Lecture 7
IL2218 Analog electronics, advanced course

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

![Diagram of signal generator and noise signal](image)
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

\[ V_n^2 = 4kTR(\Delta f) \]
\[ I_n^2 = \frac{4kT}{R} \]

\[ R = 50, \ T = 300K \rightarrow V_n = 0.91 \ nV/\sqrt{Hz} \]
Thermal noise in MOS transistor

Parameter $\gamma$ 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

\[ V_n^2 = \frac{K}{C_{ox}WL} \frac{1}{f} \]

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

\[ f_c \approx \frac{K}{C_{ox}WL} g_m \frac{3}{8kT} \], app. for long channel
Noise in circuits

Example 7.7

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

M1 thermal + M1 flicker + \( R_D \) thermal
Input referred noise is a fictitious quantity that allows comparison between different circuits.
Input referred noise, example 7.7

\[ V_{n,\text{in}}^2 = \frac{\bar{V}_{n,\text{out}}^2}{A_v^2} = \frac{\bar{V}_{n,\text{out}}^2}{g_m^2 R_D^2} \]

\[ V_{n,\text{in}}^2 = \left( 4kT \frac{2}{3} g_m + \frac{K}{C_{ox} W L} \frac{1}{f} g_m^2 + \frac{4kT}{R_D} \right) R_D^2 \frac{1}{g_m^2 R_D^2} \]

\[ = 4kT \frac{2}{3g_m} + \frac{K}{C_{ox} W L} \frac{1}{f} + \frac{4kT}{g_m^2 R_D} \]
Input referred noise voltage and current
Output noise current transformed to input noise voltage

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

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

\[ V_{n,\text{in}}^2 = 4kT \left( \frac{2}{3g_m} + \frac{1}{g_m^2 R_D} \right) + \frac{K}{C_{ox} W L f} \]

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

\[ I_{n,\text{in}}^2 \approx 0 \text{ for low frequencies} \]