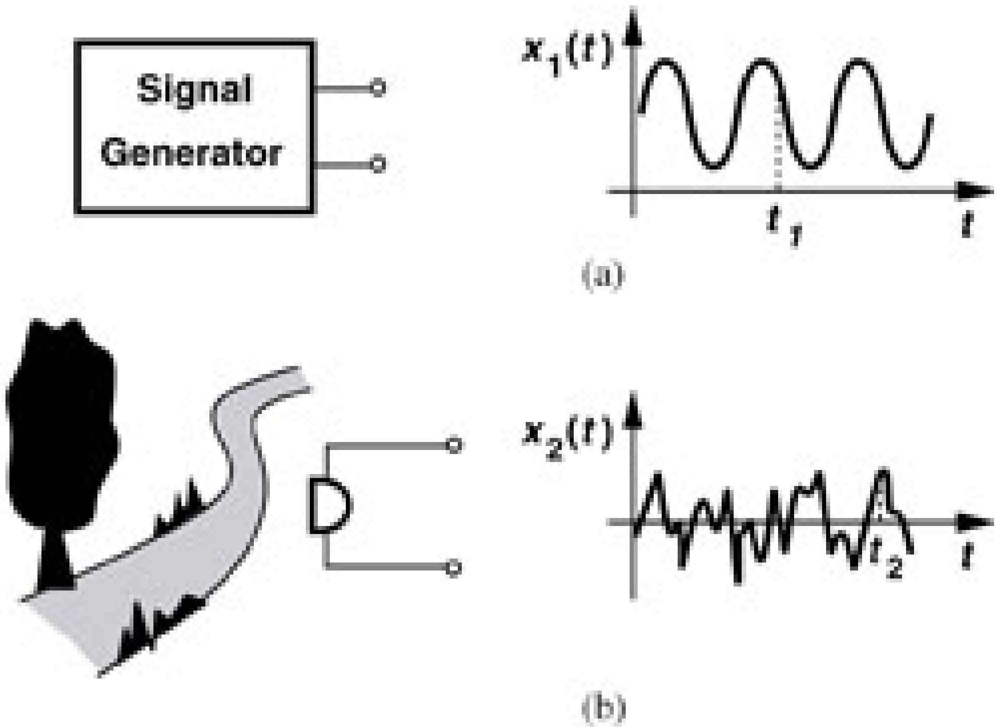
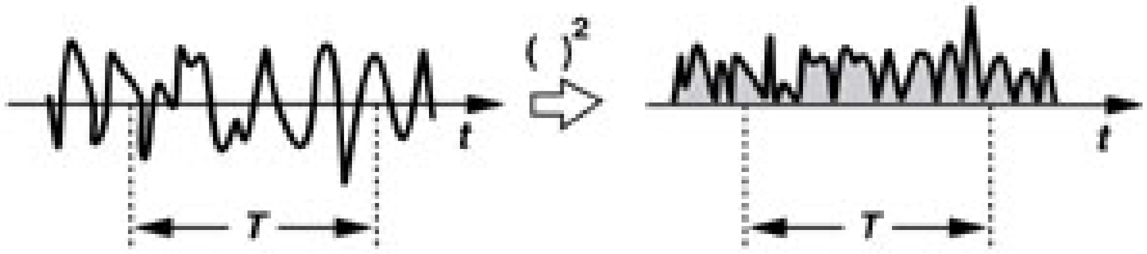
Lecture 7
IL2218 Analog electronics, advanced course

- Noise in MOS
  – Thermal noise
  – Flicker noise
- Noise calculations
- Input referred noise

Noise



Noise power

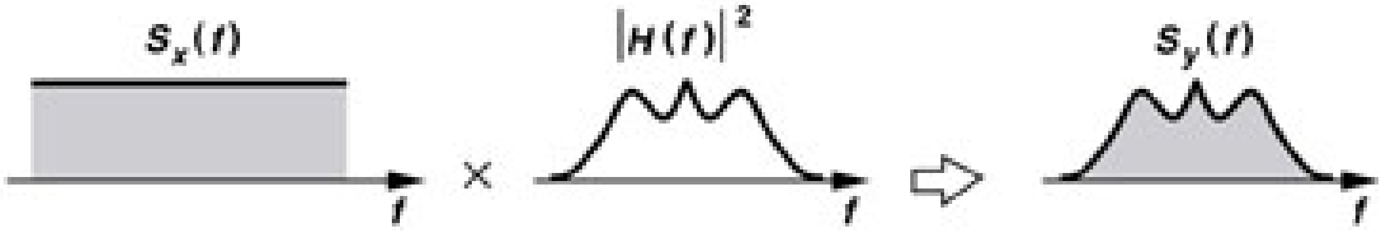


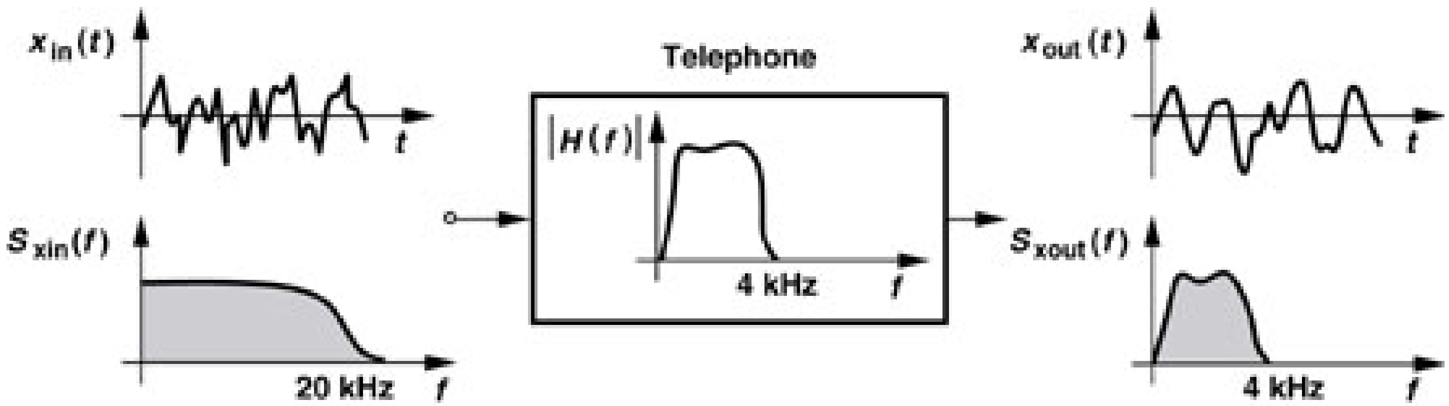
$$P_{av} = \lim_{t\to\infty}\frac{1}{T}\int_{-T/2}^{+T/2} x^2(t)dt$$

$$P_{av} = P_{av1} + P_{av2}$$

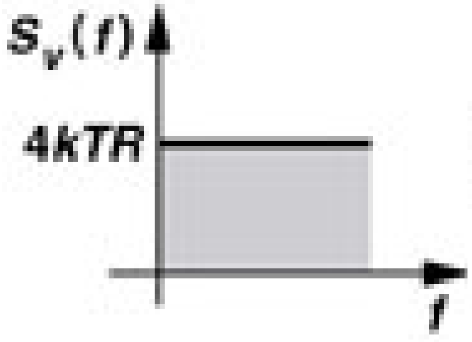
Superposition holds for the power of uncorrelated sources

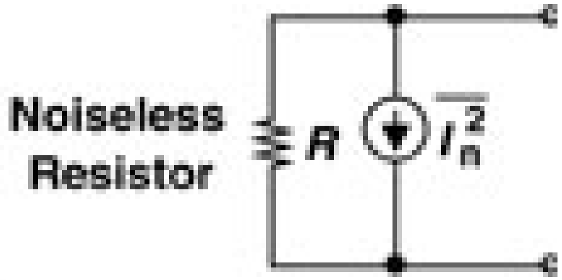
Noise shaping





Thermal noise in resistor



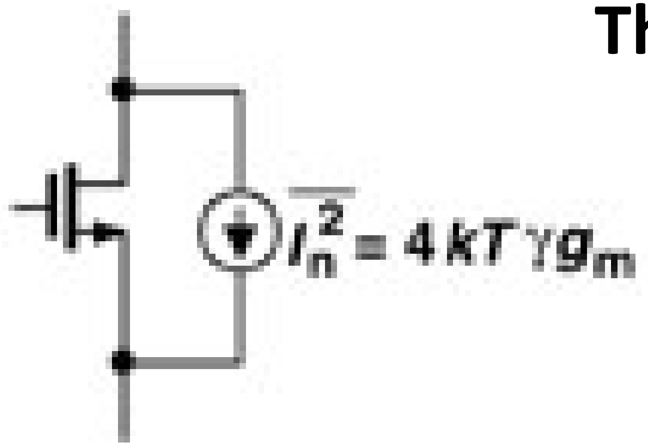


$$\overline{V_n^{\,2}} = 4kTR(\Delta f)$$

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

$$R = 50,\ T = 300K \rightarrow V_n = 0.91\ nV/\sqrt{Hz}$$

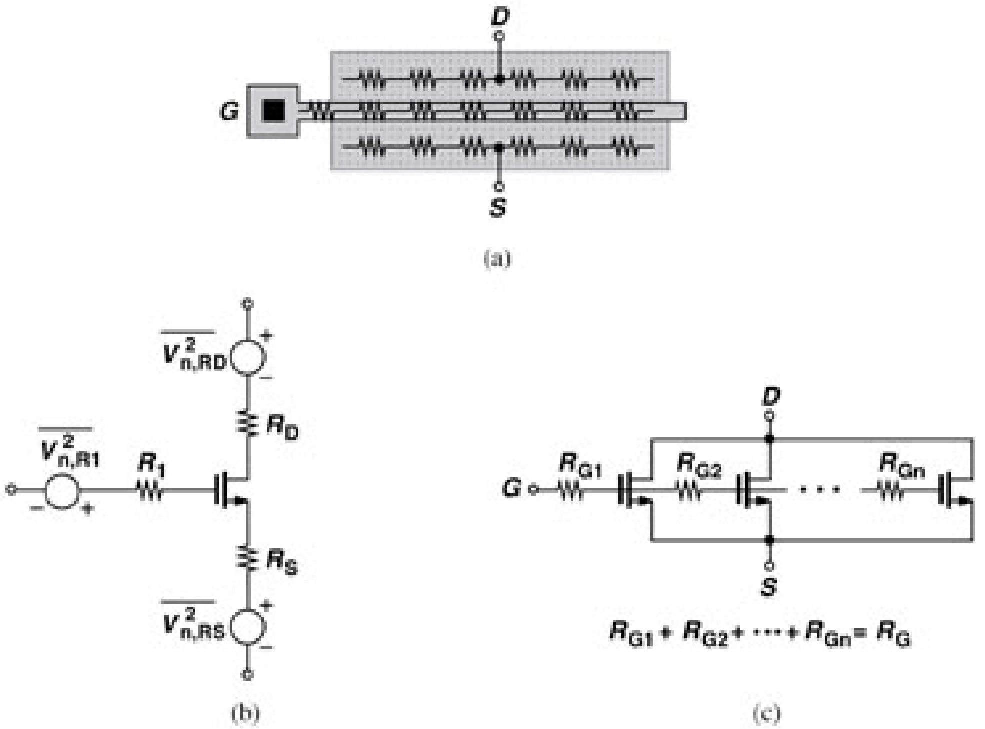
Thermal noise in MOS transistor



Thermal noise in channel

Parameter γ is typically 2/3 for long channel, as high as 2.5 for submicron devices.

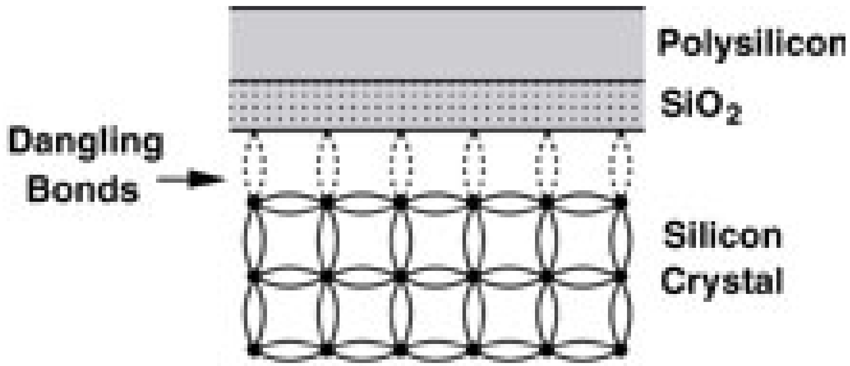
MOS ohmic noise sources

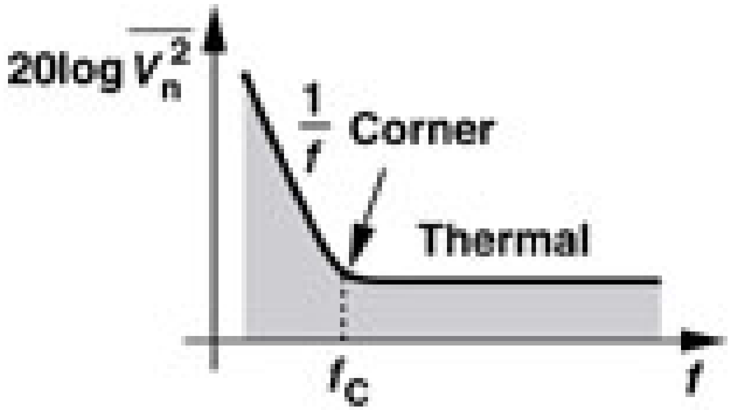


Can be reduced by proper layout. Noise in ohmic sections can usually be neglected.

Flicker noise

Generated when charges at interface is trapped and released





Corner frequency f_c

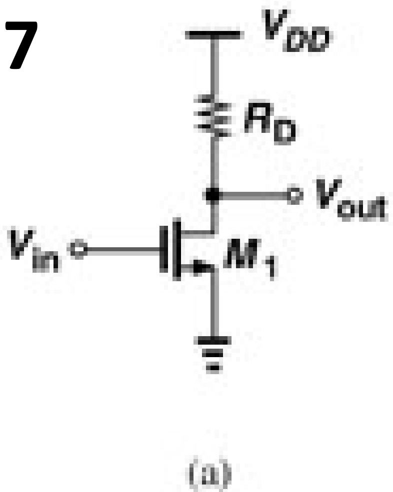
$$\overline{V_n^2} = \frac{K}{C_{ox}WL}\frac{1}{f}$$

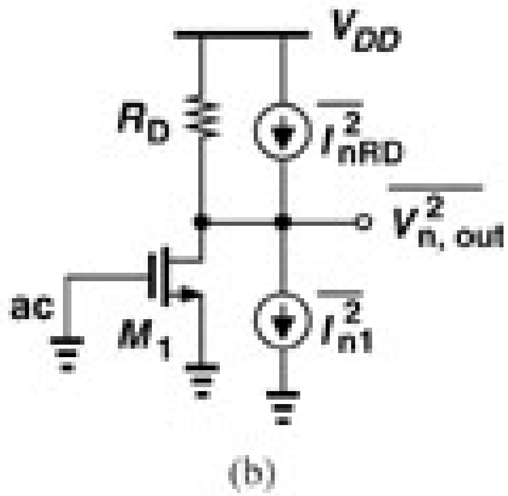
$$4kT\left(\frac{2}{3}g_m\right) \approx \frac{K}{C_{ox}WL}\frac{1}{f_c}g_m^2$$

$$f_c \approx \frac{K}{C_{ox}WL}g_m\frac{3}{8kT}$$, app. for long channel

Noise in circuits

Example 7.7

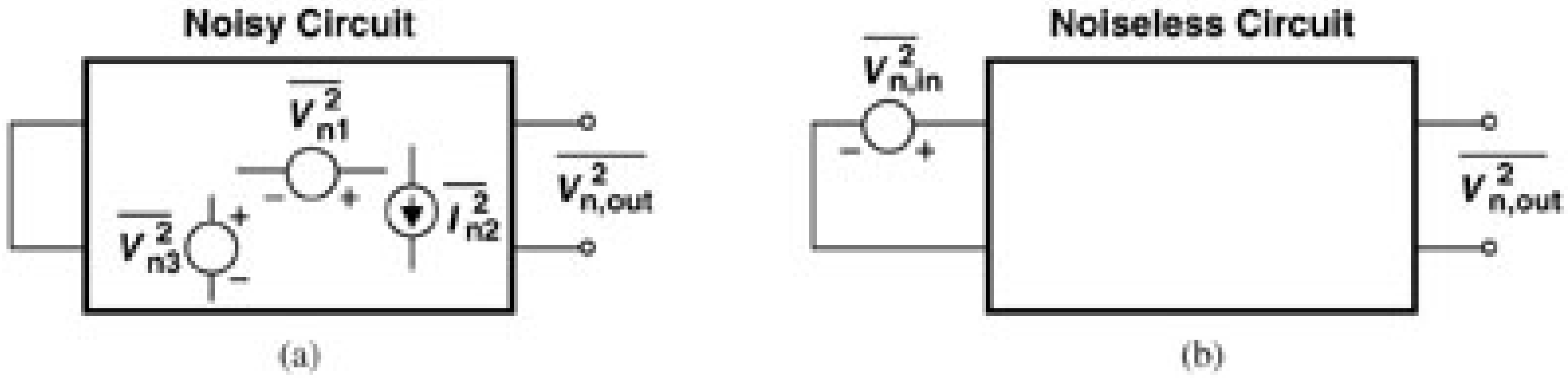




$$\overline{V^2_{n,out}} = \left(4kT\frac{2}{3}g_m + \frac{K}{C_{ox}WL}\frac{1}{f}g_m^2 + \frac{4kT}{R_D}\right)R_D^2$$

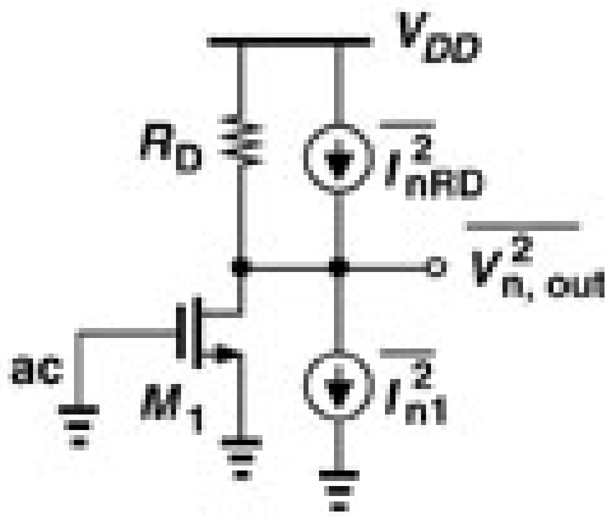
M1 thermal + M1 flicker + R_D thermal

Input referred noise



Input referred noise is a fictitious quantity that allows comparison between different circuits.

Input referred noise, example 7.7

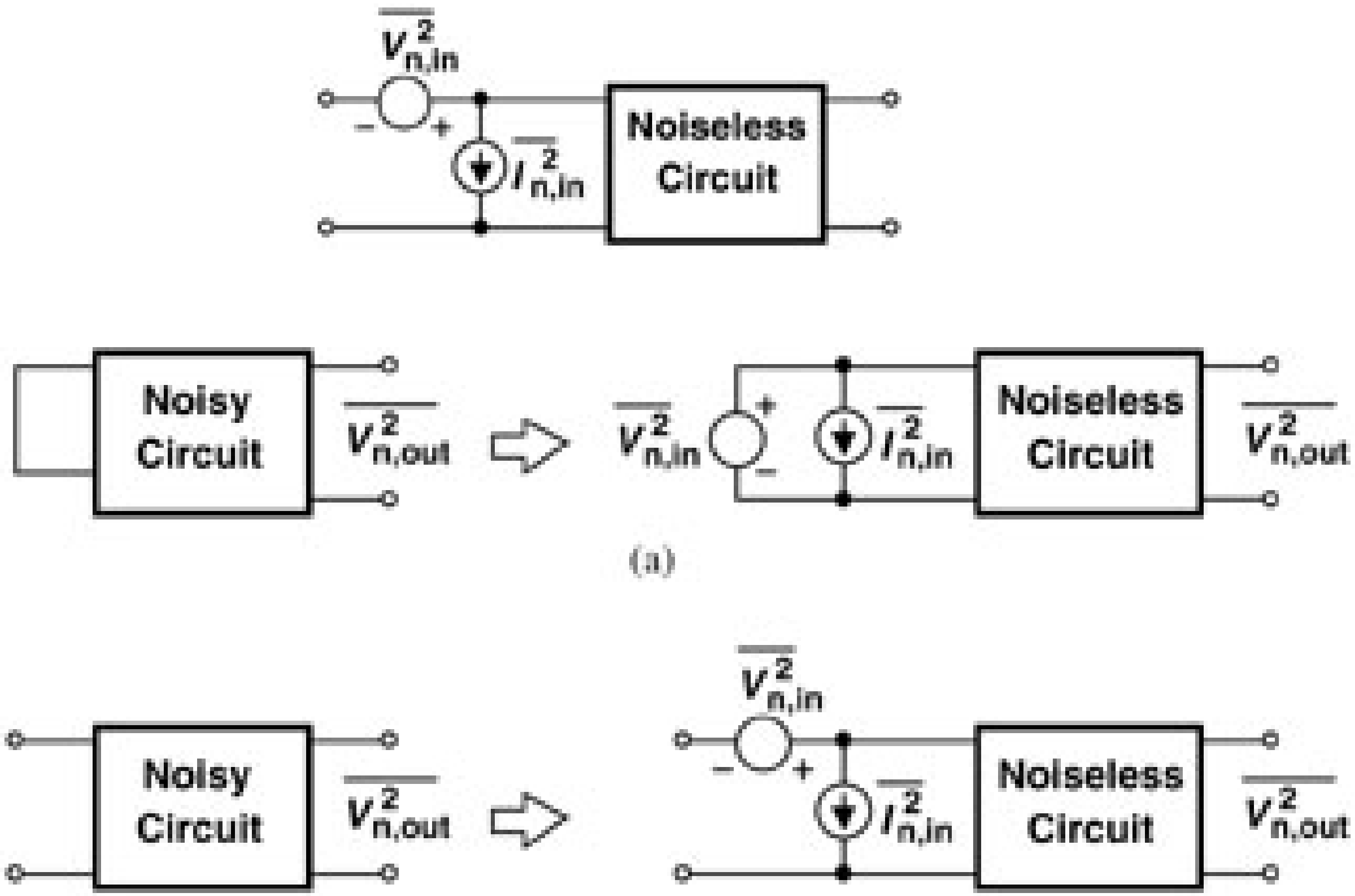


$$\overline{V^2_{n,in}} = \frac{\overline{V^2_{n,out}}}{A_v^2} = \frac{\overline{V^2_{n,out}}}{g_m^2 R_D^2}$$

$$\overline{V^2_{n,in}} = \left(4kT\frac{2}{3}g_m + \frac{K}{C_{ox}WL}\frac{1}{f}g_m^2 + \frac{4kT}{R_D}\right)R_D^2\frac{1}{g_m^2R_D^2}$$

$$= 4kT\frac{2}{3g_m} + \frac{K}{C_{ox}WL}\frac{1}{f} + \frac{4kT}{g_m^2R_D}$$

Input referred noise voltage and current

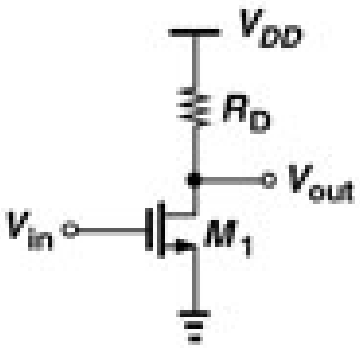


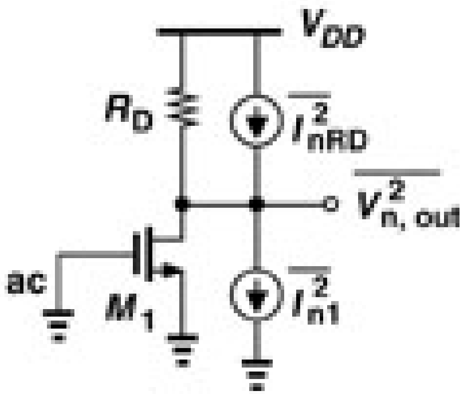
Output noise current transformed to input noise voltage

$$\overline{V_{n,gate}^2} = \frac{\overline{I_{n,drain-source}^2}}{g_m^2}$$

A noise source can be transformed from a drain-source current to a gate series voltage for arbitrary Z_s. (page 224)

Common source amplifier





$$\overline{V^2_{n,in}} = 4kT\left(\frac{2}{3g_m} + \frac{1}{g_m^2 R_D}\right) + \frac{K}{C_{ox}WL}\frac{1}{f}$$

$$\overline{I^2_{n,in}} = \frac{1}{Z^2_{in}}\left[4kT\left(\frac{2}{3g_m} + \frac{1}{g_m^2 R_D}\right) + \frac{K}{C_{ox}WL}\frac{1}{f}\right]$$

$$\overline{I^2_{n,in}} \approx 0 \quad for \quad low \quad frequencies$$