EE539: Analog Integrated Circuit Design; Lecture 15

Nagendra Krishnapura (nagendra@iitm.ac.in)

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Input Referred noise

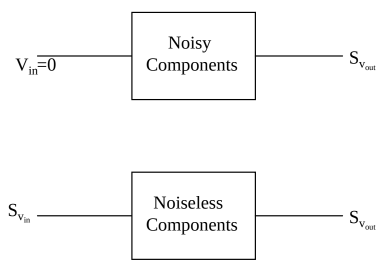

Figure 1: Input Referred noise

Consider a network whose output noise power spectral density is $S_{v_{out}}$. Now, if we make all the components in the network noiseless, then the noise that should be present at the input of the network in order to get the same $S_{v_{out}}$ at the output is called the "input referred noise".

PSD of the input referred noise ($S_{v_{in}}$) is given by
$S_{v_{in}} = \frac{S_{v_{out}}}{|H(f)|^2}$ where $|H(f)|$ is the transfer function from input to output.

Input referred noise is useful when we need to compare the noise and input signal level.
For e.g.Let us calculate the input referred noise for a MOSFET.(Fig. 2)

$$S_{v_{in}} = \frac{S_{I_D} + S_{I_R}}{{g_m}^2} = \frac{\frac{4kT}{R} + \frac{8kTg_m}{3}}{{g_m}^2} = \frac{4kT}{g_m}\left(\frac{1}{g_m R} + \frac{2}{3}\right)$$

Dynamic Range

Let us calculate the Dynamic Range of a MOSFET amplifier.
Let the input signal have a peak amplitude V_p.Neglecting noise due to load resistance and assuming a bandwidth of B,

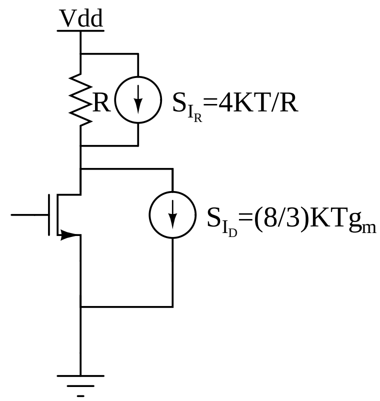

Figure 2: MOSFET noise

$$\left(\frac{S}{N}\right)_i = \frac{\left(\frac{V_p}{\sqrt{2}}\right)}{\left(\sqrt{\frac{8kTB}{3g_m}}\right)}$$

For an SNR of 0dB,

$$V_{p_{min}} = \sqrt{\frac{16kTB}{3g_m}}$$

For a max Harmonic Distortion of x%,

$$\begin{aligned}
\frac{V_{p_{max}}}{V_{p_{min}}} &= \frac{4(V_{GS}-V_T)x}{\sqrt{\frac{16kTB}{3g_m}}} \\
&= \frac{4x}{\sqrt{\frac{16kTB}{3}}}\sqrt{\frac{\mu C_{ox}W}{L}}(V_{GS}-V_T)^{\frac{3}{2}} \\
&= \frac{V_{p_{max}}}{V_{p_{min}}} = \frac{4x}{\sqrt{\frac{16kTB}{3}}}\frac{1}{\left(\frac{\mu C_{ox}W}{L}\right)^{\frac{1}{4}}}(2I_D)^{\frac{3}{4}}
\end{aligned}$$

Dynamic Range$= 20 * log\left(\frac{V_{p_{max}}}{V_{p_{min}}}\right)$

From these equations, we see that the dynamic range can be increased by

- increasing the overdrive for the same aspect ratio
- decreasing the aspect ratio while keeping the bias current constant. (But it is a weak function of aspect ratio)

Common Drain Amplifier(Source Follower)

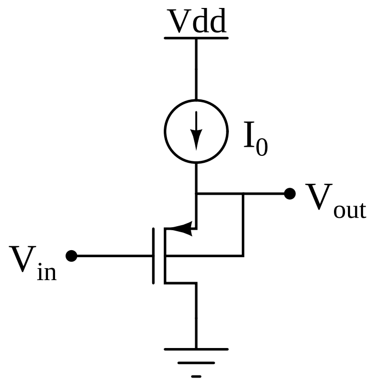

Figure 3: Source Follower

Consider the source follower (Fig. 3)

$V_{out} = V_{in} + V_{GS} = V_{in} + V_T + \sqrt{\frac{2I_0}{\left(\frac{\mu C_{ox} W}{L}\right)}}$

Small signal gain = 1 (if there is no body effect)