Noise Density Limited Amplifier Design Methodology

- **Input specifications:**
  - Minimum small signal gain $A_v$
  - Supply voltage $V_{dd}$
  - Fixed $V^*$
  - Maximum input-referred noise spectral density $v_{i,n}^2/\Delta f$

- **Goal:** minimize power
Small Signal Model and Noise Analysis

\[ V_{\text{in}} \rightarrow R_L \rightarrow V_{\text{out}} \]

Resulting Design
Discussion (1)
- Why did we not even specify the capacitive load?

Discussion (2)
- If you could exactly set $a_{v_0}$, what value would you pick?
Integrated Noise-Limited Amplifier

- **Input specifications:**
  - Minimum small signal gain $A_v$
  - Minimum 3dB bandwidth $\omega_{bw}$
  - Supply voltage $V_{dd}$
  - Fixed $V^*$
  - Maximum noise variance $v_{o,n}^2$

- **Goal:** minimize power

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Required $C_L$, $g_m$, and $I_D$
Discussion (1)

- For both noise-density and integrated noise-limited amplifiers, what $V^*$ should you pick?

Discussion (2)

- How would one know the $v_{i,n}^2/\Delta f$ or $v_{o,n}^2$ spec?
Signal Swing Limitations

Why Linearity Matters

• Option 1: Retaining the original shape of the input inherently matters
  • E.g., oscilloscope, spectrum analyzer
  • (Actually also often matters in communication systems)

• Option 2: Need to be able to discern a (small) signal out of the combination of many others
  • E.g., RF, neural front-ends
  • “Other” signals could

• Precise linearity metric depends on usage scenario
  • More next time – will use simplified metric for now
Sources of Non-Linearity

- Output limited: Non-linear $Z_{out}$ ($r_o$)
- Input limited: Non-linear $g_m$

Input Non-Linearity with a Diff. Pair
Full Circle: SNR-Limited Design (noise density)

- **Input specifications:**
  - Minimum small signal gain $A_v$
  - Supply voltage $V_{dd}$
  - Input-referred maximum linear amplitude $V_{i,max}$
  - Signal shape (usually sinusoid) and amplitude $V_{sig}$
  - Externally determined bandwidth $f_{bw}$
  - Minimum signal-to-noise ratio $SNR_{min}$

- **Goal: minimize power**

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Required $v_{i,n}/\Delta f$
SNR-Limited Design (total noise)

• **Input specifications:**
  - Minimum small signal gain $A_v$
  - Minimum 3dB bandwidth $\omega_{bw}$
  - Supply voltage $V_{dd}$
  - Input-referred maximum linear amplitude $V_{i,max}$
  - Signal shape (usually sinusoid) and amplitude $V_{\text{sig}}$
  - Minimum signal-to-noise ratio $\text{SNR}_{\text{min}}$

• **Goal:** minimize power
Discussion