Discussion 4

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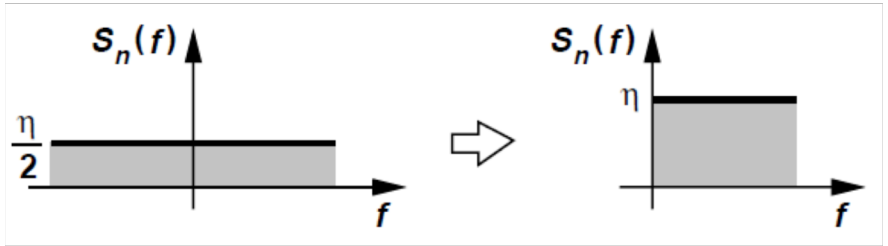
Outline

- More on noise .
  - Clarify on one side or two side , integral over ds or df
  - Decompose current noise source
  - Cascode
  - TIA noise example

Noise density

- One side or two side



- $\int_{-\infty}^{\infty} 2kT(\ldots)df = \int_{0}^{\infty} 4kT(\ldots)df$

Noise Integration

- $\int_0^\infty \left|\frac{1}{1+s/\omega_0}\right|^2 ds \rightarrow x$

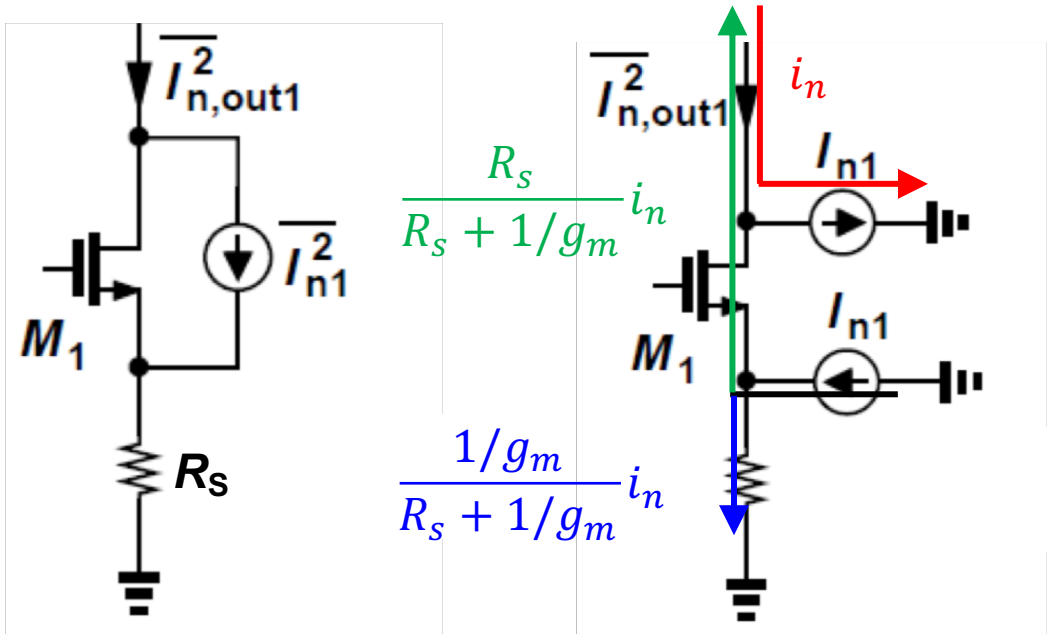
- $\int_0^\infty \left|\frac{1}{1+s/\omega_0}\right|^2 df$

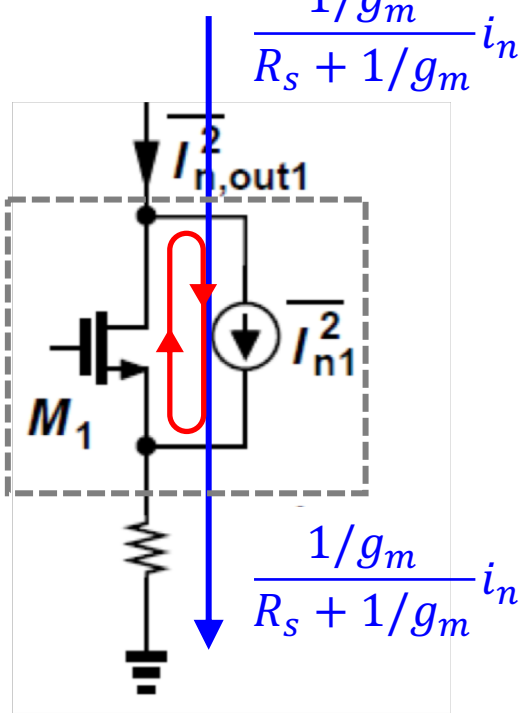
$$= \int_0^\infty \frac{1}{1^2+(2\pi f/\omega_0)^2} df$$

$$= \int_0^\infty \frac{1}{1^2+u^2} du \frac{\omega_0}{2\pi} = \tan^{-1} u \Big|_0^\infty \frac{\omega_0}{2\pi} = \frac{\omega_0}{4}$$

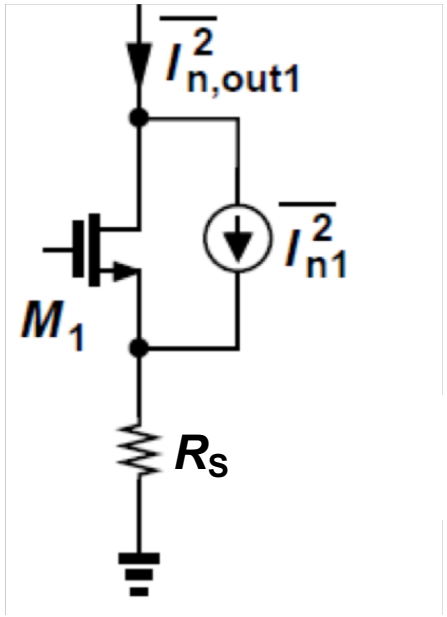
Noise with degeneration (I)

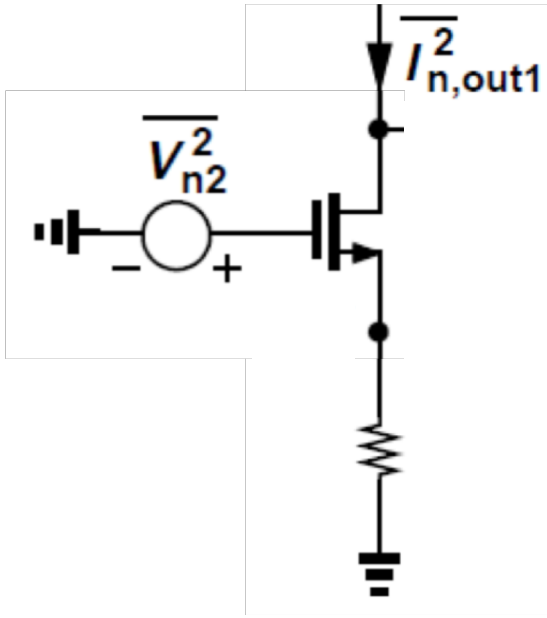
$$i_n - \frac{R_s}{R_s + 1/g_m} i_n = \frac{1/g_m}{R_s + 1/g_m} i_n$$





Noise with degeneration (II)





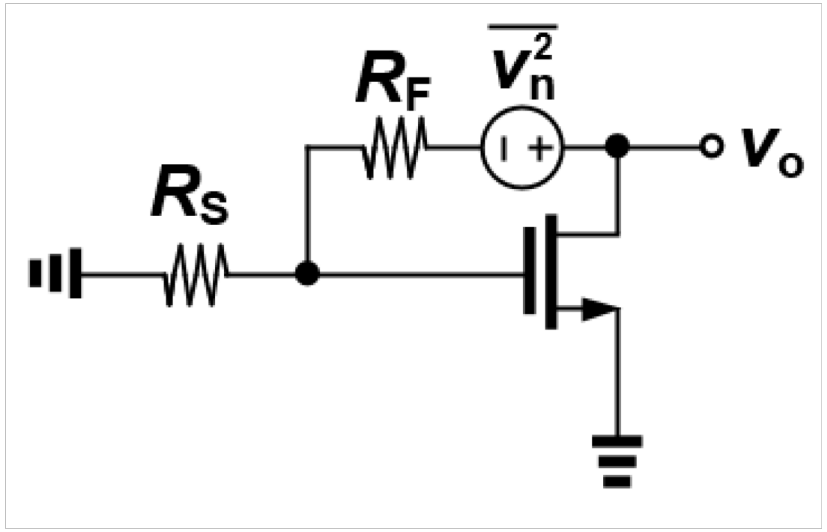
$$\left(\frac{g_m}{1+g_m R_s}\right)^2 \overline{v_n^2}$$

$$= \left(\frac{1}{R_s + 1/g_m}\right)^2 4kT\gamma/g_m$$

$$= \left(\frac{1/g_m}{R_s + 1/g_m}\right)^2 4kT\gamma g_m$$

$$= \left(\frac{1/g_m}{R_s + 1/g_m}\right)^2 \overline{i_n^2}$$

Noise of R_F

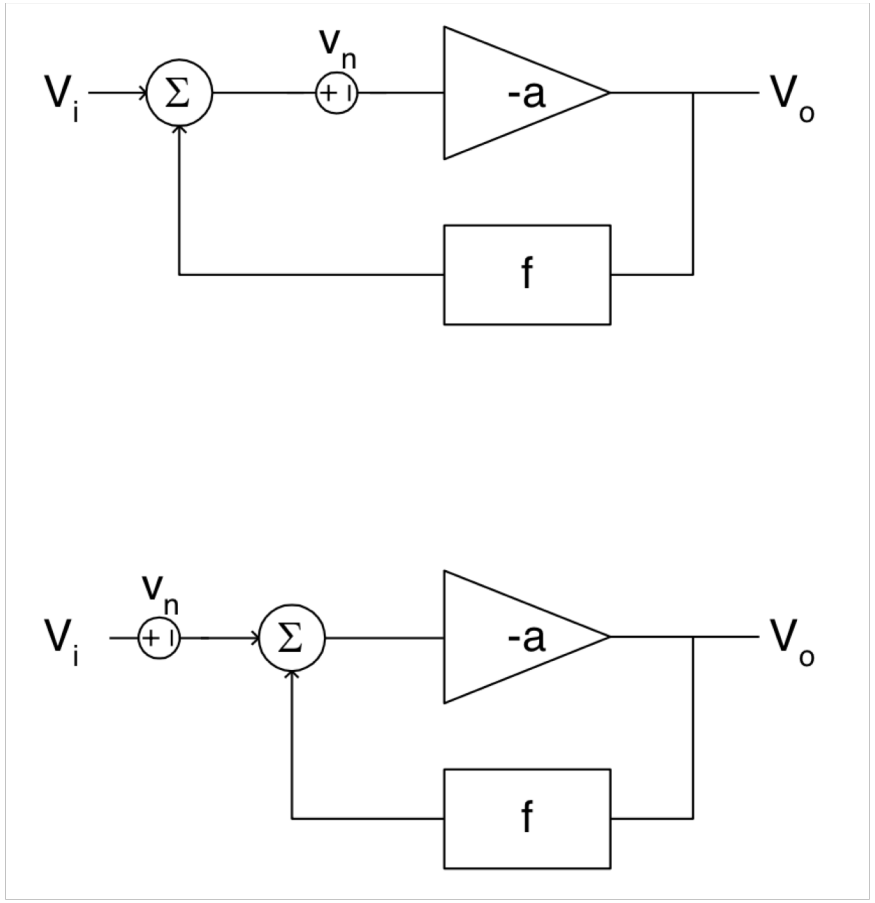


$$-(v_{n,o}-v_n)\frac{R_S}{R_S+R_F}g_m(R_S+R_F)=(v_{n,o}-v_n)$$

$$(1+g_mR_S)v_{n,o}=(1+g_mR_S)v_n$$

$$v_{n,o}=v_n$$

FB Noise



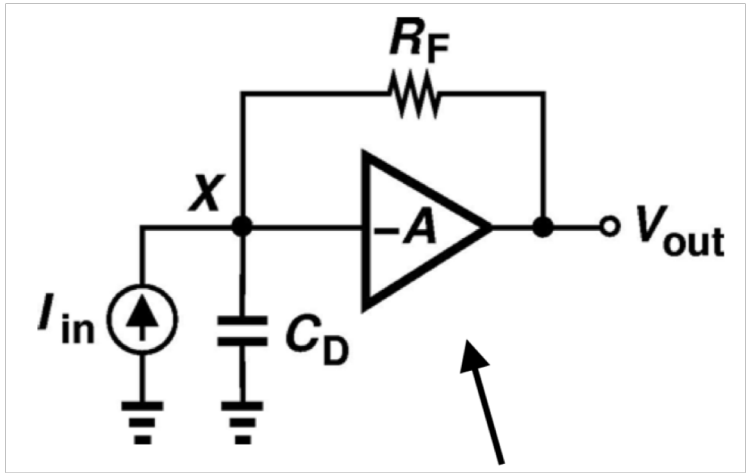
$$(V_i - fV_o - v_n)(-a) = V_o$$

$$V_o = (V_i - v_n)\frac{-a}{1-af}$$

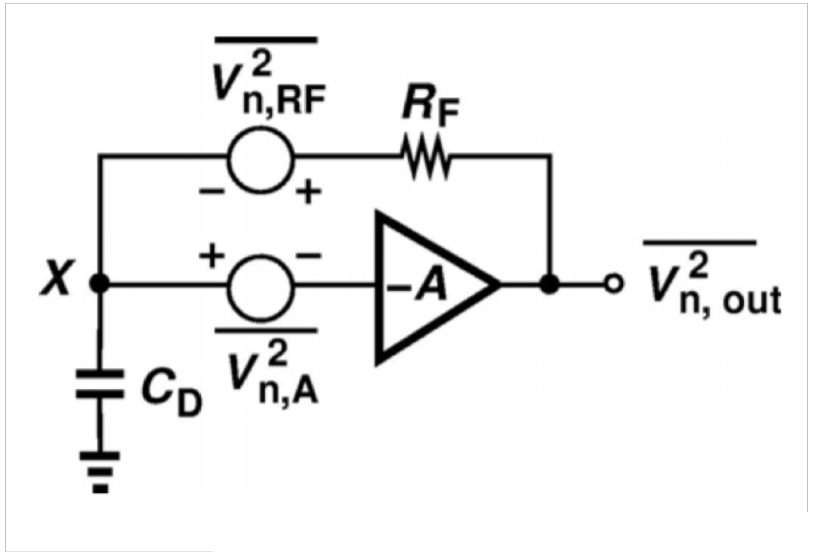
Input referred noise
open loop = closed loop

FB Noise

- Output noise of TIA



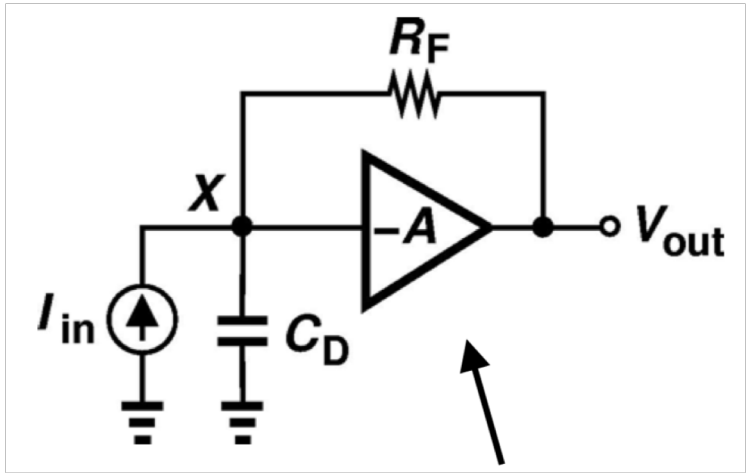
Ideal opamp



$V_{n,out} =$

FB Noise

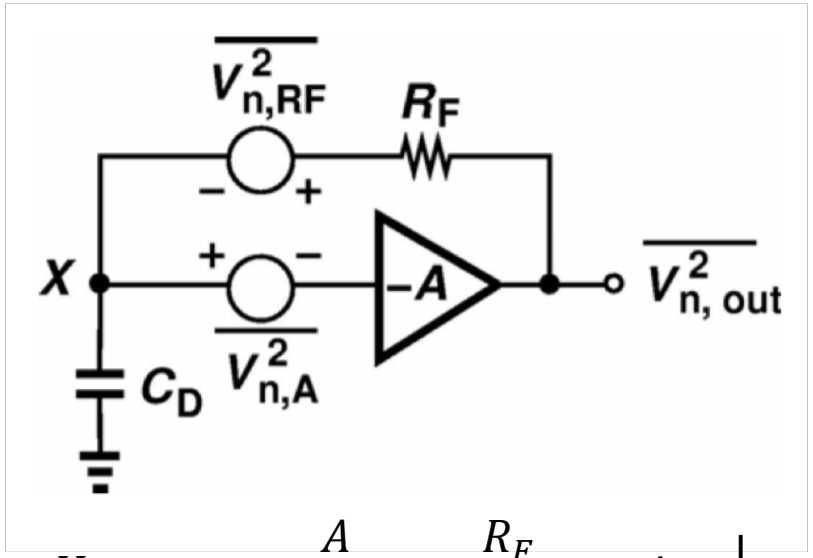
- Output noise of TIA



Ideal opamp

$$\frac{V_{out}}{I_{in}} = -\frac{A}{1+A}\frac{R_F}{1+\frac{sR_FC_D}{1+A}}$$

$$i_{n,in}\Big|_{open\ loop} = \frac{v_{n,RF}}{R_F} + \frac{v_{n,A}}{\frac{R_F}{1+sR_FC_D}}$$



$$V_{n,out} = -\frac{A}{1+A}\frac{R_F}{1+\frac{sR_FC_D}{1+A}} \cdot i_{n,in}\Big|_{open\ loop}$$

$$= -\frac{A}{1+A}\frac{R_F}{1+\frac{sR_FC_D}{1+A}} \cdot \frac{v_{n,RF} + v_{n,A}(1+sR_FC_D)}{R_F}$$

$$= -\frac{v_{n,RF} + v_{n,A}(1+sR_FC_D)}{\frac{A}{1+A} + \frac{sR_FC_D}{A}}$$