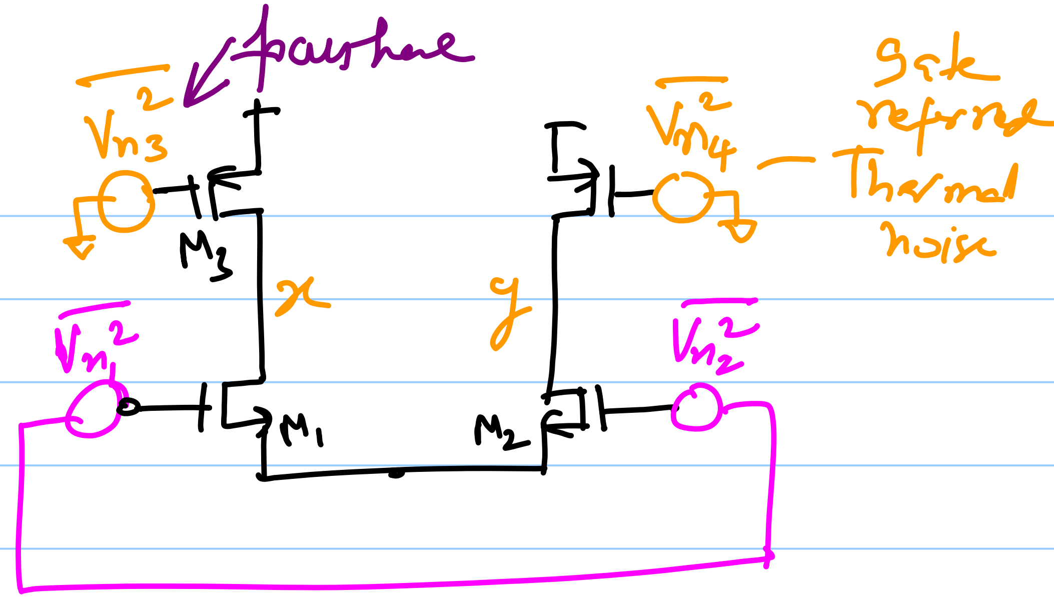


noisy
V_{om}
V_{op}
V_{ip}
V_{im}
I_{SS}

Ex:

Thermal Noise



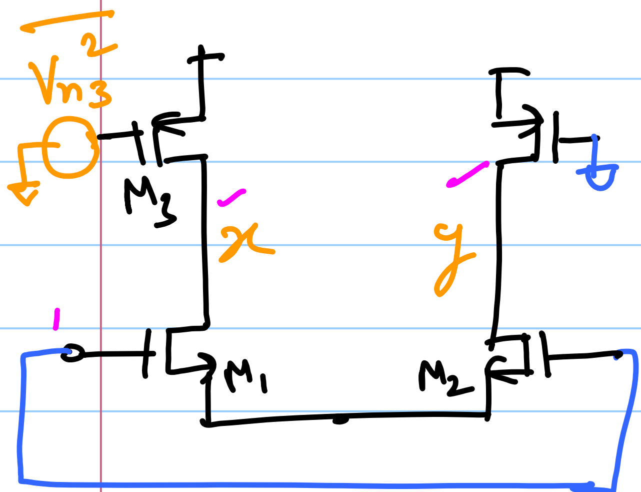


Contribution from M_1 & M_2 $\Rightarrow$ $\overline{V_{n_1}^2} + \overline{V_{n_2}^2}$

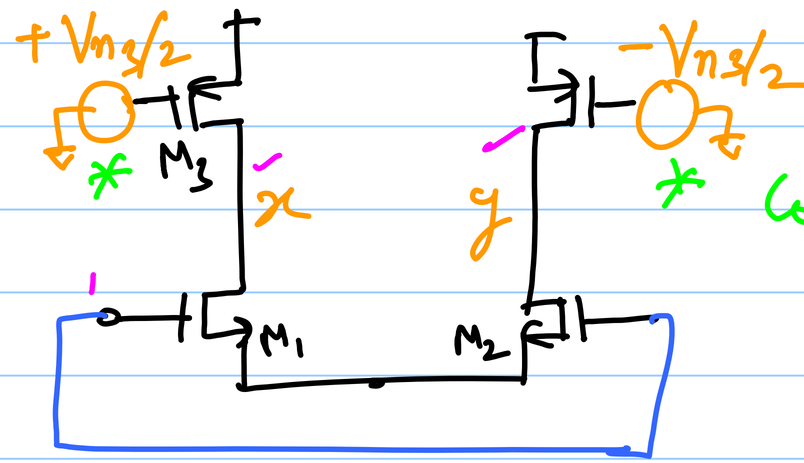
We need to refer M_3 & M_4's noise to the input

$\Rightarrow$ first refer $\overline{V_{n_3}^2}$ to the input side refer this to the input ⇒ Split into ~~CM~~ & DM noise circuits

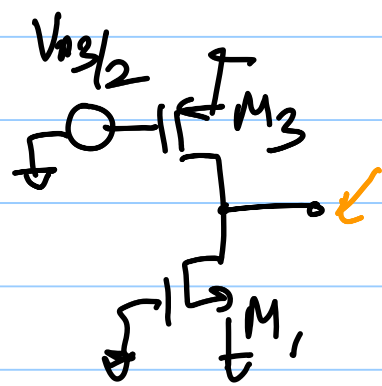
CM gets cancelled



Differential picture



Half Circuit



$$\left|g_{m3}\cdot\left(r_{o1}\,||\,r_{o3}\right)\right|\cdot\frac{V_{n3}}{2}$$

Since $\frac{V_{n3}}{2}$ & $-\frac{V_{n3}}{2}$ are correlated

⇒ Add them in voltage domain

$$\overline{V_{n,out}^2}\Big|_{M_3} = g_{m_3}^2 (r_{o1} \| r_{o3})^2 \cdot \overline{V_{n_3}^2}$$

$$\overline{V_{n,out}^2}\Big|_{M_4} = g_{m_4}^2 (r_{o2} \| r_{o4})^2 \cdot \overline{V_{n_4}^2}$$

Due to Correlation noise voltages add, not powers!

$$\overline{V_{n,in}^2}\Big|_{M_3,M_4} = \frac{\overline{V_{n,out}^2}\Big|_{M_3} + \overline{V_{n,out}^2}\Big|_{M_4}}{A_v^2}$$

A_v^2 — $g_{m_1}^2 (r_{o1} \| r_{o3})^2$

$$\overline{V_{n,in}^2} = 2\overline{V_{n_1}^2} + 2 \cdot \frac{g_{m_3}^2}{g_{m_1}^2} \times \overline{V_{n_3}^2}$$

$$\boxed{\overline{V_{n,in}^2} = 8KT\left[\frac{2}{3g_{m_1}} + \frac{2g_{m_3}}{3g_{m_1}^2}\right]}$$

Input referred Thermal Noise

Look up this example

$$\rightarrow \overline{V_{n,in}^2} = \underbrace{2\times\frac{8}{3}\frac{KT}{g_{m1}}}_{\text{diff pair}} + \underbrace{2\times\frac{8}{3}KT\cdot\frac{g_{m3}}{g_{m1}^2}}_{\text{CM loads}}$$

$$\frac{8}{3}KT\frac{g_{m3}}{g_{m3}^2} = \frac{8}{3}\frac{KT}{g_{m3}}$$

$$\frac{8}{3}\frac{KT}{\cancel{g_{m3}}}\times\frac{g_{m3}^{\cancel{2}}}{g_{m1}^2} = \frac{8}{3}KT\frac{g_{m3}}{g_{m1}^2}$$