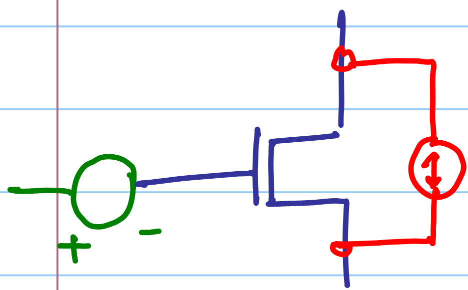
ECE 614 - Lecture 11

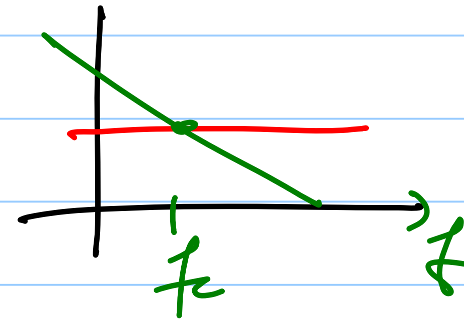
Note Title 9/30/2014

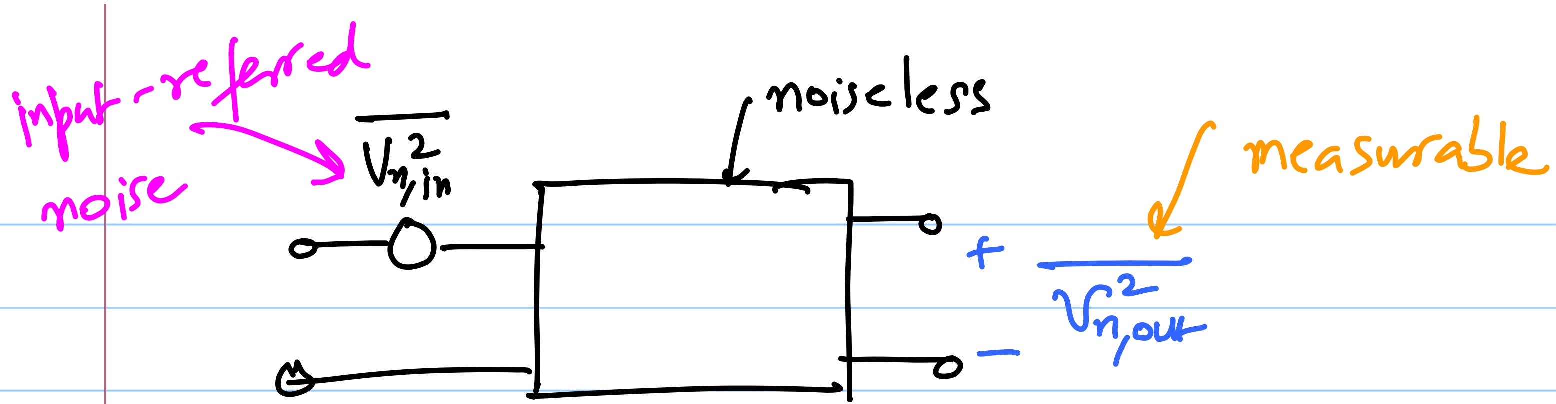


Thermal noise source

$$\overline{I_n^2} = 4kT\gamma g_m = \frac{8}{3}kT g_m$$

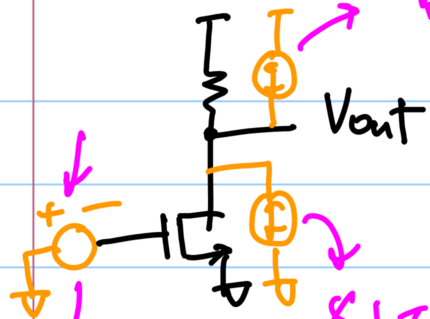
$$\overline{V_{n,1/f}^2} = \frac{K}{WLC'_{ox}} \cdot \frac{1}{f}$$





input-referred noise
$\overline{V_{n,in}^2}$
noiseless
measurable
+
−
$\overline{V_{n,out}^2}$

$\frac{4kT}{R} = \overline{i_{n,R}^2}$



$\frac{8}{3}kTg_m$

$\frac{K}{C_{ox}'WL}\frac{1}{f}$

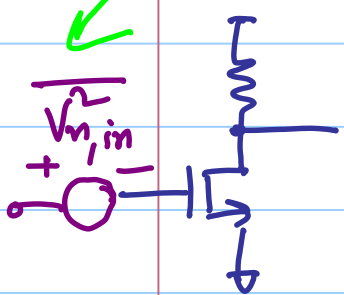
$i_d^2 = g_m^2 v_{gs}^2$

$$\overline{V_{n,out}^2} = \left[\frac{8}{3}kTg_m + \frac{K}{C_{ox}WL}\cdot\frac{1}{f}g_m^2 + \frac{4kT}{R_D}\right]\cdot R_D^2 \quad \frac{V^2}{Hz}$$

$$A_V = -g_m R_D$$

$$\overline{V_{n,in}^2} = \frac{\overline{V_{n,out}^2}}{A_V^2} = \left[\frac{8}{3}kTg_m + \frac{K}{C_{ox}WL}\cdot\frac{1}{f}g_m^2 + \frac{4kT}{R_D}\right]\cdot R_D^2 \times \frac{1}{g_m^2 R_D^2}$$

$$\overline{V_{n,in}^2} = \frac{8}{3}\frac{kT}{g_m} + \frac{K}{C_{ox}'WL}\cdot\frac{1}{f} + \frac{4kT}{g_m^2 R_D}$$



$\frac{8}{3}\frac{kT}{g_m}$: Thermal noise reflected at the gate input

$\frac{K}{C_{ox}'WL}\cdot\frac{1}{f}$: 1/f-noise

$\frac{4kT}{g_m^2 R_D}$: Resistor noise

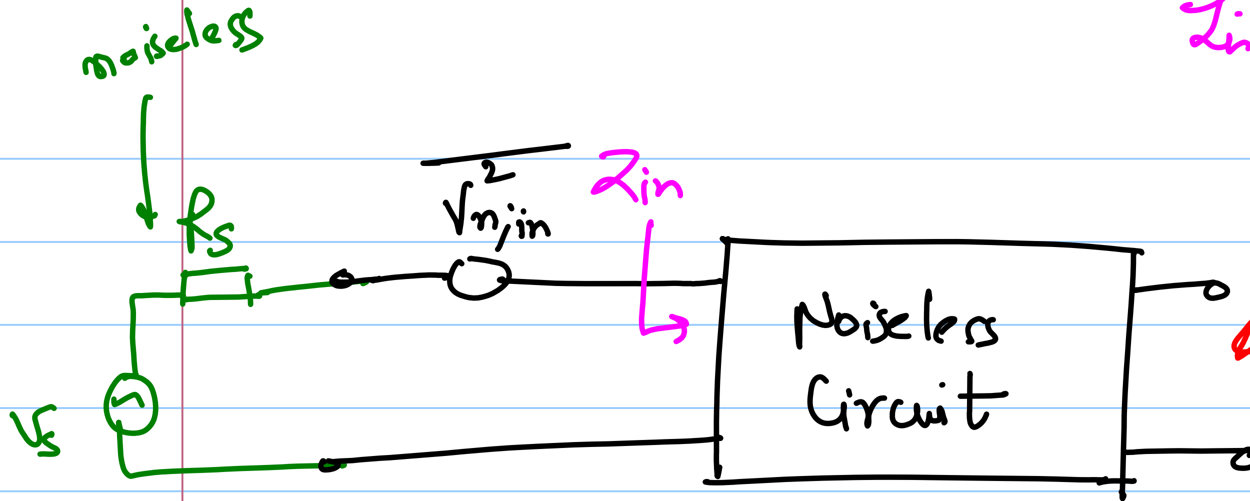
$\overline{V_{n,in}^2}$ represents how much the input signal is corrupted by the circuit's noise

↳ allows for fair comparison of two circuits

$\overline{V_{n,in}^2}$ is a fictitous quantity for calculations

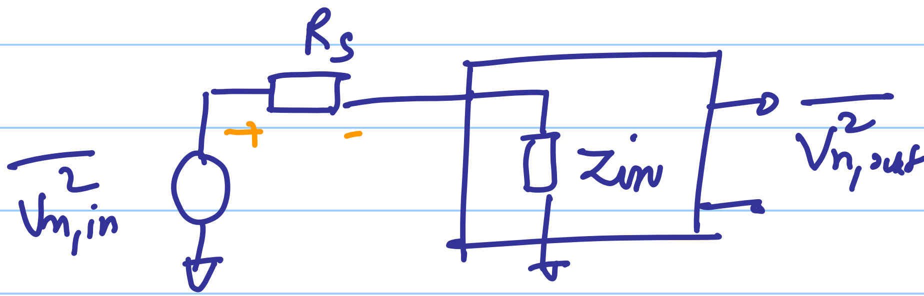
↳ only $\overline{V_{n,out}^2}$ can be measured

$Z_{in} = \infty$

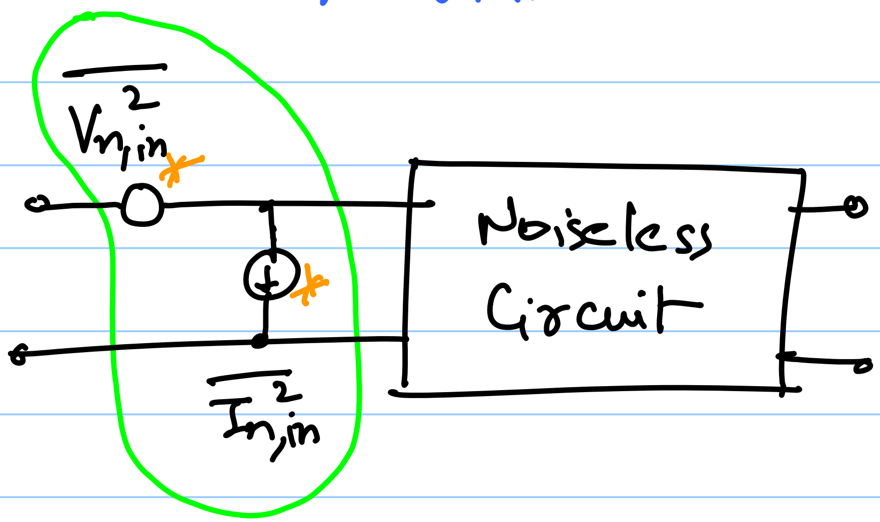


only valid for $Z_{in} \to \infty$

$Z_{in} \to 0$



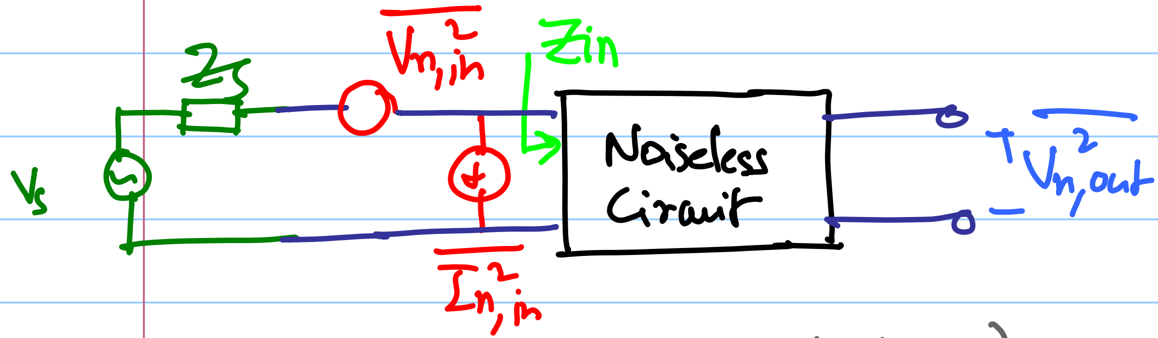
Accurate Noise Model with finite input impedance



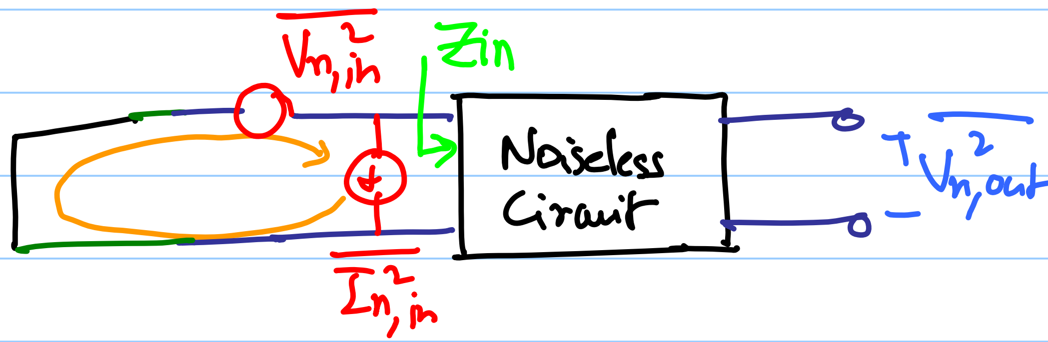
"$\overline{V_{n,in}^2}$ & $\overline{I_{n,in}^2}$ are correlated"

* $\overline{V_{n,in}^2}$ & $\overline{I_{n,in}^2}$ are necessary and sufficient to represent the noise of any linear two-port circuit.

Consider Extreme Cases for Z_s



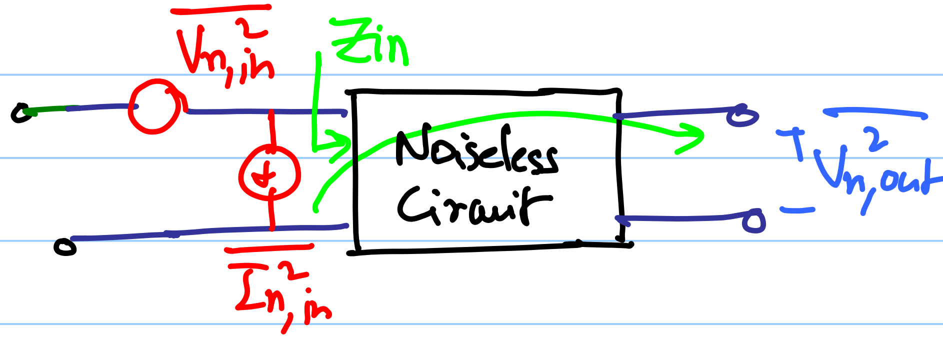
(a) $Z_s = 0$ (zero source impedance)



all noise current flows thru $\overline{V_{n,in}^2}$ and has no effect at the output

Method for finding $\overline{V_{n,in}^2}$

(b) $Z_s \to \infty$ (infinite source impedance)



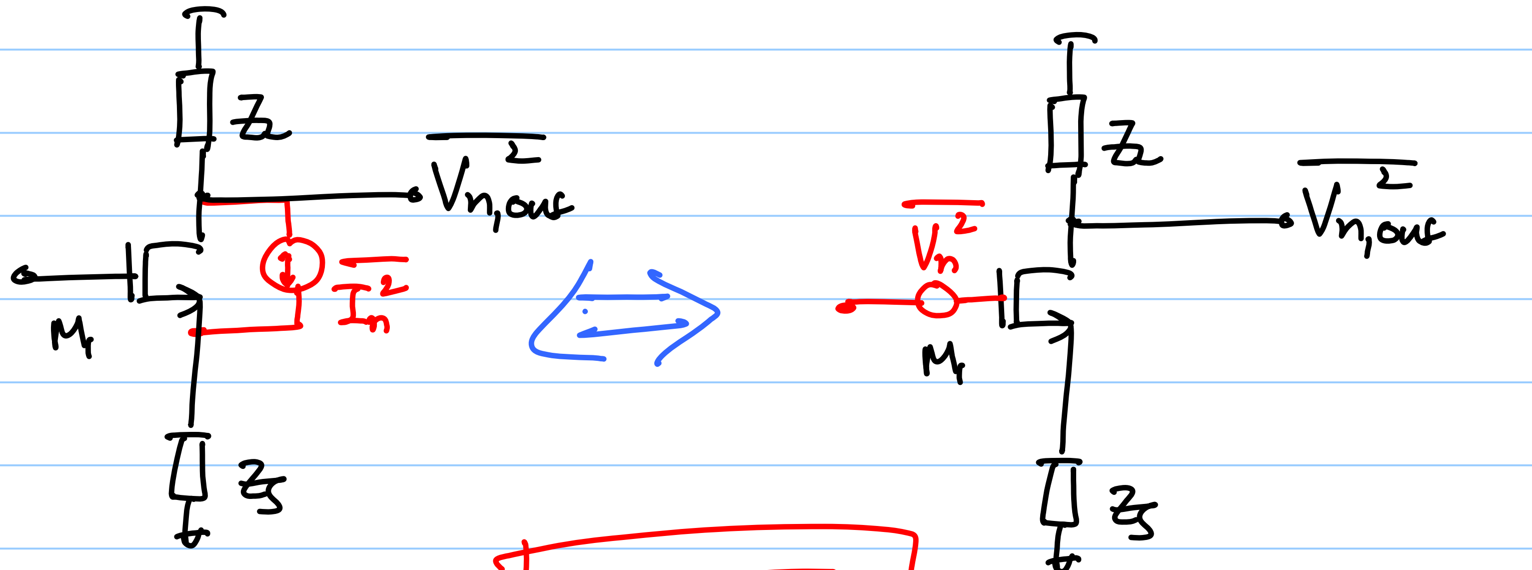
All output noise voltage is due to $\overline{I_{n,in}^2}$

Method for finding $\overline{I_{n,in}^2}$

Noise in Single-Stage Amplifiers

Theorem:

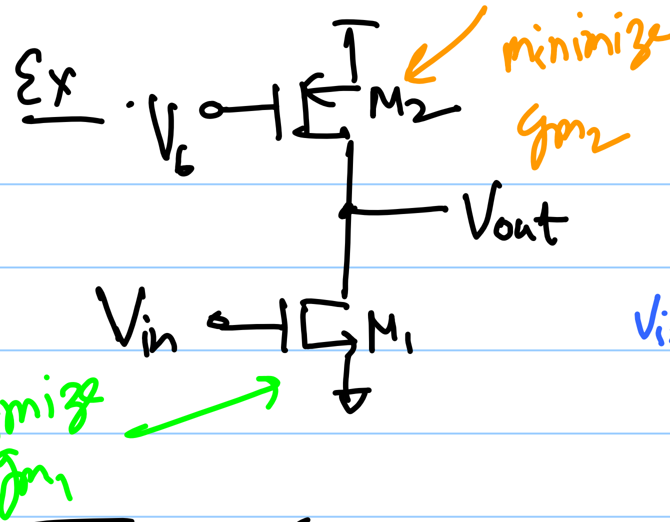
Proof in the Book

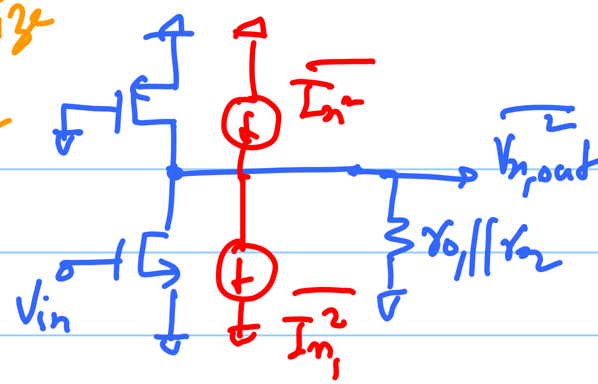


$$\overline{V_n^2} = \frac{\overline{I_n^2}}{g_m^2}$$

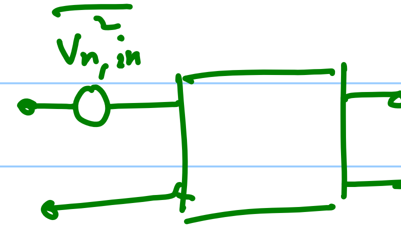
True for any value of Z_S

Ex.





$$A_v = -g_{m1}(r_{o1} \| r_{o2})$$



$$\overline{V_{n,out}^2} = \left(\frac{8}{3}kT\, g_{m1} + \frac{8}{3}kT g_{m2}\right)(r_{o1} \| r_{o2})^2$$

$$\overline{V_{n,in}^2} = \frac{\overline{V_{n,out}^2}}{A_v^2} = \left(\frac{8}{3}kT\, g_{m1} + \frac{8}{3}kT g_{m2}\right) \times \frac{(r_{o1} \| r_{o2})^2}{g_{m1}^2 \cdot (r_{o1} \| r_{o2})^2}$$

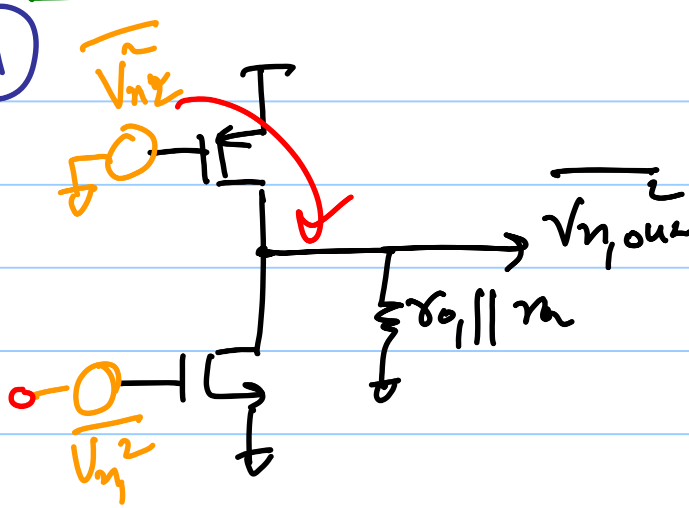
$$\overline{V_{n,in}^2} = \frac{8}{3}kT\left[\frac{1}{g_{m1}} + \frac{g_{m2}}{g_{m1}^2}\right]$$

To minimize noise $\Rightarrow$ $g_{m1} \uparrow$ * amplifier g_m

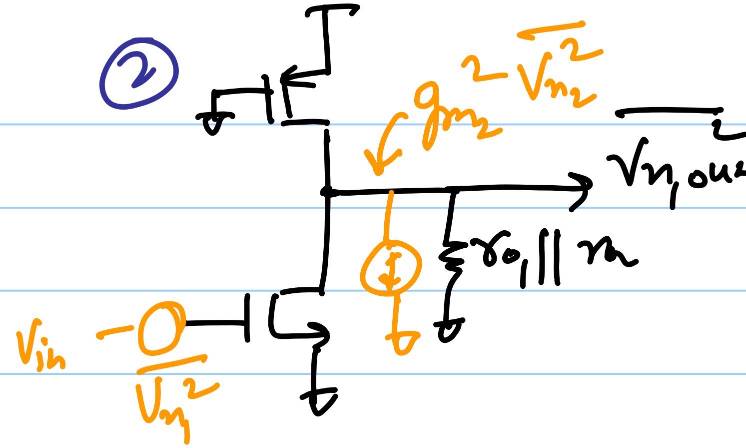
AND/OR $g_{m2} \downarrow$ * current source g_m

Flicker Noise.

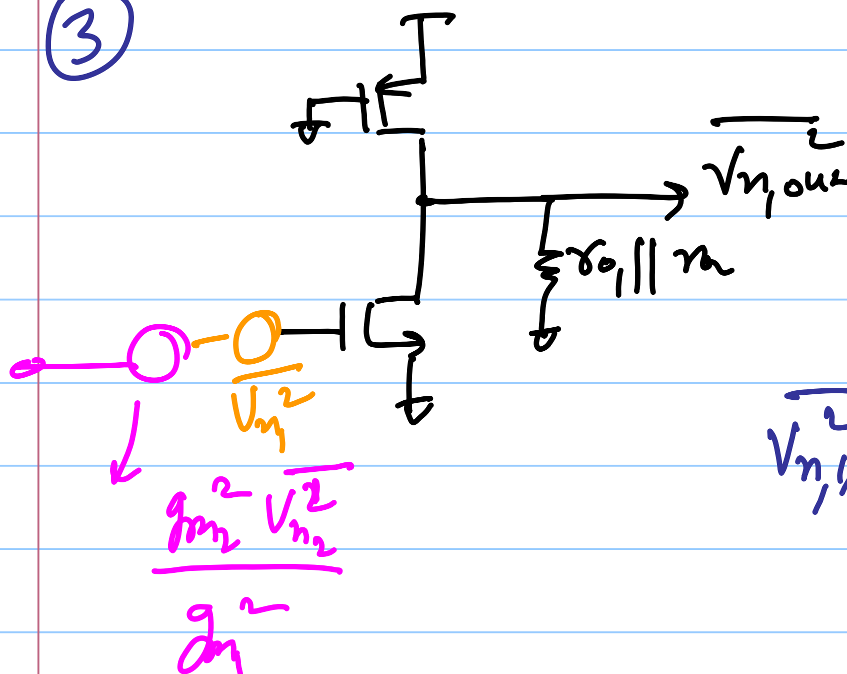
(1)



(2)



(3)



$$\overline{V_{n,1/f}^2} = \overline{V_{n1}^2} + \overline{V_{n2}^2} \cdot \left(\frac{g_{m2}}{g_{m1}}\right)^2$$

$$= \frac{K_n}{C_{ox}' W_1 L_1} \cdot \frac{1}{f} + \frac{K_p}{C_{ox}' W_2 L_2} \cdot \frac{1}{f} \cdot \left(\frac{g_{m2}}{g_{m1}}\right)^2$$

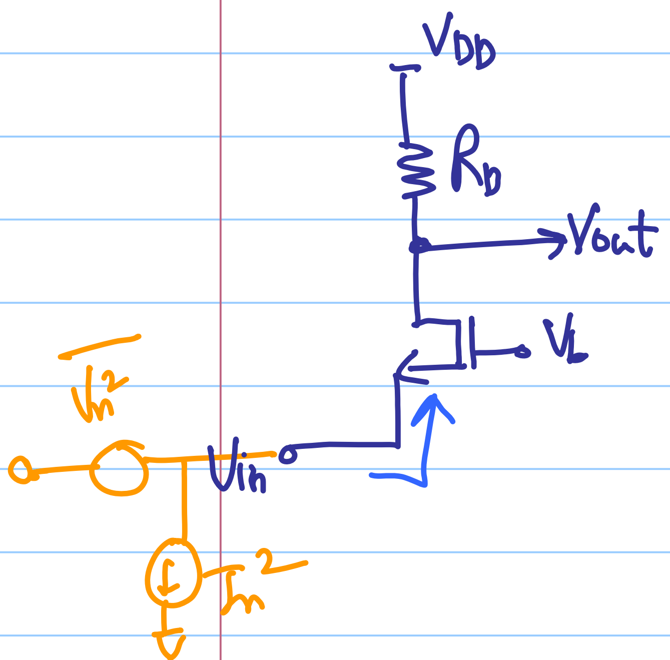
* To minimize $\overline{V_{n,in}^2}$ of a CS amplifier

* maximize g_{m1} → Increase I_D ⇒ more power, lower headroom

  ↓ increase W/L ⇐ more capacitance, lower BW

* minimize g_{m2} ⇒ $\left(\frac{W}{L}\right)\downarrow$

Common Gate Amplifier



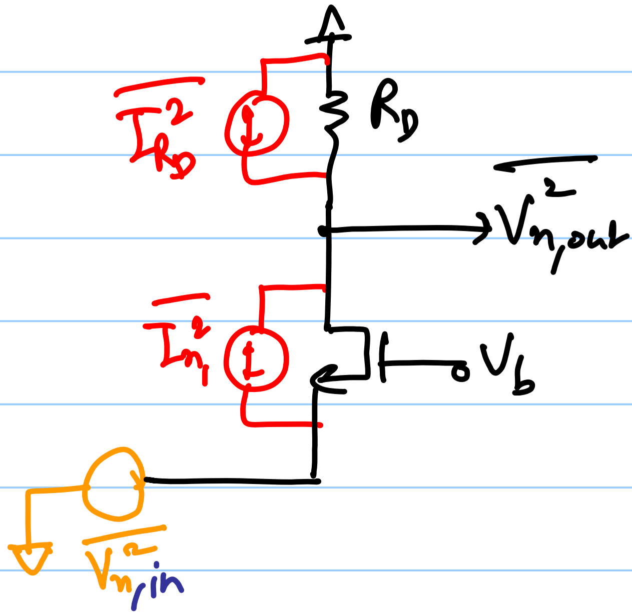
$$A_v = +g_m R_D$$

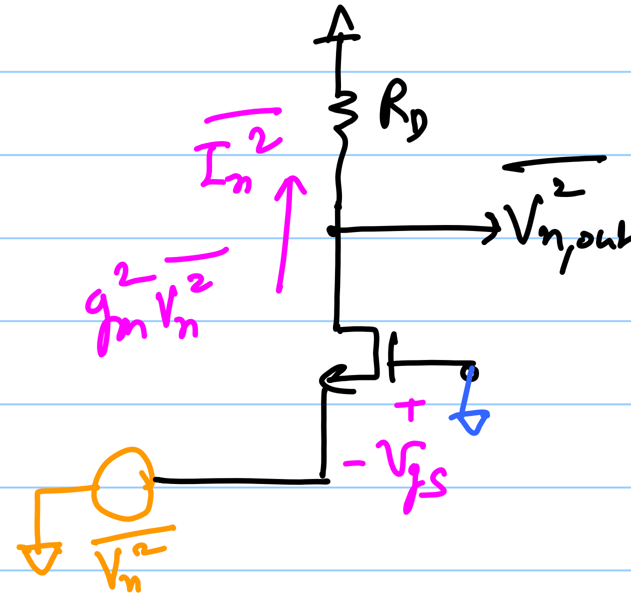
$$Z_{in} = \frac{R_D}{g_m r_o} + \frac{1}{g_m}$$

$$\simeq \frac{1}{g_m} \text{ for } R_D \ll r_o$$

Low Z_{in}

$\Rightarrow \overline{I_{n,in}^2}$ is not negligible for $\overline{V_{n,in}^2}$: Short input to ground and equate the output noise in the circuit.

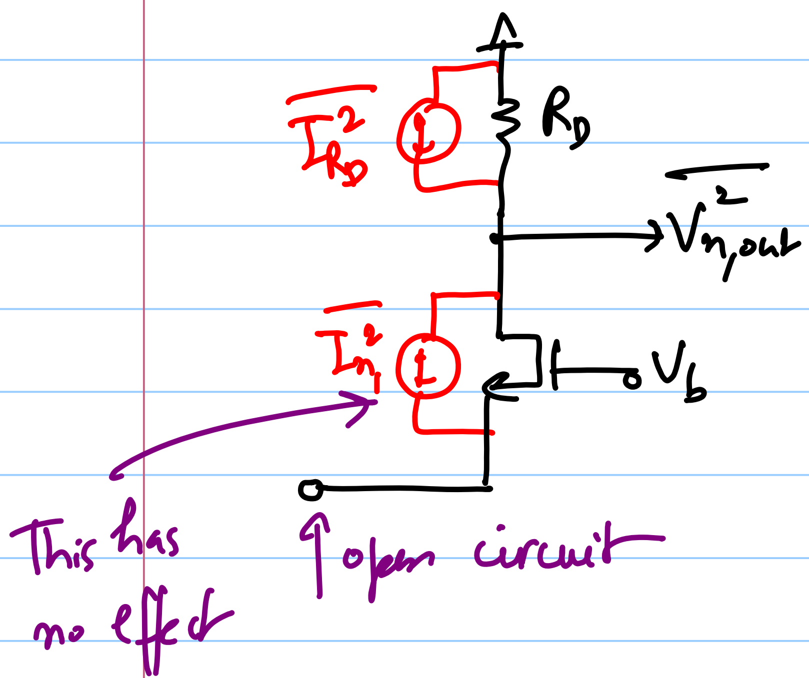


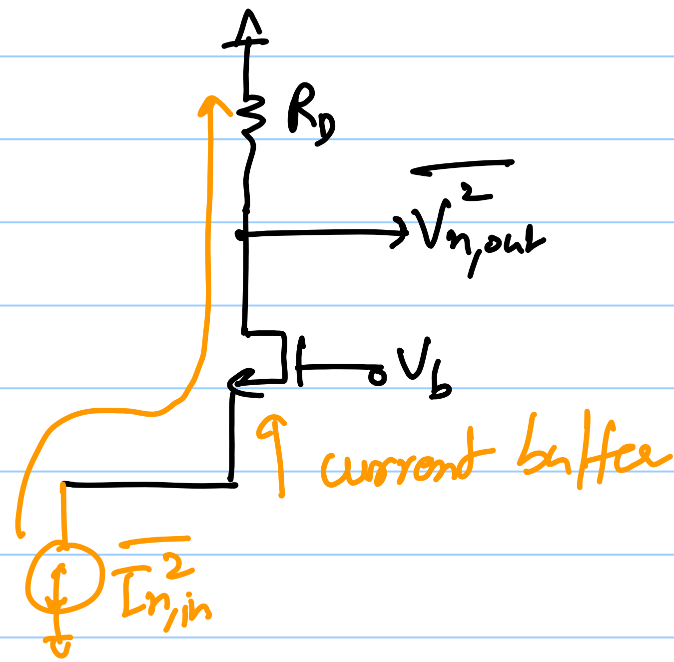


$$\overline{V_{n,out}^2} = \left(\frac{8}{3} kT g_m + \frac{4kT}{R_D}\right) \cancel{R_D^2} = (g_m + g_{mb})^2 \, \overline{V_{n,in}^2} \cdot \cancel{R_D^2}$$

$$\overline{V_{n,in}^2} = \frac{4kT \left(\frac{2}{3} g_m + \frac{1}{R_D}\right)}{(g_m + g_{mb})^2}$$

find $\overline{I_{n,in}^2}$





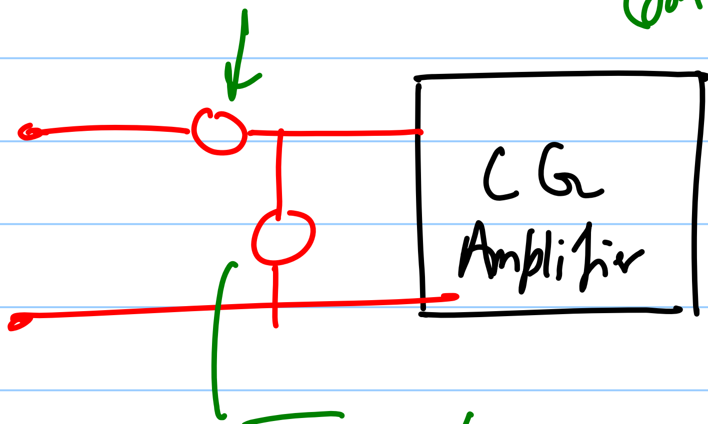
$$\overline{V_{n,out}^2} = 4KTR_D$$

$\overline{I_{n,1}^2}$ has no effect on $\overline{V_{n,out}^2}$

$$\overline{V_{n,out}^2} = 4KTR_D = \overline{I_{n,in}^2}\, R_D^2$$

$$\Rightarrow \boxed{\overline{I_{n,in}^2} = \frac{4KT}{R_D}} \checkmark$$

$$\overline{V_{n,in}^2} = \frac{4KT\left(\frac{2}{3}g_m + \frac{1}{R_D}\right)}{(g_m + g_{mb})^2}$$



$$\overline{I_{n,in}^2} = \frac{4KT}{R_D}$$

(–) CG topologies directly refer the noise current produced by the load to the input.

⇒ no current gain