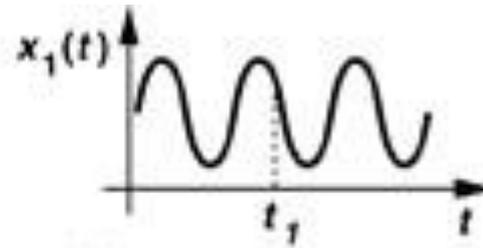
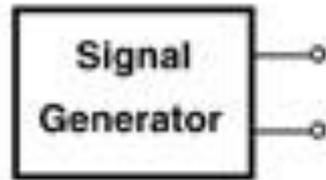


Lecture 7

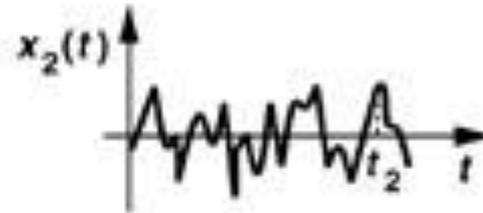
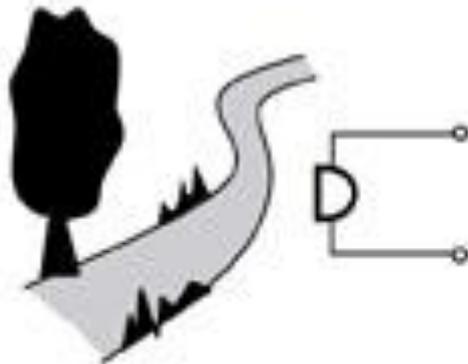
IL2218 Analog electronics, advanced course

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

Noise

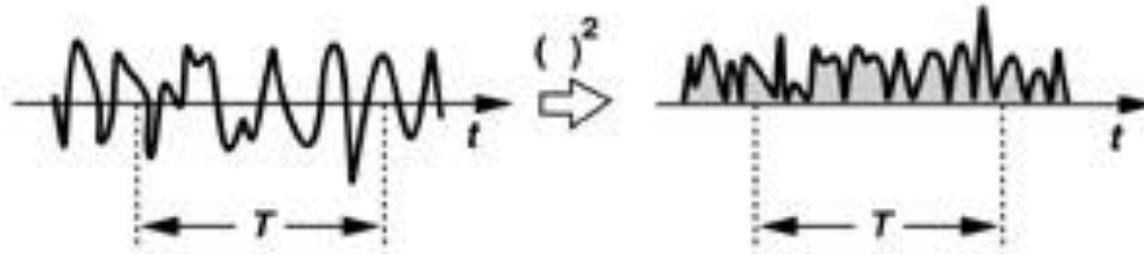


(a)



(b)

Noise power

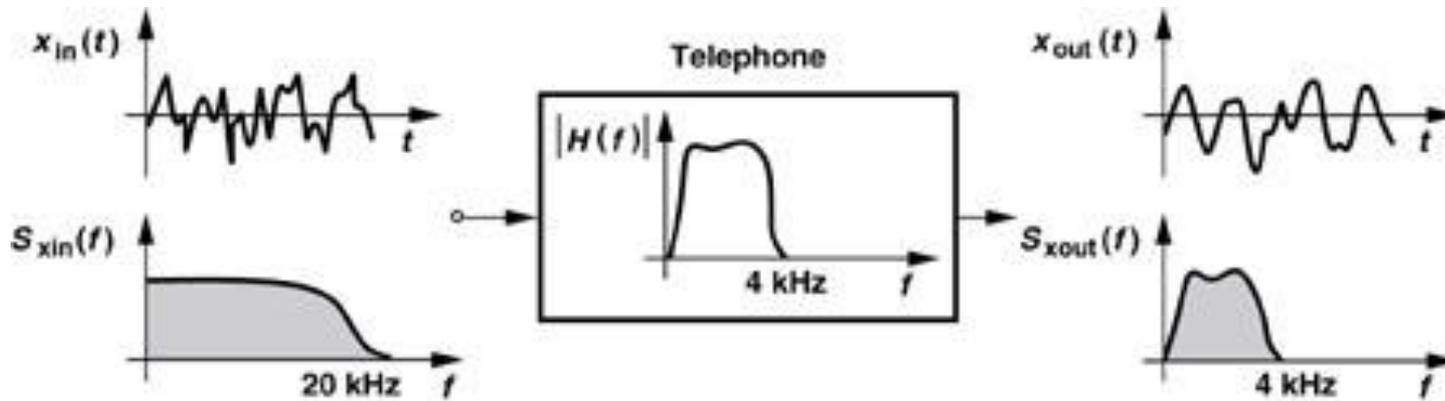
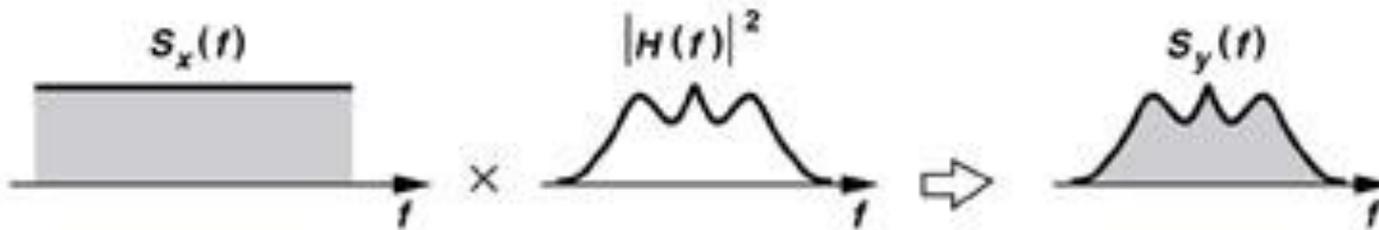


$$P_{av} = \lim_{T \rightarrow \infty} \frac{1}{T} \int_{-T/2}^{+T/2} x^2(t) dt$$

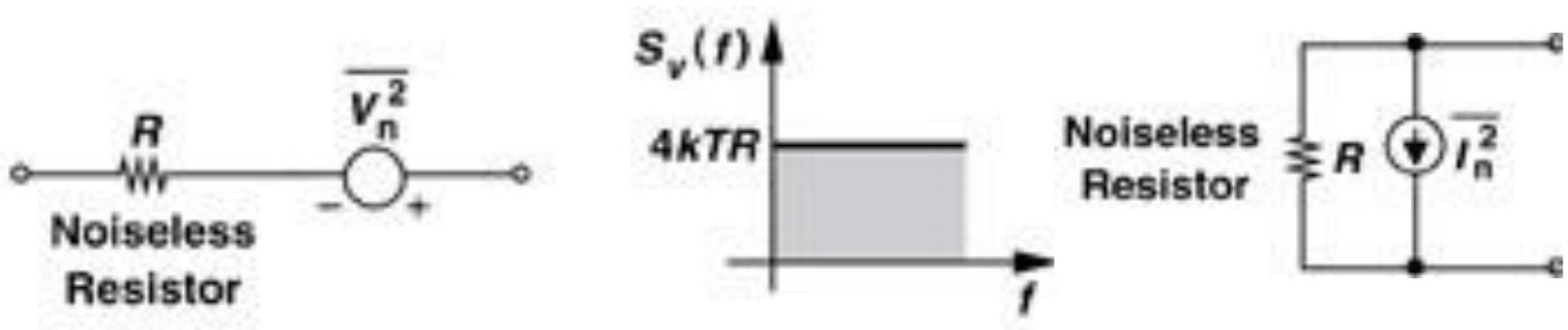
$$P_{av} = P_{av1} + P_{av2}$$

Superposition holds for the power of uncorrelated sources

Noise shaping



Thermal noise in resistor



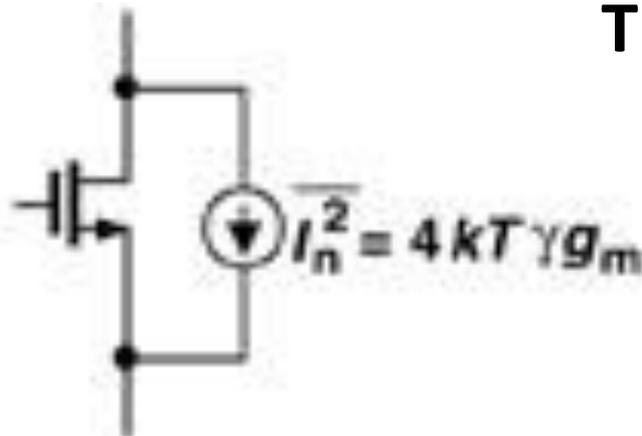
$$\overline{V_{n,tot}^2} = 4kTR(\Delta f)$$

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

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

Thermal noise in MOS transistor

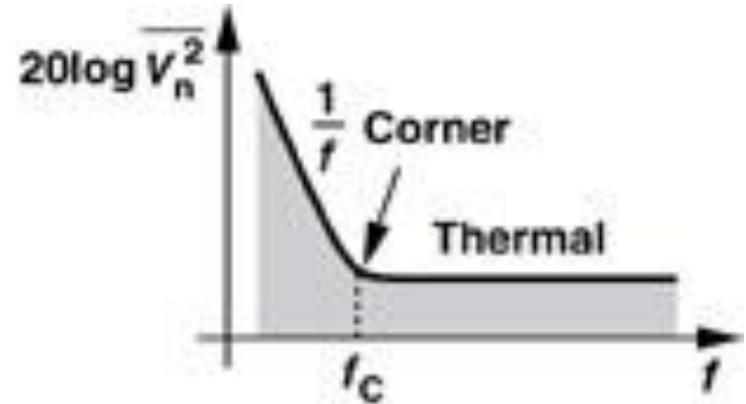
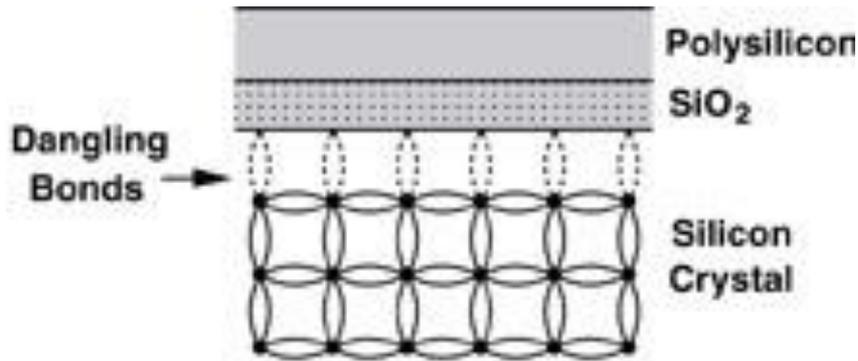
Thermal noise in channel



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

Flicker noise

Generated when charges at interface
is trapped and released



Corner frequency f_c

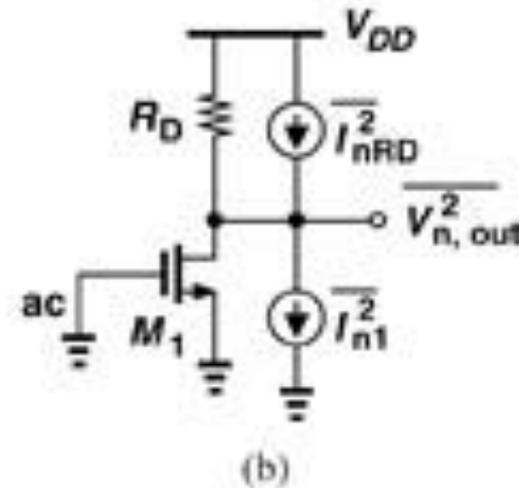
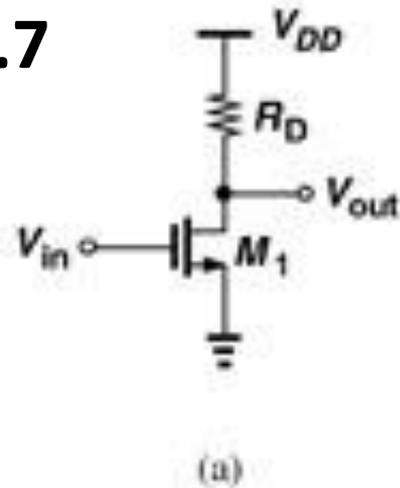
$$\overline{V_n^2} = \frac{K}{C_{ox}WL} \frac{1}{f}$$

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

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

Noise in circuits

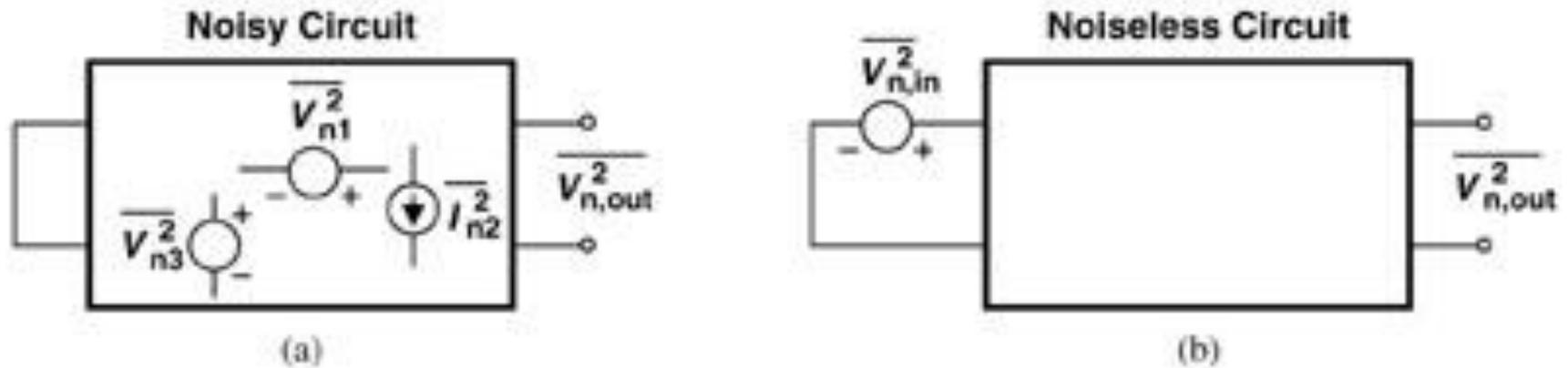
Example 7.7



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

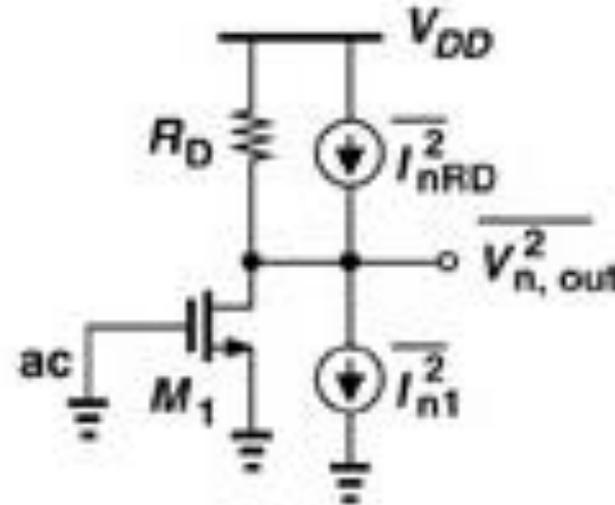
M1 thermal + M1 flicker + R_D thermal

Input referred noise



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

Input referred noise, example 7.7

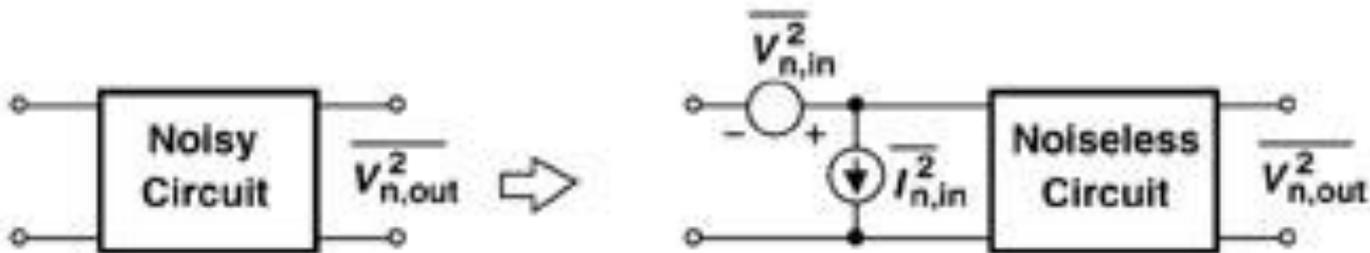
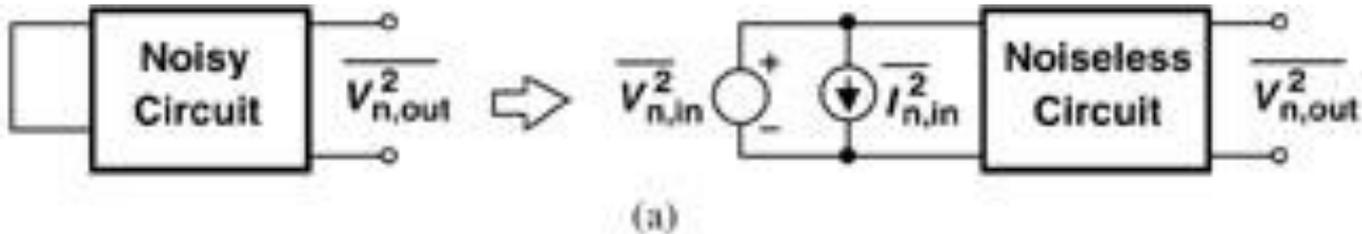
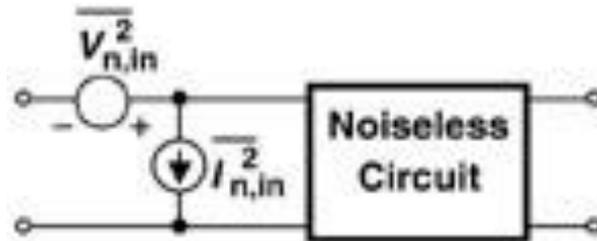


$$\overline{V_{n,in}^2} = \frac{\overline{V_{n,out}^2}}{A_v^2} = \frac{\overline{V_{n,out}^2}}{g_m^2 R_D^2}$$

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

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

Input referred noise voltage and current

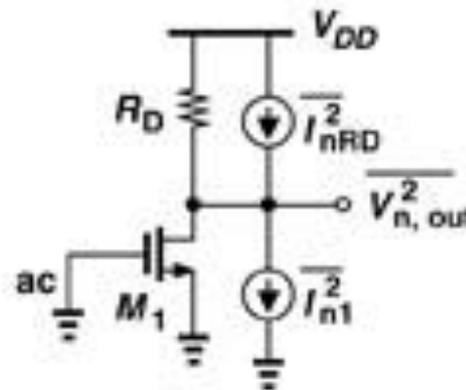
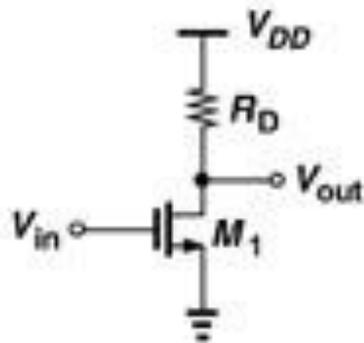


Output noise current transformed to input noise voltage

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

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



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

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

$$\overline{I_{n,in}^2} \approx 0 \text{ for low frequencies}$$