ECEN4827/5827 Lecture 38

HW12 due by 10am MT on Friday, December 6
Analysis of frequency-dependent circuits with noise: a simple example
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Analysis of frequency-dependent circuits with noise:
a simple example

\[ f_{p1} = \frac{1}{2\pi C_1 R_{11} R_2} \]
Analysis of frequency-dependent circuits with noise: a simple example

\[ V_{in}^2 = \frac{V_{in}^2}{R_1 + R_2} \left( \frac{R_2}{R_1 + R_2} \right)^2 \frac{1}{1 + \left( \frac{f}{f_{pc}} \right)^2} \]

\[ V_{n, rms}^2 = \int_{f_{pc}}^{f_{pc} \cdot 10} \frac{df}{1 + \left( \frac{f}{f_{pc}} \right)^2} \]

ECEN4827/8827 Analog IC Design
.noise Spice simulation results

- Interval Start: 1Hz
- Interval End: 10MHz
- Total RMS noise: 957.28μV

- Interval Start: 1Hz
- Interval End: 10MHz
- Total RMS noise: 28.711μV
MOS transistor model with noise

\[ i_{dn} = \frac{1}{R_{\text{channel}}} \]

\[ \bar{i}_{d}^2 = 4kT \left( \frac{2}{3} g_m \right) \Delta f + \frac{2\mu K_f}{L^2} \frac{I_D}{f} \Delta f \]

Conductive channel.

Thermal noise.

Flicker or 1/f noise.
Flicker ("1/f") noise

\[ S(f) = \frac{2mA^2 K_f}{L^2} \cdot \frac{I_D}{f} \]
MOS transistor model: input noise

\[ \overline{v_n^2} = \frac{i_{id}^2}{g_m^2} \]

\[ g_m = 2 \sqrt{V T D} \]

\[ K_f = \frac{1}{2} \frac{W}{L} \]

\[ \overline{v_n^2} = 4kT \left( \frac{2}{3} \frac{1}{g_m} \right) \Delta f + \frac{K_f}{C_{ox}} \frac{1}{WL} \frac{1}{f} \Delta f \]

Class 0.35u CMOS process: \( K_f/C_{ox} \)

NMOS: \( 40 \cdot 10^{-12} \text{ V}^2 \text{um}^2 \)

PMOS: \( 8 \cdot 10^{-12} \text{ V}^2 \text{um}^2 \)
Example: common-source amplifier

\[ \frac{V_{no}^2}{V_{nRd}} = \frac{V_{nRd}^2}{(g_{mRd})^2} + \frac{V_{nRd}^2}{(g_{mRd})^2} \]

\[ \frac{V_{nRd}}{V_{nRd}} = \frac{V_{nRd}}{(g_{mRd})^2} \]

\[ V_{no} = \frac{V_{nRd}}{(g_{mRd})^2} + \frac{V_{nRd}^2}{(g_{mRd})^2} + \frac{V_{nRd}^2}{(g_{mRd})^2} \]
\[ A(s) = \frac{v_{out}}{v_{in}} \text{ magnitude and phase responses} \]
.noise Spice simulation results

![Graph showing noise simulation results with annotations]
.noise Spice simulation results

![Graph showing noise voltage versus frequency]

- Flicker noise
- thermal noise

- Total RMS noise: 544.22 nV
Example: diff pair with active load

\[
\frac{I_{o,n}}{\nu_{n1}} = g_{m1}
\]

\[
\begin{align*}
\bar{v}_{i,n}^2 &= \left( g_{m1}^2 \right) \bar{v}_{n1}^2 + \left( g_{m1}^2 \right) \bar{v}_{n2}^2 + \left( g_{m3}^2 \right) \bar{v}_{n3}^2 + \left( g_{m3}^2 \right) \bar{v}_{n4}^2 \\
\bar{v}_{o,n}^2 &= g_{m1}^2 \bar{v}_{i,n}^2
\end{align*}
\]
Example: diff pair with active load

\[ V_{m}^2 = V_{n,1}^2 + V_{n,2}^2 + \left( \frac{g_{m3}}{g_{m1}} \right)^2 \left( V_{n3}^2 + V_{n4}^2 \right) \]

- PMOS is a good choice.
- NMOS is good.

\[ = \text{Flicker} + \text{Thermal} \]

\[ \frac{2 K_f \text{mos}}{C_X W_1 L_1} \left( 1 + \frac{K_f \text{mos} \mu_n (L_1)}{K_f \text{mos} \mu_p (L_3)} \right)^2 \]

- PMOS
- NMOS

\[ \frac{4kT \cdot 4}{3 \sqrt{2 \mu_C (W/L)}} \text{, } I_{D1} \]

- Larger \((W/L)\)
- Smaller \((W/L)\)

Large \(W, L_1\) \(\text{and}\) \(L_3/L_1\)