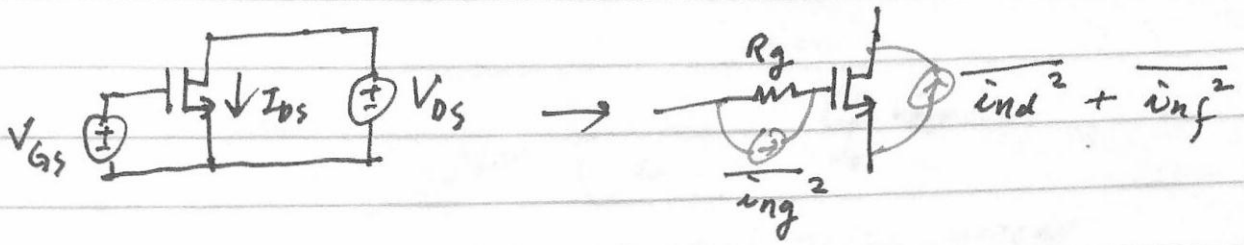
⊛ MOS Noise Model

In the noise analysis part, we developed this noise model.



① $\overline{i_{ng}^2} = \dfrac{4KT\Delta f}{R_g}$

② $\overline{i_{nd}^2} = 4KT\gamma g_m \Delta f$ ↘ more exact expression

$= 4KT\gamma g_{do}\Delta f$

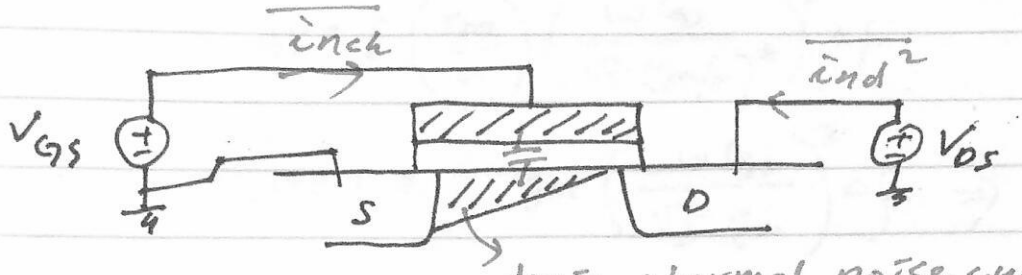
($\gamma = \frac{2}{3}$ for long channel; $\gamma \sim 4$ for short channel)

- γ: drain thermal noise coefficient
- for long channel ⇒ $\boxed{g_{do} = g_m}$
- for short channel ⇒ $\boxed{g_{do} = g_m/\alpha}$

③ $\overline{i_{nf}^2} \cong \dfrac{K_f}{W \cdot L \cdot C_{ox}} \cdot \dfrac{g_m^2}{f}\Delta f$

(Let's ignore this flicker noise in this LNA designs)

④ Now let's introduce another noise ~~se~~ which is induced gate noise (or induced channel noise).



drain thermal noise current generates noise voltage across channel.
This noise voltage will be coupled capacitively into the gate terminal, causing a gate noise current.

⇒ This is "induced channel noise" (or induced gate noise).

$$\overline{i_{nd}^2} = 4KT\gamma g_{do}\Delta f$$

⇒ effective channel noise voltage

$$\overline{v_{nd}^2} \propto \overline{i_{nd}^2} \times \left(\frac{1}{g_{do}}\right)^2 = \frac{4KT\gamma}{g_{do}}\Delta f$$

⇒ effective induced ~~data~~ gate noise current

$$\overline{i_{n,ch}^2} \propto \overline{v_{nd}^2} \times \omega^2 C_{gs}^2 = 4KT\gamma \frac{\omega^2 C_{gs}^2}{g_{do}}\Delta f$$

$$= 4KT\gamma g_{do}\left(\frac{\omega C_{gs}}{g_{do}}\right)^2 \Delta f$$

⇒ More exact expression
(according to "Van Der Ziel" noise model)

$$\overline{i_{nch}^2} = 4KT\delta g_{do}\left(\frac{\omega C_{gs}}{\sqrt{5}\cdot g_{do}}\right)^2 \Delta f$$

~~δ = gate noise~~ · δ = induced gate noise coefficient.
· typically $\delta = 2\gamma$.

$$\overline{i_{nch}^2} = 4KT\delta g_{do}\left(\frac{\omega C_{gs}}{\sqrt{5}\, g_{do}}\right)^2 \Delta f$$

$$= 4KT\delta\left(\frac{g_m}{\alpha}\right)\left(\frac{\omega C_{gs}}{\sqrt{5}\,(g_m/\alpha)^*}\right)^2 \Delta f$$

$$= 4KT\alpha\cdot\delta\cdot g_m\left(\frac{\omega C_{gs}}{\sqrt{5}\, g_m}\right)^2 \Delta f \Rightarrow \text{another expression in terms of } g_m.$$

NOTE) - Drain thermal noise current and induced gate noise are originated from same source.

- The two noise sources can thus to be expected to be correlated.
- They are completely correlated?

  No, because of the capacitive coupling there is only a partial correlation.

Let's separate $\overline{i_{nch}}$ into correlated and non-correlated part to drain noise current.

$$\overline{i_{nch}^2} = 4KT\delta g_{do}\left(\frac{\omega C_{gs}}{\sqrt{5}\, g_{do}}\right)^2 (1-|c|^2)\Delta f \Rightarrow \text{uncorrelated part}$$

$$+ 4KT\delta g_{do}\left(\frac{\omega C_{gs}}{\sqrt{5}\, g_{do}}\right)^2 |c|^2 \Delta f \Rightarrow \text{correlated part}$$

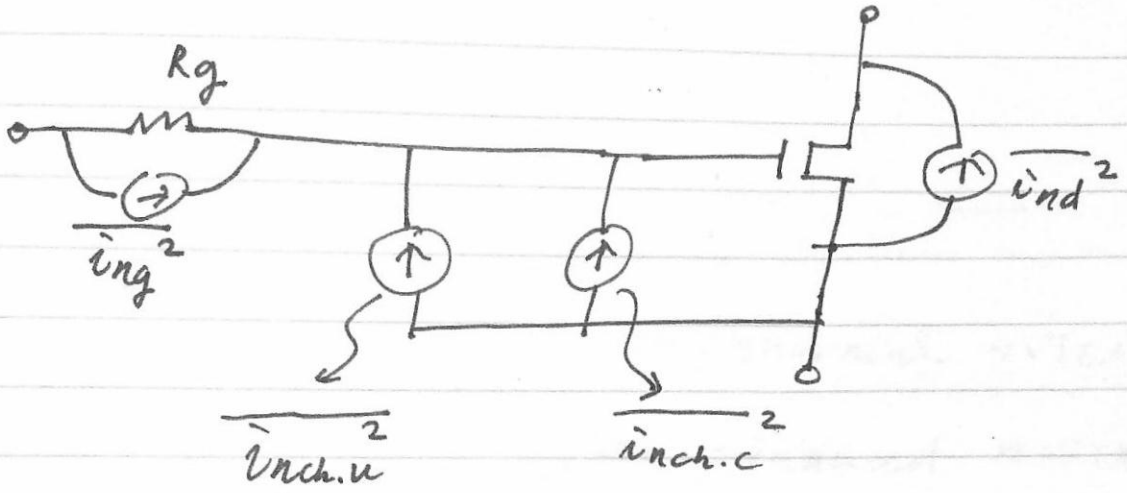
$$= 4KT\delta g_g (1-|c|^2)\Delta f + 4KT\delta g_g |c|^2 \Delta f$$

where, $g_g = \frac{\omega^2 C_{gs}^2}{5 g_{do}} = \alpha\frac{\omega^2 C_{gs}^2}{5\cdot g_m} = \alpha g_m\left(\frac{\omega^2 C_{gs}^2}{5 g_m^2}\right)$

$$= \alpha g_m\left(\frac{1}{\sqrt{5}}\frac{\omega}{\omega_T}\right)^2$$

$$C = \frac{\overline{i_{nch}\cdot i_{nd}^*}}{\sqrt{\overline{i_{nch}^2}\cdot\overline{i_{nd}^2}}} \simeq ; 0.395$$

complete MOS noise model for LNA design



① $\overline{i_{ng}^2} = \frac{4KT}{R_g}\Delta f$

② $\overline{i_{nd}^2} = 4KT\,\gamma\, g_{do}\Delta f = 4KT\frac{\gamma}{\alpha} g_m \Delta f$

③ $\overline{i_{nch.u}^2} = 4KT\,\delta\, g_g (1-|C|^2)\Delta f$

④ $\overline{i_{nch,c}^2} = 4KT\,\delta\, g_g |C|^2 \Delta f$

where / $g_g = \frac{\omega^2 C_{gs}^2}{5 g_{do}} = \alpha \frac{\omega^2 C_{gs}^2}{5 \cdot g_m}$

$C \simeq j0.395 \simeq j0.4$

γ : drain noise coefficient $\simeq \begin{cases} 2/3 & \text{for long channel} \\ 2 & \text{for short channel} \end{cases}$

δ : induced gate noise coefficient $(\simeq 2\gamma) \simeq \begin{cases} 4 & \text{for short channel} \\ \frac{4}{3} & \text{for long channel} \end{cases}$

α : $g_m/g_{do} \simeq \begin{cases} 0.8 & \text{for short channel} \\ 1 & \text{for long channel} \end{cases}$